4 The Power of Experience: Farmers' Knowledge and Sustainable Innovations in Agriculture

Marian Stuiver, Cees Leeuwis and Jan Douwe van der Ploeg

1 Introduction

It is starting to become widely recognised that farmers' knowledge has an important role to play in bringing about sustainable innovations in agriculture (Röling and Jiggins 1998; Chambers 1989; Hobart 1993). In this chapter, we first outline some of the backgrounds to this renewed interest in the potential of farmers' knowledge (Section 2). Following this, we discuss the characteristics of farmers' knowledge in more detail, and how it may differ from scientific (or scientists') knowledge (Section 3). This leads us into a discussion of practical ways in which farmers' knowledge may be drawn upon more effectively and the role that scientists may play in this respect (Section 4). In the concluding section we reflect briefly on the institutional changes that may be required in agricultural knowledge systems in order to stimulate scientists to take up this challenge (Section 5).

2 The agricultural knowledge system in transition

2.1 Introduction

In recent decades, great efforts have been made to modernise European agriculture towards high productivity and efficiency. This so-called modernisation process was assumed to be unilinear: the combination of scale enlargement and modern (science based) technologies was presented as the only route to success. Those who were able to make this combination were seen as 'vanguard' farmers and scientists (van der Ploeg 1999). This model encouraged, farmers to become more integrated in markets and dependent on the use of external inputs, technologies and capital (Toledo 1990; van der Ploeg and Frouws 1999). It encouraged a more uniform pattern of farming. As such it resulted in a weakening of linkages between farming and local ecology (Renting and van der Ploeg 2001).

Since the 1970s there has been a countervailing societal pressure for a reorientation of agriculture towards sustainable production. The emphasis on high productivity and efficient agriculture has had to be changed to accommodate different sustainability criteria within agrarian production processes.[1] In this dynamic context several factors have contributed to the enlarged interest in farmers' knowledge. These include the discovery that such knowledge is indispensable in view of the need to re-balance growth factors, increased recognition of the significance of diversity in agriculture, and changed perceptions about the nature of innovations and innovation processes.

2.2.The need to re-balance external and internal growth factors

From Von Liebig onwards, the agricultural sciences have conceptualised and understood processes of production as the ongoing co-ordination of a wide and flexible range of growth factors, literally those factors that influence growth. Each growth factor describes an element within the production process that actually or potentially influences the yields obtainable within the process of production, for instance the quantity and composition of nutrients in the subsoil, water availability or plant variety. Together these growth factors determine the outcome of the process of production (de Wit 1992).[2] The upgrading of specific growth factors and the necessary adjustment of others has been the main concern of the agricultural sciences. The growth factor shortest in supply is seen to determine the level of production, whilst the utilisation of other factors clearly influences the costs.

At the same time, growth factors also include the different tasks and sub-tasks that together compose the agricultural labour process. Farm labour might be considered as the ongoing discovery and mutual adaptation of growth factors (see Figure 1). Through centuries farmers have been trying to identify the limiting growth factors and to design new farming methods in order to go beyond the known limits. From an analytical point of view, the associated farmers' innovations are characterised by several features. Examples include (1) assessing the relevance of interventions and change above all through their effects on other 'sub-systems' and/or on the level of the farm as a whole[3], (2) the importance of feedback and 'feed-forward' linkages[4]. Furthermore (3) farmers' innovations stress 'what might be possible' instead on 'how things are (Kessel 1990), (4) they show the importance granted to diversity and (5) the importance of the local 'horizon of relevance'.[5]

Within the modernisation process the upgrading of certain growth factors and the adjustment of others was overwhelmingly geared towards the economic goal of maximising productivity growth. The associated 'green' revolution brought technological innovations, such as water management, mechanisation, fertilisers and new plant varieties. These technologies and the use of external inputs, resulted in the subsequent upgrading of other growth factors and increases in yields.

At present a process is taking place in which these growth factors (and especially those related to external inputs) are playing a less important role within farm practices because of sustainability criteria. This downgrading of certain growth factors, in turn is inducing a wider set of changes within the processes of production. While some growth factors need to be downgraded, others need to be upgraded. New growth factors need to be discovered that fit the new demands of sustainability. What is required, in short, is a systematic and integral re-organisation of the production process in order to create a new balance that is both ecologically and economically sustainable. All relevant subsystems need to be reorganised in such a way that a new equilibrium is created (van Bruchem and Tamminga 1997). Both scientists and farmers need to develop insights in the specificity of the farming systems and their dynamic relations with local conditions and available growth factors (be it the subsoil and its dynamics, natural processes and contingencies, or the manure produced at the farms).

It is important to note here that in order to help realise these new societal goals, a greater emphasis is required upon internal rather than external growth factors. Local ecological conditions and locally available growth factors need to be the starting point for arriving at sustainable balances. In view of this locally specific knowledge regarding the farm and its environment acquire a new relevance. Since farmers are important carriers of such knowledge, it is not surprising that the issue of farmers' knowledge attracts more attention now than before. Experiences reported upon elsewhere in this book (see for example chapters 8 and 12) show that farmers often have a rich understanding of local resources, and that they engage in many attempts to maintain social and ecological systems. Farmers' knowledge can be a useful source in better understanding how ecosystems can and cannot be transformed, how ecosystems can be managed and how social systems might be designed to mesh better with ecosystems (Toledo 1990).[6] For too long, however, the focus on the possibility of using and enhancing farmers' knowledge has remained hidden within the context of the prevailing dominant scientific knowledge system (see Section 2.4).

2.3 The re-discovery of diversity

For a long time agricultural scientists have assumed – implicitly or explicitly – that agricultural development is something that progresses in one particular direction (e.g. towards high input, high output and hi-tech farming). The idea was that given certain conditions there is basically *one* optimal way of managing a farm. Much used categorisations of farmers such as 'vanguard farms', 'followers', 'early adopters', 'late adopters' and 'laggards' (van den Ban 1963; Rogers 1983) reflect this idea, namely that everybody is (or should be) moving in the same direction, even if some may do so more quickly than others. In recent years, many studies have indicated that this idea is flawed. Farms that are (initially) characterised by comparable lay-outs and household composition, and which operate under very similar conditions, can still develop along different, economically viable, paths (Bolhuis and van der Ploeg 1985). A key factor in explaining such different patterns of farm development (often labelled 'farming styles') are the diverse strategies, modes of thinking and aspirations that farmers may have *vis-à-vis* their social and natural environment. Another key factor is the diversity in the way they organise their livelihoods, including variations in the role agriculture plays *vis-à-vis* non-agricultural activities (Wiskerke 1997).

While the existence of diversity was often considered to be 'a problem' in the context of the modernisation trajectory, it is looked upon as an opportunity and challenge in the context of debates on ecological sustainability. This newly found legitimacy is due to the fact that differential farming styles can, at least partly, be understood as forms of adapting to diversity in local ecosystems. Farming styles are an outcome of *co-production,* that is the ongoing interplay and mutual transformation of the social and the technical (Law 1986), including evidently local ecosystems. In view of the adaptive nature of farming styles, understanding their underlying logic and rationale is important when the aim is to foster sustainability. And as logic and rationale are closely intertwined with cognitive processes, we see that the increased attention for diversity provides another impetus to re-examine farmers' knowledge.

2.4 *Changing views on innovation*

Modes of thinking about innovations and innovation processes have changed considerably over the last decades (both within the realm of agricultural science as well as in a broader context). In the research tradition of 'adoption and diffusion of innovations' (Havelock 1969; Rogers 1983) () the basic opinion was that innovations originate from scientists, are transferred by extension agents and other intermediaries and are applied by agricultural practitioners. This mode of thinking is labelled 'the linear model of innovation' (Röling and Jiggins 1998), as it describes a straight and one-directional line between science and practice[7]. The model is further characterised by a clear task division between various actors; some actors are supposed to specialise in the *generation* of innovations, others concentrate on their *transfer,* while the farmers' role is merely to *apply* innovations (Long and Long 1992).

However, when scholars started to analyse in retrospect how successful innovations came about in practice, they soon discovered all sorts of deviations from this linear model. It appeared, for example, that researchers often got 'their' innovative ideas from practitioners and farmers made significant adaptations to the packages developed by scientists. Furthermore many innovations occurred without the involvement of scientists. The function of extension agents was not so much to transfer knowledge and information from scientists to farmers, but rather the other way around, or even to play a role in knowledge exchange between farmers (Richards 1985; Vijverberg 1997; Leeuwis 1993). In view of such findings it was concluded that innovation requires close co-operation in a network of actors, who all contribute to the 'generation' and 'transfer' of knowledge and innovations (Engel 1995). In short, farmers are also regarded as having valuable knowledge, and as being able to play an active and creative role in innovation processes.

In connection with the foregoing, the ideas about the nature and dynamics of innovation processes have also altered significantly. While the tendency was to look at innovation primarily as a process of 'scientific research' and 'discovery', scholars now tend to look at innovation as a process of 'network building' (Callon, Law *et al.* 1986), 'alignment', 'social learning' and 'negotiation' (Leeuwis and Remmers 1999). Similarly, the idea that 'an innovation' could be described in one-dimensional terms has been abandoned by many, replaced by the notion that 'an (successful) innovation' is composed of various technical and social arrangements (or 'sub-innovations') that together form a 'coherent novel working whole' (Roep 2000). When the aim is to arrive at such novel pattern of co-ordinated action, the views and perceptions (i.e. knowledge) of farmers and other stakeholders somehow need to accessed and incorporated in a design process (see for a more elaborate discussion on innovation, chapter 2 of this book).

2.5 Further drawbacks in utility of the formal agricultural knowledge system

Current debates within agrarian research communities lead to a greater recognition of farmers' knowledge. Yet, there remains a number of, historically derived, drawbacks to incorporating such knowledge in the research activities that take place in the formal agricultural knowledge system (i.e. universities, research institutes, etc.). An overarching obstacle in this respect is that both unilinear modes of thinking about farm development and linear models of thought regarding innovation fade only slowly (or perhaps not at all) (Leeuwis 2000a).[8]

The agricultural knowledge system has always been very closely connected to the modernisation process in agriculture. In that respect one can even speak of the scientification of agriculture (van der Ploeg 1987).

Scientification is the systematic reorganisation of agriculture according to models designed within the realm of the agricultural sciences. Thus, for decades science has been about how farming ought to be instead of how it is.[9] Basic to these models were – and often still are –.widely shared normative assumptions such as: 'Good farming is high productive farming' or 'Good farming is technology-driven and market-oriented'. Given its historical roots within the modernisation project, the current (formal) agricultural knowledge system is still characterised by such (often unspoken) limitations that need to be changed in view of sustainability demands.

Scientific knowledge is not responsive to societal needs
Patterns of development that did not match the modernising ideal have long been neglected and considered to be irrelevant within the agricultural sciences. The generation of scientific knowledge was not so much oriented towards existing societal practices and problems, but rather to a distant future to be reached eventually (van der Ploeg 1999). Scientists were supposed to develop blueprints for good farming. Good farmers were the ones who acted according to these blueprints. Thus, science tended to be separated from everyday farming practice and practitioners, both in terms of decision-making and implementation. Still, many structures and procedures in science, including funding arrangements for research, do not provide much opportunity for farmers and other societal stakeholders to make their voices heard and ensure that the activities of scientists are responsive to their immediate needs.

The limitations of dominant epistemologies
The epistemological culture from which most agrarian sciences still depart is one based on the proposition that one needs to 'reduce' complex wholes to their component parts[10]. The underlying premise of this approach is that by focussing on the individual parts, and the relations between isolated variables, one can understand the functioning of the complex whole. In this Cartesian view, a relevant whole (be it a cow, a field, a farm, a regional farming style) is understood as the mere *sum* of its constituent elements. Given this tradition, it has proved to be extremely difficult to come to grips with interactions at higher levels of integration – especially with those interactions that reshape or remould some of the composing elements or 'building blocks'. In most agrarian sciences, for instance, 'a field' is studied as a separate unit in a research station with controlled environments (or even simulated in a laboratory or computer). That is; it is studied in isolation from the interactions between the field and, on the one hand, its wider bio-physical (including chemical, biological, etc.) environment, and, on the other, its social environment (e.g. farm labour organisation, farmer strategies, markets, etc.).[11] This approach, deeply ingrained in the agrarian sciences, gives rise to

particular (and often limiting) approaches to sustainability. Higher levels of sustainability are often thought of as something to be achieved through the improvement of the *partial* efficiency of the different building blocks, rather than being dependent upon new balances at higher levels of aggregation.[12] In all, the formal agricultural knowledge system is not epistemologically well equipped to look at, and/or make, sensible statements about complex wholes.

From maximising to optimising results

The production of scientific knowledge has long tended to focus on maximising results through the replication of knowledge gained from one locality (the laboratory or research station) to the others (in the case of agrarian science, the farm). What does well on the research stations in controlled environments and with easy access to input is mainly useful to those farmers whose conditions resembled those at research stations. Thus, the conditions of the research stations (or laboratory) where the research has been conducted need implicitly to be imitated.[13] The models provided by science often fail when the farming system differs from the circumstances in which the scientific experiments are conducted.[14] For these reasons, a wide range of farmers normally finds that 'experts' knowledge' is of limited practical value. (Eshuis 2001; Scoones and Thompson 1994)(). This gap between theory and practice becomes even pronounced when sustainability issues need to be considered. Thus, a new mode of working is required that enables scientists to optimise knowledge within and for different local conditions. However, appropriate methods and approaches for doing so are lacking, or at best in their infancy.

The fragmented and scattered nature of agricultural sciences

Much agricultural research and education is organised around disciplines (e.g. soil science or sociology) and classical agricultural sectors (e.g. dairy farming and pig farming). Thus, a large number of agricultural institutions (including extension services, research institutes, university departments, educational programmes) are still segmented and organised according to these differentiation. That is; they either focus on crop farming, horticulture, dairy farming, pig farming, etc. Furthermore, academic disciplines become increasingly scattered and fragmented. Scientist have become an experts in their own field that addresses a very narrow element of agriculture; this in contrast to the approach advocated by classical agronomists (see for example Timmer 1949).[15] This development makes it all the more difficult to tackle problems from an integrated perspective. In response to this we have – from the 1980s onwards – witnessed calls for interdisciplinary and/or multidisciplinary research in which different experts co-operate together on one theme (Nooij 2001).[16] Also new forms of education have come to exist in which

students are trained within several disciplines. Within science, therefore, we currently see a tension between knowledge that is supposed to be all-comprehensive and the scientific practice of individual disciplines that are still hard to link to each other.
In conclusion we can say that within the formal agricultural knowledge network there is an increasing acknowledgement that farmers' knowledge is important, and that farmer induced innovations need to be given space. These insights are slowly permeating the agenda and resulting in adapted practices. Potentially, this can result in radical changes of agriculture and its knowledge network. However, the structures that have emerged from the 1950s onwards seem persistent and practical methods and approaches for moving forward are still in short supply (van der Ploeg 1999; Taskforce 2001).

3 Coming to grips with farmers' knowledge

3.1 Introduction

In this section we further explore the nature of farmers' knowledge. We discuss important characteristics. Moreover we touch on differences and similarities between scientists' and farmers' knowledge.

3.2 Characteristics of farmers' knowledge

In this chapter, farmers' knowledge is defined as the capability of a farmer to co-ordinate and to (re-) mould a wide range of socio-technical growth factors within specific localities and networks towards desired outcomes (e.g. sustainable levels of production). Evidently this capability assumes a range of experiences which allow the farmer to come at grips with the relevant growth factors and/or to discover new relevant growth factors. Furthermore the ongoing identification of unknown and unexplored growth factors underpins the dynamic nature of farmers knowledge and associated practices. Knowledge and farm labour can therefore not be considered separately.

Figure 1 illustrates the linkages between growth factors, farm labour and specific localities and networks. First, the farmer needs to make a set of decisions to rebalance growth factors. Growth factors, such as livestock, grassland, nutrients and water are evidently linked with each other. Second, farm labour involves the choice between utilising local or external growth factors (in this case the choice between fertiliser or manure, seeds or local vegetation, so on and so forth). Third, these growth factors are embedded in specific socio-material localities and networks (markets, government, landscape and technologies).

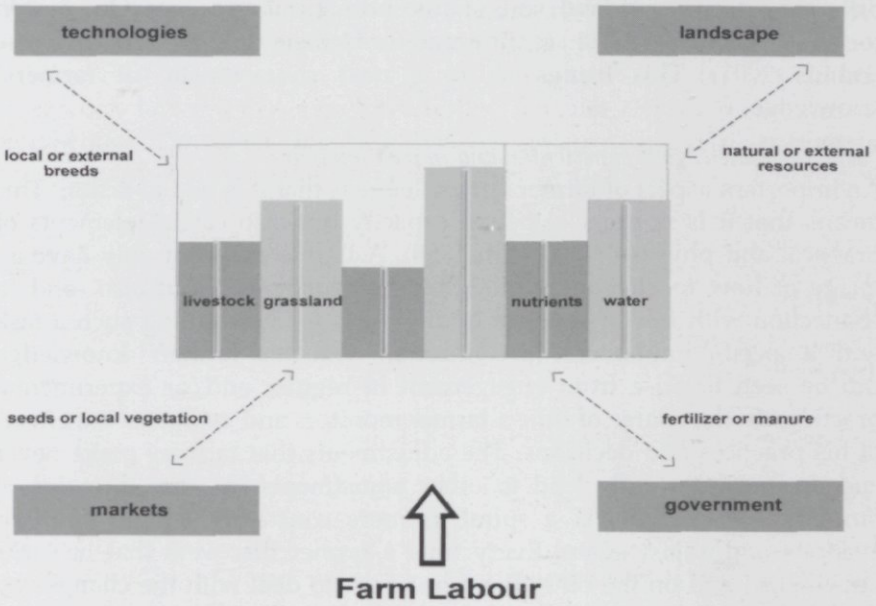

Figure 1 The co-ordination of growth factors within specific localities and networks.[17]

The following sections highlight several characteristics of farmers' knowledge in order to clarify its nature.

Farmers' knowledge refers to a specific local context

Farmers' knowledge incorporates elements that derive from 'outside' (e.g. from science, formal education and/or other spatial settings). Nevertheless, this knowledge needs to be meshed with knowledge that is specific to the farm and its constituent elements (e.g. fields, cows, soils, community, etc.). In other words 'universal knowledge' needs to be localised to the farmer's specific setting. This knowledge has often been build-up over generations. As Mendras (1970: 47) puts it:

> *'The traditional peasant tilled the field he had inherited and learned to cultivate from his father. He knew all the most minute details of the field, the composition and depth of the arable layer, which often varied from place to place, its rock, humidity, exposure, relief and so on. The result of long years of apprenticeship, work and observation, this knowledge that he alone possessed was the basis of his skill as a farmer* (Mendras 1970).

Thus, farmers' knowledge involves the art of developing agriculture within local conditions and to rebalance growth factors towards these local conditions. A related term that is often coined is that of 'indigenous knowledge' (Scoones and Thompson 1994). Often farmers' knowledge is expressed in specific languages and classification schemes. Farmers, for example, often use different words than scientists to distinguish between different categories of land, soil, plants and natural resources. One reason for this is that the criteria are different: for farmers they are related to use (Eshuis 2001). This brings us to a next characteristic of farmers' knowledge.

Farmers' knowledge is experiential and in part implicit

An important aspect of farmers' knowledge is that it is tied to action. This means that it is not just a mental capacity but also carries elements of practical and physical skill (Scott 1998). A farmer may not only have an image of how to effectively plough a particular field, but also -and in connection with this- a series of bodily skills for performing such a task with a specific implement. In connection with this, farmers' knowledge can be seen to arise from engagement in regular and/or experimental practices. In the course of time a farmer monitors and evaluates the effects of his practices and decisions. The adjustments that farmers make never end as they constantly lead to other adjustments in other domains of farming. This process is a spiral; farmers constantly adjust, monitor, evaluate and adjust again. Every time a farmer discovers that he lacks knowledge, and on the other hand he needs to deal with the changes on the basis of his available knowledge. In this way he learns by doing and does through learning. It is important to note that much of this practical and experiential knowledge of farmers may remain implicit or 'tacit' (Giddens 1984). That is; it is often difficult for farmers (or others) to express this knowledge in unambiguous rules and/or find words to express what they know.

Farmers' knowledge is about co-ordination and integration

In many ways farmers' knowledge refers to the capacity to meaningfully co-ordinate and integrates practices in different domains of farm labour. Farmers' knowledge is in part integrated knowledge as it refers to the relevant whole of different farming domains, production objects, processes and sub-processes. It centres on the different possibilities for evolving and unfolding production processes:

> *'....operating within as wide a range of cultivation and animal rearing as possible, integrating these into a system in which the by-products of each could be utilised to the maximum for the others'* (Mendras 1970).

Simultaneously, farmers' knowledge is the art of adjusting the processes of production to contingencies and unintended effects, *'through diversified speculation, furnished security against inclement weather and uncertain harvests'*(Mendras 1970). Farmers' knowledge entails the understanding of the effects of wind, water and temperature on the processes of production. Furthermore farm labour presupposes the active interplay of the farmers with these contingencies and diversity in circumstances and outcomes.

'*Every cow reacts differently to a new form of nutrient supply, with different outcomes in health, milk production and meat production. I adjust the fodder intake to these diverse reactions of the cows, but also to the available fodder, that changes with the seasons and with the harvest of grass, corn or other yields* (Friesian farmer).'

On this basis we can describe farmers' knowledge as referential knowledge; farmers know their soils through the grassland production, they know the grassland through the effects on the animals, they know the cows through the manure and the manure through the grassland production.

The term 'craftsmanship' is often used to refer to the capacity to coherently integrate and co-ordinate a range of practices and the possibility to act under given circumstances or actively influence these circumstances (Baars, de Vries *et al.* 1999). Thus, craftsmanship is what an actor can do to combine several elements of the production process. It entails detailed knowledge of the necessary, and most appropriate, use of the concerned instruments and labour-objects, the locally available instruments and objects of labour. As van der Ploeg emphasises, craftsmanship is generated in an experiential manner described earlier. It entails a permanent interaction between mental and manual labour and presupposes a continuous (re) interpretation and evaluation of the process of production so as to enable intervention at any required moment and in any desired way (van der Ploeg 1993).

Finally, from Figure 1 it has also become clear that farmers' knowledge does not only include technical knowledge. Farmers' knowledge also refers to the social and the technical surroundings. It is embedded in, reflects and acts upon local and historically available socio-material resources. It is not only important for farmers to gain knowledge on the technical artefacts and the way they work, but also the way they can be aligned in the socio-material environment in which they are applied.

3.3 Farmers' knowledge versus scientists' knowledge

When comparing farmers' knowledge to scientists' knowledge some differences are immediately evident. First of all, the generation of scientific knowledge tends to take place in totally different experiential environments than the production of farmers' knowledge (e.g. laboratories, research stations and universities versus real-life farms). Moreover, although scientific action (i.e. the process of arriving at scientific knowledge) may well involve tacit knowledge and skills (e.g. laboratory work, interviewing, etc.) the scientific endeavour is all about making knowledge explicit and formal. Thus, many scientists feel they cannot suffice to keep their knowledge implicit, which poses different demands on the process of knowledge production. In connection with this, scientists often adopt a reductionist epistemology. As we have already discussed in Section 2.4. this epistemological culture makes it difficult for scientists to arrive at knowledge of complex and co-ordinated wholes, whereas we have seen that this is one of the strengths of farmers' knowledge. In all, it is clear that the modes in which farmers generate and evaluate knowledge deviate significantly from those of scientists. Farmers tend to generate knowledge from practical experiences, and not from formal experiments and research. And even if farmers engage in deliberate experimentation, their experiments have very different characteristics from those of scientists (see our discussion in section 4). Moreover, farmers are likely to have a different form of evaluating and validating knowledge than scientists, in that they are likely to apply a much more holistic frame of reference than scientists who tend still to take a reductionist approach.

The local dimensions of scientists' knowledge

An issue that deserves some more attention is whether or not these two forms of knowledge differ with regard to their 'locally specific' character. For a long time scientists have claimed scientific knowledge to be 'universal', generally applicable and superior to farmers' knowledge. Moreover, many scientists identified themselves as 'experts' and others as 'laymen'. More recently we see that there is increased recognition that the knowledge that scientists produce is not 'universal', but has important local dimensions. That is, it is realised that the knowledge produced in scientific laboratories may be valid within the specific local conditions of the laboratory, but not necessarily in contexts that have different characteristics (e.g. a farm). Moreover, scientific endeavour is influenced and affected by specific 'local' considerations and conditions (Knorr-Cetina 1981; Latour 1987). Essentially, we see that agricultural research rather than being a series of discrete and rational acts, is in fact part of a process of coming to terms with conflicting interests, a process in which choices are made, alliances formed, exclusions effected and worldviews imposed (Scoones and Thompson 1994). Time and financial constraints, conditionality and donors influence choice of methodology. Also personal criteria play a role like habit and fear of not being respected. Methodology is political and personal (*ibid.*). Scientific propositions, claims, hunches and ideas take on the status of facts and become robust even before they have proved their universal validity (Rip 2000). In addition, it is important to realise that the questions underlying scientific investigation too often derive from a specific local context. Questions and problem definitions are never neutral: they are asked and/or funded by specific stakeholders, for a specific reason, and in connection with specific goals and interests.[18] The above implies that even if, within the parameters of a well-defined context and conceptual framework, natural scientists can claim to arrive at, at least temporarily, valid or 'objectively true' conclusions, they cannot claim to arrive at *neutral* conclusions. This is because the conclusions arrived at are more often than not directly linked to the (research) questions that were asked.

In view of these considerations we prefer not to use the conventional distinction between 'scientific' and 'local' knowledge from hereon, but speak simply of scientists' versus farmers' knowledge. Since all knowledge is contextual by nature, the term 'local' can not be used to make a distinction. Scientific knowledge is also bound to locality, even if it is presented to be universal knowledge (Lash, Szerszynski *et al.* 1996; Leeuwis 2000b).

Arguing that scientific knowledge tends to be valid in a specific locality certainly does not imply that conventional natural science research has nothing to offer to farmers in specific contexts. In fact, current farmers' knowledge may well incorporate elements that derive from scientists in one way or another. Moreover, much of the existing farmers' knowledge needs to renewed, adapted and supplemented because of rapid contextual changes that take place (e.g. population growth, migration, climate change, industrialisation, ecological changes, globalisation, degradation, etc.). And farmers' experiments and knowledge do have certain strengths, but also a number of weaknesses, and therefore tend to leave a number of questions unanswered. In some cases conventional (positivist and reductionist) laboratory research can provide extremely valuable 'building blocks' for solving farmers problems. In short: there is nothing wrong with conventional (applied or fundamental) research, as long as it answers the relevant questions (Leeuwis 2000b). Much of the critique of conventional scientific research, then, boils down to the assessment that it tends to operate in isolation from real-life innovation processes, and generates its own questions rather than addressing the questions and specific problems that societal stakeholders find relevant. Hence, the frequent plea to make agricultural science more interactive (Röling 1996).
In view of the above, we currently witness several efforts to arrive at new epistemological approaches that transcend the old dichotomy of the 'scientific' and the 'unscientific' (Röling 2000). In the next section we suggest some practical ways in which scientists and farmers may benefit from each other in developing sustainable agriculture.

4 Gaining farmers knowledge, experiences and insights

4.1 Introduction

We have argued so far that farmers' knowledge, experiences and insights can be an important resource for the sustainable development of farming systems as well serve as a resource for (interactive) scientific research. The aim of this section is to explore various ways in which farmers' knowledge can become more robust. First we will investigate how we can make farmers' knowledge more explicit. Second we will describe methods to enlarge farmers' knowledge. Third we analyse means to use farmers' knowledge as a resource for scientific purposes.

4.2 Making farmers' knowledge, experiences and insights more explicit

We have seen in Section 3 that farmers' knowledge tends to be partly implicit. This is true of several aspects of farmers' knowledge. First, practical knowledge concerning rebalancing growth factors and the interrelations between growth factors on the farm is often implicit. Finding new indicators for recognising and discovering growth factors that are now implicitly present can therefore be important. Second, specific farming practices that support the rebalance of these growth factors may not be immediately visible and/or explicit.[19] Third, in addition to the explication of technical growth factors, there is often a need to make their socio-economic alignment more tangible. One can think about forms of labour organisation, contracts between farmers and government or the development of regulations and technologies. Frequently, such socio-organisational dimensions of innovations are overlooked, although farmers have a lot of knowledge and ideas on these matters. Thus, a first strategy for collecting and capitalising on farmers' knowledge is to make it more explicit and recognisable. This includes explicating farmers' uncertainties, knowledge gaps and research questions, as these too can be seen as expressions of knowledge. In relation to all this, several basic strategies may be of use.

Recording experiences

A first strategy to make implicit knowledge more explicit is to stimulate the development of reflective routines. There are impressive examples of farmers who have their own methods of collecting experiences and impressions (van der Ploeg 1999). Farmers continuously experience things, but do not always record them. Simple notebooks or pocket tape recorders are amongst the devices that farmers can (and do) use to memorise and store their thoughts while going about their daily work.

Creating opportunities for (group) discussion

An important strategy for making knowledge explicit is to encourage farmers to talk about their knowledge, ideas and experiences. This may happen in a one-to-one interview situation, but useful insights may also be elicited from group discussions. Thus, one may, for example, bring farmers together in a group to talk about certain issues and problems. These kind of discussions can contribute making implicit knowledge explicit, helping to fill in the blind spots of what is not (yet) known and simultaneously improving awareness self-consciousness of what is already known.

Farm comparison
Group discussions can be aided greatly by encouraging forms of farm comparison. Through observation of several farms and farm practices differences can be noted between one's own farm and those of others. This can pose mental and interpretative challenges, which in turn encourages debate whereby underlying views and rationales may become more explicit. More generally, it helps farmers to take a fresh look at the existing processes on their farm. Farm comparison can take place in various forms and incorporate farm visits and excursions as well as systematic (possibly computer supported) collection, exchange and analysis of information from different farms(Leeuwis 1993).

Scientists who want to discover farmers' knowledge through supporting these kinds of activities may usefully play a double role. They can bring their own expertise on the specific areas in order to stimulate (not dominate) debate and they can act as facilitators in the discussion. The role of facilitator needs particular attention, as farmers can bring much expertise when scientists are able to skilfully facilitate this process (Baars 2001). As scientists are trained in the analysis of problems they need to take a modest role in this role, in order not to override the analysis of the farmers. Scientist's role in the facilitation of discussion should focus on promoting the need and methods for joint investigation, enhancing the strategies for experiential learning and giving space for feedback.

4.3 Enlarging farmers' knowledge, experiences and insights[20]

In the discussion on how to make farmers' knowledge explicit we have already touched upon the issue of how to enlarge farmers' knowledge. Indeed, one could argue that by making knowledge explicit the learning process has started and the enlargement of knowledge is already taking place. Nevertheless, it is relevant to differentiate between the two processes because the process of making knowledge explicit requires, in part, different methods than are used when enlarging knowledge. Moreover, making knowledge explicit involves discussing practical or tacit knowledge, while enlarging knowledge implies a step further in the learning process. Frequently, the enlargement of farmers' knowledge is associated with 'farmer experimentation'. We therefore turn to discuss the specific nature of farmer experimentation, and how it may be supported. In doings so it will become clear that supporting farmer experimentation also requires elements of explication; this underlining our earlier observation that 'explication' and 'enlargement' are closely intertwined.

Farmers often already engage in 'experimental' activities, even if this may not be immediately clear and visible to outsiders. Often farmers do not refer to their activities as 'experiments' or 'trials'. Perhaps more importantly, farmers' experimentation can take many forms, which usually deviate to a large extent from the ways in which scientists think about experiments. This relates to the issue of different epistemological cultures. In connection with this, scientists may well fail to recognise farmer experimental activity. Let us discuss various important characteristics that farmers' experiments may have in this respect:

Different horizons in comparing treatments.
Farmers do not always 'run' different experimental 'treatments' (including a control treatment) simultaneously. Instead of comparing simultaneous treatments (as scientists usually do), they may well compare different 'treatments' over the years. And instead of having their own 'control treatment' they may well use other farmers' farms and practices as a point of reference. Thus, farm comparison is, in many ways, a form of farmer experimentation.

Ex-post reconstruction.
In connection with the above, farmers' experiments – unlike scientists' experiments – are not necessarily designed deliberately and planned prospectively. Experiences may well become constructed *as* experiments in retrospect. By comparing one's own practices and results with those of others or from previous periods, for example, one can come to think about observed differences as the outcome of an 'experiment' (see Baars 2001). Similarly, experiments may happen accidentally, for example when two household members carry out the same task in a slightly different way, or when two fields are handled in the same way, but at a different point in time.

Experimentation as improvisation.
Although farmer experiments may often be carried out from sheer interest, farmers may sometimes also be 'compelled' to engage in 'experiments' in the face of external conditions, such as the non-availability of inputs used normally. Here, experimentation takes the form of improvisation.[21]

Multiple 'independent' variables.
Farmer trials do not usually take place under controlled conditions but take place in the context of wider farming activity. Due to both the carefully co-ordinated nature of farming practices, uncontrollable conditions, and the different horizons of comparison that farmers may apply, there are usually several 'independent' variables at the same time (whereas scientists often prefer to isolate *one* independent variable). This is especially true when the horizon of comparison is a previous year. When, for example, a farmer tries out a new maize variety there will usually be more relevant differences (e.g. weather, sowing dates, etc.) with previous years than just the variety used.

Holistic evaluation and measurement.
Even if scientists do consider several 'dependent' variables when evaluating an experiment, farmers are likely to take into account an even wider range of 'variables'. In a fertiliser experiment, they may not only evaluate 'yield', 'cost effectiveness' and 'pest-infestation', but also 'taste', 'marketability', 'crop-residue', 'labour demand', etc. Moreover, while scientists usually prefer precise measurement of variables, farmers may also use less tangible (i.e. tacit) modes of evaluation, such as impressions, intuitions and feelings (Eshuis 2001).

In view of the above we can conclude that it is perhaps better to speak of farmers' *experimental activities* rather than of farmers' *experiments*, as the latter term suggests a degree of deliberateness and demarcation that is misleading. Nonetheless this does not weaken the importance of the activities as learning experiences.

Modes of supporting farmer experimental activities to enlarge knowledge
In our view, supporting farmers' experimental activities should not be equated with 'turning farmers into scientists' or 'imposing scientists' epistemological culture'. Knowledge creation may have a rather different meaning and purpose for farmers than for scientists. For instance, it is often impossible and/or inefficient for farmers to wait to explore new practices until scientists are fully convinced of their efficacy. They may want, and need, to 'go ahead' when they have sufficient evidence that something 'works', even if such evidence does not live up to scientific standards. Rather than replacing current modes of investigation and farmer research, the support of experimental activities could build on existing practices in various ways:

Explicating and exchanging existing experimental activities
Many of the existing experiences may not yet have been explicated and shared among farmers. Hence, identifying, collecting and exchanging existing experiences may contribute much to problem solving and innovation (see Section 4.1).

Improving measurement, memory and feedback
Often the capacity to draw inferences from experimental experiences can be enhanced by adapting modes of measurement, and by the collection and storage of information about regular and experiment-like activities.

Supporting interpretative debate in groups:
Due to the nature of farmers' experimental activities, it is often not easy to draw clear conclusions, as there tend to be a number of possible explanations for certain phenomena. One way of improving the capacity to draw valid conclusions is through talking with people that have similar

experiences. Here too organising group discussions around such experiences can be of use.

Identifying issues and adding options for deliberate experimentation
Outsiders can organise group debates and analytical activities that are geared towards identifying areas that require experimentation. Forms of joint socio-technical problem analysis and priority ranking can be of use here. Moreover, outsiders can be useful in suggesting new options and opportunities for experimentation and/or providing farmers with insights that lead them to adapt their research agenda (Veldhuizen, Waters-Bayer *et al.* 1997). Agricultural innovations frequently emerge from accidental experiences or from experimental activities that neither farmers nor scientists considered very promising initially. Therefore it may be useful not only to think about 'the obvious' but also to solicit and seriously consider 'crazy' and/or unconventional ideas and solutions.

Including social-organisational 'experiments'
Very often the focus on on-farm experimentation is solely on technical experiments and issues. Given the experience that innovation requires new social-organisational arrangements as well this is a rather one-sided approach, which may well lead to technically sound solutions that can never be applied. Thus, in many instances it can be relevant to experiment with (or work towards) alternative social-organisational arrangements as well. More so than with technical experiments only, such alignment activities may exacerbate social tensions, and hence requires efforts to facilitate conflict resolution.

Debating the design and management of deliberate experiments
When making plans for new on-farm experiments, the design of such experiments is obviously an area for discussion with farmers. Without necessarily imposing scientific modes of experimental design, scientists' concerns and insights on systematic experimentation may still serve as inputs in such a discussion. Sometimes small changes in the design of farmers' experiments can lead to a considerable increase the potential to draw accurate conclusions. In this context it is pertinent to discuss where to conduct, and how to administer, experiments. It may be important to consider that one need not necessarily arrive at one single design or location. It can be enriching to make use of the existing diversity in farmers' preferences and views, and run several on-farm experiments at the same time.

Reducing risks
Sometimes potentially interesting experiments go along with prohibitive (perceived) risks and uncertainties. Farmers may, for example, be wary of experimenting with reduced use of pesticides, due to fear of losses in yields. In such cases, outsider agencies may provide insurance and

resources that allow farmers to experiment and reduce their risk. One form of protection that farmers need can be *vis-à-vis* each other. Scientists can play a facilitating role among farmers when the experiments they are doing are not clear to one another and may possibly cause problems within the farming community.

Co-ordination and interaction with formal research

It is recognised that on-farm experimentation and research in formal scientific research institutes can fruitfully enrich, inspire and complement each other(Baars, de Vries *et al.* 1999; van Schoubroeck and Leeuwis 1999). In general, carrying out similar experiments in several locations tends to lead to different experiences and serendipitous discoveries. Moreover, formal on-station research can provide a back up to on-farm experimentation in several ways. Farmer experiments may 'fail' due to a variety of reasons (related to natural conditions, technical practices or socio -organisational issues) and comparison with on-station research may at times provide clues about such reasons. Moreover, formal research facilities often allow for more in-depth exploration of underlying mechanisms, provide some 'free creative space' for scientists to follow their gut-feelings and intuitions, and allow for more rigorous and frequent data collection. As van Schoubroeck (1999) indicates, complementarity is more easily achieved when the same persons are involved in both on-farm and station research.

4.4 Use of farmers' knowledge as a resource in scientific endeavour

In addition to supporting farmer experimentation, scientists can use farmers' knowledge as a resource for their own research. One often-practised method is by treating farmers, their practices and knowledge as *objects* of research. The role of farmers is very often limited to this, which implies that they are not actively involved in the design of the research or in analysing its results. . In this section we explore some relevant issues for consideration when including farmers as equal partners in scientific research.

Choosing partners

An important aspect when one wants to engage farmers in research is the selection of the right partners. Very often this selection is the same way as when selecting research colleagues or partners. Farmers with an interesting worldview, interest and expertise can enrich the contents and meaning of new research. One could call these farmers 'pioneers', who are interesting to have as partners in research. Also farmers who have specific questions can become partners in experimentation, although a selection of the questions with respect to relevance is always needed. The ways in which to involve partners can differ. One may organise and facilitate group discussions among farmers, speak and experiment with farmers individually, or have group meetings in which both scientists and farmers participate simultaneously.

Different roles for farmers
In designing a research agenda, farmers should be involved from the outset as in this way they come to 'own' (and feel that they own) the research agenda. Furthermore, farmers can play different roles in the research process. Farmers can take a look at the research proposals and comment on the relevance and validity of the research questions and design. Moreover, one can use the hypotheses of farmers in scientific research or allow oneself to be inspired by the questions farmers ask themselves in their farming practice. Depending on the nature and the layout of the research, one can incorporate e farmers' observations by actively searching, monitoring and observing together with farmers. Do they see the same things as you or are their observations different and for what reasons? What are the ways in which a farmer collects experiences and insights and how does it contribute to science and *vice versa*? In this way both parties can find the blind spots and enrich each other in their farm and scientific practices.

Contextualising knowledge within research processes
If farmers' knowledge is to become incorporated into research agendas, close attention needs to be paid to the contextualisation of the research process and the knowledge involved. Often, scientists consult farmers for specific observations and questions, but in the translation to research, the contextuality of these observations and questions becomes obscured. Yet, this contextuality (or local horizon of relevance) can give great opportunities for innovative research, as farmers try to find ways to innovate, starting from their local opportunities and constraints. When one wants to involve farmers throughout the whole research process their strategies to search for ways within their own farm practices needs to take a central role in the research agenda.

In all, there is a myriad of ways in which farmers can be involved in scientific endeavour, and the 'optimal' way of involving farmers may vary from in different contexts. It is important to recognise that involving farmers in scientific research is quite different from scientists becoming involved in farmers' research, even if complementarity between the two may be forged.

5 Final considerations

We have spoken a lot in this chapter about knowledge. However, it is important to recognise that sustainable innovations do not come about through (farmers or scientists) knowledge alone. In our discussion of about changing views of innovation, we have emphasised that innovation requires network building, learning, coalition building and negotiation in order to arrive at new forms of co-ordinated action. Thus, arriving at sustainable innovation is in many ways a political process, and it is in this context that knowledge plays a role. Indeed knowledge and learning can contribute to coalition building, political claim-making and conflict management. But it is clearly only one of the ingredients for arriving at new social and technical arrangements. Moreover, placing knowledge in this context underlines once more that various types of knowledge need to be accessed and acted upon during (the management of) innovation processes. These include substantive knowledge, knowledge about stakeholders and knowledge on process dynamics and/or management. In this chapter we have tended to focus on substantive (social and technical) knowledge.

In concluding, we want to recall that we have identified a number of problems with current agricultural knowledge systems (see section 2.4). Analysis of these suggests that it is far from self-evident that scientists can or want to take on board the practical suggestions we have put forward. In many scientific institutes there is ample room for scientists to include farmers' knowledge in a meaningful way. In order to facilitate the inclusion and development of farmers' knowledge these institutions may need to reposition themselves in terms of their scientific culture and organisation, including epistemological beliefs and reward structures within the scientific community. We have signalled that scientific epistemologies and views on scientific knowledge are slowly changing. It is becoming more widely acknowledged that scientific knowledge does not represent *the* objective truth, but can be more accurately described as a model that is accepted by the scientific community in a certain temporal, spatial and social context. However, while this view of science may be more widely accepted among scientists themselves, it is not so often expressed when scientists communicate with the outside world. Internal tensions within the scientific community tend to be shielded from the outside world and conflicting views and controversies tend not to be brought out into the open. One challenging aspect of engaging more with farmers' knowledge is that the 'social' construction of all forms of knowledge is made more transparent to outsiders, and that it becomes clear that scientist are actively engaged in this process.

Finally it is crucial that societal relevant research becomes something that scientists can derive status from. This may well require an adjustment of current reward structures in science. In addition to evaluation on the basis of publications in established journals (which currently dominate peer evaluation of scientific endeavour) other scientific products, such as the participation in farm developments, engagement in projects, or writing for farmers' magazine, etc.) need to be incorporated in evaluation and assessment systems. In this way scientists' accountability towards society can be enhanced. Moreover, financial streams in the scientific community may need to be re-directed so researchers can effectively obtain resources for interactive research with farmers.

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Notes

1 This was due to the fact that new actors emerged that influenced the agenda of the agricultural policy community, for instance animal welfare, nature, and environmental organisations.

2 The relation between a yield (for instance milk production) and one growth factor (for instance protein) is not a linear one. In practice the whole set of growth factors determines the production process, being the limiting growth factor in this respect strategic (see de Wit 1992).

3 This knowledge was often obtained indirectly through observing interactions with other growth factors. Thus the benefits of using manure were known indirectly, through its effects on grassland production. The composition of different grassland varieties was known through its effects on milk yield and cattle health. The quality of milk was known through the cheese making process. Knowledge was based on the *interactions* that emerged at different levels of aggregation.

4 As a consequence, knowledge and practice are intertwined and therefore cannot be separated. We will come back to this issue in section 3.

5 An innovation that might function well in certain circumstances might be useless in other situations, precisely because the conditions under which it can be applied do not exist, and cannot readily be created.

6 But, farmers' knowledge is not always in harmony with nature, it can cause serious degradation. Farmers' knowledge should therefore not be confused with environmental friendly knowledge. The romantic assumption that people's achievements logically result in agro-ecological wisdom runs the risk of ethnocentrism (see Hobart, 1993).

7 In connection with this, Chambers (1989) speaks of the Transfer of Technology approach.

8 Leeuwis (2000) has argued that commercialising knowledge and new financial arrangements such as 'output financing' may -perhaps unintentionally- contribute to a resurgence of these linear modes of thinking.

9 'Agriculture' as represented by agricultural sciences was not in the first place the representation or expression of specific empirical farming practices, but became first of all the outcome of models.

10 For instance the development of genetically modified crops.

11 At the level of everyday knowledge, however, it is quite evident that a field is not just a particular and relatively stable point within a multi-dimensional space defined by chemical, physical and biological dimensions. A field is worked and reworked, fertilised, drained and/or irrigated, trodden on and taken care for. That is, it is transformed, through time, into what it is (see Mendras, 1970).

12 A typical example is the endeavor to raise sustainability at farm level through an accelerated increase of milk yields per cow (see chapter 7 in this book).

13 In other words, the farmers who followed the models of science profited the most of the results of science. Here we see that science reshaped the locale in a fashion that allowed their artefacts to work (Long and Long 1992).

14 This has been called the yield gap: where farmers did not get the yield that was obtained at research stations this resulted in constraints in farming systems research (See Chambers, 1989).

15 Agricultural scientists from before the modernisation of agriculture seemed more able to combine and integrate elements of (nowadays) different disciplines within their academic practices.

16 E.g. within Wageningen University and Research Center there are special funds for 3I-research; interactive, innovative and interdisciplinary research.

17 The unlabelled bars represent other (here) not mentioned growth factors.

18 Leeuwis with van den Ban (2003) gives the example of a director of a fertiliser industry who might want to know what combination of fertilisers can best be applied (when, in what dosage, etc.) in maize production in a region of Tanzania. Local farmers however, may be more interested in developing a cropping system that minimises the use of chemical fertiliser. Thus, we see that different stakeholders might ask different questions, set different priorities, and hence are bound to arrive at different conclusions. However, it is clear that -in this case- the director of the fertiliser company may well be in a much better position (i.e. may have more access to relevant resources) to effectuate his research interests than local farmers

19 We want to give an example from the mineral project of the environmental cooperatives Vel and Vanla (see section 2 of this book). Within the project, internal growth factors associated with natural manure, roughage and soil have gained new importance as the use of external growth factors, like nitrogen fertilizer had to be decreased. Still, farmers need to find ways to discover these items. Some of the farmers already have found indicators to understand these growth factors, for instance through the observation of the cattle, the characteristics of the soil or roughage. One can learn from this example that farmers may also use less tangible (i.e. tacit) ways, such as impressions, intuitions and feelings to come to indicators, as smell of the manure, the way hay feels in the hand, humidity and so on. They also found new ways to integrate these growth factors in their practices. Making their findings explicit can result in knowledge that serves as a resource for other farmers and scientists.

20 This section is based on the draft version of Leeuwis with van den Ban, 2003.

21 By way of example, the founders of Rachel's Diary, now the largest organic creamery in Wales only started processing their milk as a result of heavy and prolonged snowfalls, which stopped milk collections for some time. Thus the seeds of a major business were sown by the reluctance of the owners to pour milk down the drain that couldn't be collected or stored (Nick Parrot, personal communication).