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Revealing different understandings of soil held by scientists and farmers in the context of soil protection and management

Abstract

This paper aims to analyse and draw together results from similar studies in England, Switzerland and France which investigated farmers' understanding of soil and compared it with that of scientists, researchers and advisors (collectively called scientists in this analysis). A range of methods were used across the three studies and different theoretical approaches, looking at forms of knowledge, local practice of knowledge production and conceptions of reality, were employed to explain the results. Despite the different contexts, methodologies and theoretical approaches in the three studies, the results reveal similar patterns of difference in farmer and scientist understanding of soil. In the English study farmers demonstrate a 'know-how' form or intuitive working knowledge of soil while advisors rely on scientifically established forms of 'know-why' and seek to understand and explain soil processes. Similarly in the Swiss study farmers' and scientists' differing perceptions are directed and shaped by their respective aims, methods and context of work. In the French study farmers and researchers are shown to have different conceptions of soil, they attribute different meaning to the same activities, and use different words and language to describe the same features. In all three studies understanding is shown to be cultural and contextual, as such an integrative theoretical framework is proposed.

1. Introduction

There has been extensive research on the technical aspects of soil protection management in the context of soil erosion and diffuse pollution in Europe (Imeson 2006). Invariably the practices proposed by scientists and technicians rely on farmers to implement them, ultimately the farmers' actions will determine the state of the soil. The difficulties in bridging the divide between technical solutions and implementation in the field, or translating science into practice, are well known (Eshius and Stuiver 2005). Often these difficulties are underpinned by a difference in understanding between those developing soil conservation technologies and those being asked to use them. Many researchers have recognised that different actors in the context of agricultural management will have different perspectives informed by their knowledge, values, interests and experiences (Long 1992; Harrison et al. 1998; Tsouvalis et al. 2000; Johnston and Soulsby 2006). This has been specifically noted in the context of soil (Liebig and Doran 1999; Fairhead and Scoones 2005). Failure to recognise and accommodate such differences has been central to the criticisms of traditional agricultural extension and development (Vanclay and Lawrence 1994; Olivier de Sardan, 1998).

The apparent difference between scientific and farming communities presents a challenge for those seeking to implement soil protection practices. Understanding the nature of this divide between farmers' and scientists' perceptions of soil and its management is important to enable effective communication between the two communities. There are increasing efforts by the research community to bridge this gap, by consulting farmers and trying to understand their motivations, perspectives and knowledge and incorporating these into scientific developments (Walter et al.

1997, Liebig and Doran 1999; Doran 2001; McCown 2001, 2002; Eshius and Stuiver 2005; Carr and Wilkinson, 2005; Carolan, 2006). At the same time some farmers are endeavouring to become more competent and scientific in their soil management in response to policy demands. However, our understanding of how perspectives differ is still limited.

A number of commentators have looked to the duality of scientific and local knowledge to explain these differences and the respective value of farmer and scientist knowledges about natural resources has been widely debated in the context of agriculture (Morgan and Murdoch 2000; Kloppenburg 2001; Agrawal 2002). Others relate different perspectives to farmers' and scientists' differing norms, values and expectations. Some researchers have suggested that differing contexts of knowledge production explain actors' different perspectives and understandings (Agrawal 2002; Turnbull 1993). Others emphasise the contextual, cultural and social dimension of understanding and have framed their research in terms of differing conceptions and systems of meaning (Weber 1956); habitus (Bourdieu 1985); farming styles (van der Ploeg (1993; 2003); conflicting life worlds (Long 1992); knowledge communities (Raedeke and Rikoon 1997); knowledge systems (Turnbull 1993; Carr and Wilkinson 2005) and knowledge cultures (Tsouvalis et al. 2000). Despite this body of literature, many studies have been empirically and theoretically discrete, there has been an absence of any comparative analysis, as noted by Turnbull (1997). As such, this paper aims to compare results from similar studies in England, Switzerland and France which described knowledge, perception and conception of soil held by farmers and by scientists (including advisors and researchers). This analysis aims to examine the nature of the difference in understanding between the two communities (farmers and by scientists) in the three studies and provide a theoretical synthesis.

2. Theoretical considerations

This paper brings together three theoretical perspectives which attempt to explain the differences between scientists' and farmers' understanding of soil and its management. The term 'understanding' is used here broadly to encompass knowledge, perception and conception which are defined below.

In the first perspective (used in the study in England) the nature of knowledge is taken as the conceptual basis of the study. Understanding 'knowledge' in the context of agriculture has challenged many commentators (Thompson and Scoones 1994; Morgan and Murdoch 2000; Tsouvalis et al. 2000) and it is not the intention here to discuss this in detail. The tensions between the local or tacit knowledge[1] and codified scientific knowledge[2] forms and the debate about the validity and superiority of these knowledges particularly in terms of achieving sustainable agriculture is well known (Richards 1985; Kloppenburg 1991; Molnar et al. 1992; Morgan and Murdoch 2000). This research uses a refinement of knowledge forms into 'know-how' and 'know-

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[1] Local knowledge, also called lay/indigenous/informal/traditional has strong tacit elements. It is thought to be 'strongly rooted in place… location specific' (Murdoch and Clark 1994); and 'has to do with theories, beliefs, practices and technologies that all people have elaborated without direct inputs from the modern, formal and scientific establishment' (McCorkle 1989).

[2] Scientific knowledge is also referred to as codified /expert/formal/ standardised/codified and institutionally legitimate. It is described as explicit knowledge which can be systematised, written, stored and transferred (Norgaard 1984).

why', as proposed by Lundvall and Johnson[3] (1994), although it accepts that these are not discrete categories but are fundamentally complementary and supplemental to one another (Long 1992; Romig et al. 1995; Walter et al. 1997; Morgan and Murdoch 2000).

In the second perspective (used in the study in Switzerland) central theories of philosophy of science such as thought collectives by Ludwik Fleck (1979) as well as tacit knowledge by Michael Polanyi (1974, 1975) helped to find a basis for comparing the perception of farmers and scientists, where perception is the way in which individuals analyse and interpret incoming information and make sense of it. By choosing the local practice of knowledge production of farmers and scientists a differentiated perspective was developed to describe differing, and similar, perceptions (Turnbull 1993; Agrawal 1995; Fry 2001). It is argued that farmers' and scientists' differing perceptions are directed and shaped by their respective aims, methods and context of work (Fry 2001). Scientists and farmers rarely reflect on, or acknowledge, these differences in aims, methods and context. When moving in another working context, which is necessary when we are interested in implementing soil protection in agriculture, inevitably there are problems.

In the third perspective (used in the study in France) a social perspective is used to explain the different conceptions between farmers and scientists (Weber 1956, 1971; Putnam, 1984). A conception is defined as the way farmers or scientists consider the objects they manage, including their judgement values (Darre et al. 2004). In this perspective, conceptions of a reality depend on activity and social position where a social group qualifies an object using features that are relevant to its own viewpoint; this, it is argued, is why actors do not have the same representations of, nor use the same language to talk about, the world (Weber 1956, 1971; Putnam 1984). The sociological explanation of the behaviour of actors lies in what the behaviour means for the subjects themselves. Collective forms of thinking, and not external variables, are considered as causing the behaviour. During interaction and communication within social groups (farmers or scientists), conceptions are built, they can be understood as the set classifications of a group.

Whichever conceptual approach is used to theorise different knowledges or views held by the scientific and farming communities, the fact that there are tensions between them is clear. Whilst research has focused on these tensions, very little time has been spent examining how these different knowledges, viewpoints and conceptions interact.

3. The three studies

Details of theoretical perspectives and methodological approach in each study, are available in the respective publications (Ingram 2008; Fry 2001; Mathieu 2005), and are not repeated here. On a methodological point the authors understand, as argued by others (see Turnbull 1993), that scientists and farmers are not homogenous groups of people, that an arable farmer in England with >500 acres of cereal, not only differs

[3] In Lundvall and Johnson's (1994) typology 'know-how' refers to skills, the capability to do something at practical level, as reflected in action and has a significant tacit component. 'Know-why' is the knowledge of principles, rules and ideas of science and technology.

from a mixed small scale farmer in rural Switzerland, but may also differ from his or her neighbour. Equally scientists concerned with soil may be specialists linked to experimental farms, geomorphologists concerned with catchment level processes or agricultural advisors interested in crop-soil interactions with regular interaction with farmers in the field. Although the authors accept that the categories 'farmer' and 'scientist' are very broad and that they are interpreted and described differently in each study (i.e. advisor, scientist, researcher), the results do indicate that actors within groups demonstrate a similar approach to, and a distinctive collective understanding of, the soil.

4. The study in England: results

4.1 Context and Methodology

The aim of the research in England was to gain an understanding of the nature and extent of knowledge held by farmers and by advisors about soil and its management in the context of projects enhancing soil protection. For further details see Ingram (2008). Advisors in this study are considered to be from the scientific community, they are agronomists, agri-environment and conservation advisors. They are often science graduates, and are trained and qualified to use codified tools (Codes of Good Agricultural Practice, Fertiliser Recommendation Systems, soil analysis etc) which have been derived from scientific research (see Ingram and Morris (2007) for further details).

Qualitative data was derived from semi-structured interviews with fourteen farmers and twenty six advisors involved in two soil management initiatives in England promoting soil management such as good cultivation practice to improve soil structure. These comprise arable farmers typically from large arable units (>500 acres) in the eastern regions as well as mixed farmers in the south west of the country. In addition quantitative data from an extensive survey of 162 agricultural advisors, was also gathered nationally to gauge their nature and extent of knowledge and, since advisors regularly meet farmers and observe their practices, to solicit their views on farmers' soil knowledge.

4.2 Results

A number of advisors consider farmers to be technically knowledgeable and as having an understanding of principles that underpin good soil management. For them there is clear evidence of good techniques being used, as these comments demonstrate:

Most farmers I deal with are aware of good husbandry techniques and go to great lengths to keep soil in good order (Agronomist A).

Sustainable soil management is brought about by increasing our understanding of the soil dynamics and to use techniques that maintain/enhance the delicate balances as far as possible in the soil, this I would suggest has been practised for years (Agronomist D).

However there was lack of consensus among advisors responding to the questionnaire about this aspect of farmers' knowledge with only an average of 48% of all advisors (excluding conservation advisors) agreeing that farmers are technically well informed about soil management. One advisor commented:

I feel soil management is a very important issue that is frequently ignored due to lack of knowledge by farmers, they do not seem to understand the correct balance of nutrients needed within the soil and the cultivation methods related to all the different soil types (Agricultural advisor D).

Views explored in interviews suggest that it is the depth of farmers' technical understanding of soil management that is limited, as an advisor noted:

In a very broad sense farmers practice good husbandry. They are aware of gross errors of management but not aware of more subtle things they can do. For soil protection, they're aware of most obvious things but most don't fully understand the topic. There's awareness that the problem exists on one level but not yet sufficient awareness of issues leading to it (Agri-environment scheme advisor F).

Whilst awareness has increased and most farmers now know about soil degradation and the on and off site impacts of poor management it is claimed they do not necessarily tie it down to their own practice. This was borne out in the interviews where, although farmers acknowledged that certain management practices lead to increased run-off, none accepted that their individual practices were responsible, attributing the problem instead to other sources such as highways or to their neighbours. Even when the run-off was traced to their own farm, they blamed extreme weather events rather than their own practices. A farmer's remark epitomises this view:

I've seen water run-off from my fields and it's brown flowing straight into the river. Nothing could be done about it, we're on free draining land if it's washing off here it's washing off everywhere (Farmer A).

Some farmers accept they are ignorant about soil, for example one remarked '*I know everything about machinery, a little about crops, but very little about the soil. Even though I work the land, I still don't know enough about soil*' *(Farmer B).* Here he is talking in a technical and scientific sense but not acknowledging that by working the land he knows the soil in another sense.

These views demonstrate that some advisors define farmers' ignorance in terms of knowledge of 'balance of nutrients' and 'cultivation method' and understanding. However many farmers consider that they possess a less tangible form of knowledge described in terms and phrases such as 'intuitive knowledge', 'being in tune with the soil', or 'understanding the soils'. This feel for soil is linked to their central function on the farm, as one advisor remarked '*They [farmers] don't know necessarily about soils but they have an intuition about soils because that's their livelihood'*. Associated with this is the attachment some farmers have for soil, as one advisor commenting on farmers' response to soil erosion said '*It's like loosing their birthright, farmers hate to see the soil running off.*' Advisors are suggesting that the farmers' lives are intimately tied up with the soil.

All farmers interviewed appear to have developed a practical 'working knowledge' of their soils through regular cultivation which enables them to gauge physical properties, such as structure and texture as well as spatial heterogeneity. Accordingly soils were often described by farmers in terms of their ease of cultivation, with terms such as ‘light and easy’, ‘boy’s land’ or ‘heavy’ used. Some drew relationships between soil texture, structure and soil moisture, distinguishing heavier soils as having better natural structure and better water retention but being more difficult to plough. Farmers talked about working the land and tended to describe and judge soil in terms of its response under cultivation drawing on their knowledge of local conditions such as weather, and on the knowledge of their forebears, as one farmer states:

The weather is so important, this land, my father taught me, he said ‘the one thing that works this land is weather and you will never force it’, and he was so right. Because it is heavy land, you have to cultivate dry or drill dry, you can't do both wet and expect to get a good crop (Farmer Y).

However farmers’ poor cultivation decisions and practices, regarded by the majority of advisors as the main reason for soil structural degradation and consequent erosion, are attributed to lack of thought, as one advisor said ‘*My view is that the level of competence in terms of cultivation is not necessarily that great because farmers don’t think about what they are doing’ (Agronomist B)*. More specifically farmers’ lack of observation and examination of soil is blamed. Although there is thought to be an enormous amount of understanding of soil amongst farmers, the main problem, in the opinion of those advisors involved with helping farmers improve soil structure, is that ‘*they do not know how to examine their soil to determine how much cultivation is required’*.

This problem is recognised by some farmers as well, one for example, describing other farmers, commented:

There is not enough kicking plods, it's more crash bang wallop and getting in before the next job rather than thinking things through. They only look at top, OK they will scuff in with their boot, the surface where the seed is going, to make sure it's in a good condition, but what happens beyond there… they have very rarely gone out and put a spade in the ground and dug a hole to see what's happening (Farmer L).

In terms of evidence for the nature of knowledge held by advisors, the research revealed that the advisors who were interviewed and who responded to the questionnaire, tended to align themselves to the scientific community. These advisors valued, demonstrated an understanding of, and often participated in, research. They also disseminated research findings through their recommendations. Nearly 90% of questionnaire respondents were trained in providing soil best management practices and many were qualified in a scientific discipline. They also applied various scientific tools (FRS etc) when making recommendations, the majority of respondents using the Soil Code at least sometimes. They appreciated and sought out research outputs from experimental stations and many regarded research outputs as the only sound basis on which to base their recommendations to farmers. The comment below, for example, from one advisor, reveals this:

It’s [research] vital. It’s got to be a key driver for what I do. My view is from my … job.. is that I can’t be credible unless I can be objective and I can’t be objective *unless I have research behind me. It's as simple as that, so from my point of view it's absolutely critical (Agri-environment advisor P).*

This confidence in the objectivity of science is demonstrated by others, for example the principles of reduced tillage, which is promoted by one of the initiatives studied, are believed to be firmly grounded in formal research trials and some advisors associated with the initiative were reluctant to consider any anecdotal evidence which contests the value of the practice, as one explained '*People who do un-replicated experiments and a few observations and draw conclusions, which are not scientifically validated, that's what we're up against (Advisor B)*

Examination using a spade is a process that advisors have come to rely on and implement as a method for interpreting the soil condition throughout the profile. Whilst they criticise farmers for not examining soil, farmers criticise advisors for not being knowledgeable about cultivating the soil and as not having to experience the multitude of other imperatives that farmers' experience in running a farm. Even within the advisor community there is recognition of advisors' limitations, as one commented:

A lot of people I know who work in the soils field and agronomy advisory are actually very weak on soils, on hands-on soils, they really are. They just haven't got their minds around it….. The only way you'll understand about soil capability and timeliness is by doing it and doing it for quite a while and that's the problem, these people, they don't actually do it (Advisor R).

These results suggest that although some farmers in the study have considerable knowledge of the soil, they do not have sufficient understanding to make the link between certain practices and their consequences; 'there's awareness that the problem exists at one level but not yet sufficient awareness of issues leading to it'. This suggests that their understanding of how things happen, and the processes involved, are poorly developed. The farmers do have variable levels of spatial and working knowledge and experience, some demonstrate intuitive knowledge and a detailed understanding of how their soils behave under cultivation or changing weather. Their lives and livelihoods are intimately connected to the soil. There is a sense however that this knowledge is not enough, they are 'in tune but equally ….there is considerable ignorance' or 'there is an enormous amount of understanding about the soil but where farmers fall down is they won't examine it' (Agronomist B). Advisors conversely rely on objective knowledge and scientific rules, principles and tools, they look for explanation and use visual examination as a method of enquiry, they seek explanation. However they are criticised for being weak in terms of 'hands-on' soil knowledge because they do not actually work the soil nor face the practical constraints that farmers do on a daily basis.

5. The study in Switzerland: results

5.1 Context and Methodology

The aim of the research project in Switzerland was to study farmer perception of soil, compare it with scientific perception and derive suggestions for implementation of soil conserving practices in agriculture. Several actor groups are involved in soil protection. The perception of small farmers in the midlands of Switzerland is compared with the perception of scientists working as researchers in the field of soil science here. The farmers were chosen according to the criteria: organic farming/integrated production, experience, age, education and gender. The scientists were chosen according to the criteria: experience, topic of work and gender. The perception of farmers and scientists was examined by means of qualitative methods (participatory observation and episodic interviews) and compared using document analysis (publications, photographs). For details on the context and methodology see Fry (2001).

5.2 Results

While farmers tend to perceive soil and plant properties incidentally mainly during field work, when using farming equipment under varying conditions, scientists focus on certain soil properties by intentionally choosing a site, taking a sample and transporting it into the laboratory where analytical measurements and specific experiments are carried out under controlled conditions. The first example illustrates these findings:

During the interview farmer George M. described his soil as follows:
There, the soil has a yellow tinge when freshly ploughed. Over there, it has some marshy areas and back there it gets loamy. There, I have to change gear, it is much tougher. And there in front of the hollow, the whole spot is marvellous. When I've ploughed it's already nearly harrowed. The soil crumbles, it is so fine. And one can see that as well; it has run up beautifully (*George M., farmer*).

For each area of soil George M. mentioned a characteristic sign: the first has a yellow tinge, the second has marshy patches and is loamy, and the third is crumbly and fine. The farmer describes colour and structure of the soil properties by describing his experiences while working the soil: he has to change gear because a certain part of the field is much harder to plough. He also relates the soil characteristics to plant growth.

On the other hand soil scientist Hans W. describes another procedure:
P. Fry: *When you go to a farm, how do you assess soil quality?*

Hans W. Agronomist: *I divide the problem into different aspects to deal with. So, first of all I would go into the natural soil properties, independent of the farming: Am I situated in moorland? Am I on sandy soil? What is the "mother material"? What vegetation was there before the soil was cultivated? Is it a young soil, an old soil?*

As an agronomist he first looks at natural soil properties which are independent of farming. He knows how the soils developed in that specific area during the last centuries and what vegetation grew then. From that he goes on to the actual situation today. So his view has a totally different scale with respect to time and space. He refers to knowledge derived from scientific literature.

In the following example the perception of soil compaction is compared:

The farmer does not think of soils suffering damage over the long term. Moreover he pays attention whether the cultivation he wants to sow suffers damage. But at least indirectly there are connections. My father passed on the following experience: When *he was able to mould a ball out of this soil like a snowball, and then ploughed and sowed never the less, then the rapeseed turned red fourteen days after running up. When the leaves discolour it is a sign that the rapeseed somehow does not get soil like it should. That means that the roots cannot get down. These are typical signs for damages. (Kurt I., farmer).*

This farmer has made a connection between texture (the ability to mould a ball) and crop growth. However other farmers while they recognise compaction do not refer to soil texture or workability, for example:

At those parts where the harvesting machine turned the water stands in the winter. When the water goes away nothing grows. The wheat which was sown in autumn has died or grew yellow because the soil just does not work: Compacted, no oxygen, bacteria don't work, the decomposition does not go. (*Paul K., farmer).*

The farmer Paul K. explains in what situations he observed soil quality. What he sees is also embedded in time and space. But he refers to his daily experiences with working the soil, seeing how the plants come up well or badly and with harvesting. He does see a connection between soil texture, soil moisture and compaction. He sees that heavy machines compact the soil and that the wheat did not grow properly in those parts. It is relevant to him when the plants don't grow properly. But it is not the changing soil quality over the long term which he is interested in. He also uses scientific knowledge about decomposition processes in the soil which need oxygen.

The perception of soil compaction by soil scientists is dominated by their methods of inquiry. They use methods like the spade test which can be conducted in the field. With a special spade a 50-60 cm deep profile is excavated. By looking at the structure, texture, colour, moisture and even smell of the soil very detailed connections between the cultivation, machinery used and soil properties can be derived. But mostly soil scientists work with sophisticated laboratory methods. They choose a site, take samples and transport them to the laboratory where they can measure unnumbered properties under controlled conditions. This allows the comparison of different soils around the world. The methods soil scientists use lead to quantitative data. In a report on soil quality observation for the public we read the following:

The average of the medians of the total pore space for the topsoil over all ten examination sites is 53.1 Vol % for the pastures and 47.6 Vol % for the artificial pastures respectively. (Soil Protection Agency Canton Berne 1997, p.155 (Translated in English)

This difference between pasture and sown grassland is evaluated as follows:

The difference of the total pore space (only topsoil) of absolute 5.5 Volume % seems to be small at first. When one takes into account however that a soil with 30 Volume % total pore space is considered to be extremely compacted and therefore not fertile, the difference becomes even more crucial. When one simply relates a pore space of >53 % (Pasture average) with 100 % fertility and <30 Volume % (extreme compaction) with nil, the comparison for the average sown grassland comes to a *reduction of fertility of 76.2%. The difference amounts to nearly 24 %. (Soil Protection agency Canton Berne 1997, p.155)*

These results show that we move to a different world when comparing how farmers and scientists talk and write about soils. They both describe soil texture, colour, moisture etc. but they use different methods and describe soil properties in a different context. Farmers use the context of working the land whereas scientists choose the context of a special question and sample the land using a specific method to do so.

These results reveal that farmers face a range of economic opportunities for investment of labour and capital, of which agriculture is only one and, within agriculture, soil is only one aspect among many. In contrast scientists dealing with soil are concerned with one small element of the farmers' world – soil. As Liebig and Doran (1999, p11) note, in the context of soil, every soil's value 'depends upon its user's goals, perspectives and concerns'.

6. The study in France: results

6.1 Context and Methodology

Run-off and erosion cause great damage in Pays de Caux, a French Region underlain by loamy soils. The slope is low but the crusting factor of the soil surface is the main driver which leads to run-off. A team of researchers have produced prescriptions to counter this problem. They have proposed co-ordination between farmers to scatter the areas contributing to run-off. To make the implementation of this easier, the common points and the differences of conceptions of run-off and erosion between scientists and farmers were studied.

According to Weber (1956) conceptions of a reality depend on activity and social position. Different social groups develop different classification systems using different language and partitions of reality. These lead to different conceptions which are reported here. In this study these were revealed by a linguistic analysis of interviews which were used to identify the classification system of each group, farmer or researcher. For this research eight interviews with farmers in the same catchment were conducted, and four interviews of scientists of the team working in the same catchment. Some technical conceptions of each group are reported here.

6.2 Results

The research on countering run-off and erosion concerns two scales. For the first one, the aim is to establish references on the infiltration capacity of soils on micro-plots, linked with surface conditions in relation to crop and soil roughness. A researcher described the process: *'At the beginning, the first task consisted of identifying a relationship between surface damage and run-off and erosion appearance (Sophie).* This was linked with farmers' practices. On another level, a new approach considered not only what happens in a field, but the global organisation of the fields within a catchment area, as a researcher explains:

Afterwards, we realised that we had to take the area into account. We have seen that water flooded from one field to another, and we were interested in the effects of the fields in relation to the neighbouring fields (Pierre).

The direction of flows is modelled at a catchment scale. Compensations between fields, according to their infiltration capacity, are taken into account to propose a better (for run-off) organisation of field location. Within this frame, farmers' conceptions were studied and compared with researchers' ones.

The way farmers conceive production of surface damage processes is exactly the same as the researchers. Their descriptions can be framed in the same way. They understand that rain events following cultivation can have consequences for the soil and the crop. They understand that some techniques and crops will create surface conditions that lead to compaction of the soil surface and lowered infiltration, resulting in run-off. Different soil and weather conditions are understood to lead to different outcomes for the same technique (Figure 1). From the farmers perspective, when drilling is complete in October, when the bare soil is not too hard and small amounts of rain are able to infiltrate, no run-off results (scenario 1). However when rain is continuous and soil is compacted, further rain cannot infiltrate and run-off results (scenario 2)
[INSERT FIG 1]
The techniques and the crops which favour or prevent run-off are also perceived to be the same for the two types of actors. It is the capping of the soil which is responsible, and all the techniques which favour it are bad.

There are three main results which show that farmers and researchers do not have exactly the same conceptions about the flow of water. The first one concerns the scale of observation. Farmers can describe very precisely how the water flows in their fields but when the water leaves the field, or for the issue of where it comes from, they are not precise: *It goes toward the next owner, and then to the sea (Thierry, farmer)* or *My field gathers all the water within a radius of 15 km (Bernard, farmer).* In contrast researchers consider all the plots equally. The second result concerns what farmers see. Although they clearly see the flow of water in the thalwegs, they do not perceive diffuse run-off, as a farmer explained: *To the eye, you nearly cannot see it. And at the end, one day, water arrives here (Norbert, farmer).* Conversely researchers measure or model the quantity of water from an area at a point, whether the flow of this water can be seen or not. The third result concerns the way farmers and scientists talk about the flow of water. Farmers speak about the speed of the flow. Consequently, they consider that the way to struggle against run-off is to slow down the flow. Researchers, through spatial models (STREAM for example), talk about and calculate the quantity of water flowing, and try to reduce it.

Researchers propose changing the pattern of land use in the catchment, so that fields with low infiltration rates and most at risk of run-off are dispersed more throughout the catchment. Farmers recognise that the main cause of run-off is the enlargement of field areas, which has destroyed the traditional patchwork of land use. However, the idea that run-off can be reduced by changing the pattern of use is not an idea which appears in their discourse. For scientists, two neighbouring fields are considered in terms of the state of their soil and crop, in relation to infiltration capacity. For farmers a neighbour's field is viewed in terms of the person owning it rather than the state of its soils. The consequences of these conceptions are that farmers do not think to compare the states of the fields. When considering the question of field organisation they say:

I can't say that my neighbour sends me some water; in any case, the water has to go down (Baptiste, farmer) or: *If you say to your neighbour, hey, you, you will put a water reservoir here, and me, I will not do anything. It is you who are upstream to do something. He will say: why me and why not you? (Camille, farmer).*

The way farmers conceive production of surface damage processes is the same as the researchers. However these groups differ in terms of scale of observation and language used regarding the flow of water and neighbouring fields. In terms of these latter differences each social group, farmers or researchers, qualifies an object using features that are relevant to its own viewpoint. Farmers and researchers have different points of view and create categories of objects or meanings that differ. They may use the same word, such as run-off, water flow or neighbouring field but mean something very different.

7. Discussion

7.1 Comparison of the three case studies

The three studies, in England, Switzerland and France, reveal that, irrespective of whether we talk of knowledge, perception or conception, farmers and scientists have different understandings of the soil and its management. They also reveal that farmers in the three studies share certain characteristics with each other, in terms of understanding soil, as do scientists (advisors and researchers). This is especially interesting because the studies vary with respect to country, political framework, farm scales and the methodologies used.

The three studies demonstrated the distinctions between farmer and scientist. The results from the Swiss study strongly reflect those from the English study where farmers have a considerable working knowledge related to local conditions and soil response under cultivation. They have a wide and intuitive knowledge but not necessarily any depth of understanding, as one advisor in the English study noted, farmers 'are aware of gross errors of management but not aware of more subtle things they can do'. Farmers tend to know about 'working the land' but were criticised by advisors for not regularly examining the soil and not being able to interpret what they see: 'they do not know how to examine their soil to determine how much cultivation is required'. The results from the English study also revealed that lack of inspection before cultivation is related to an urgency to get the crop established, that is, that factors others than the state of the soil govern the farmers' actions; this was also demonstrated in the Swiss study. Advisors' knowledge conversely is characterised by seeking objectivity and a reliance on codified tools and publications derived from science. Like the scientists in the Swiss study they also use a spade to examine the soil profile which is restricted to precise locations providing site specific information on texture and structure, compared to the farmers more holistic knowledge of his land. As such both farmers and scientists in the Swiss and English study use different methods and language to describe soil properties and attribute different meaning to what they see, they operate in a different context, pursuing different goals. Farmers work within the context of land management, their aim, a successful crop whereas scientists choose the context of a special question and sample the land using a specific method to do so, their aim, understanding soil processes. Whilst it is accepted that there are different levels of scientific understanding amongst the advisory community, the results from the English study reveal that a number of advisors share similar characteristics with scientists and researchers in the Swiss and French studies in terms of knowledge about the soil.

In the French study researchers and farmers also talk about soil erosion problems using different conceptions and language, farmers talk about the speed of the flood of water, and their solutions for it, whereas the researchers talk about infiltration and catchment processes, they evaluate the quantity of water, and propose solutions to decrease the water coming from each field. Similarly in the Swiss study when using the term compaction, farmers and scientists see a connection between soil texture, soil moisture and compaction but farmers talk about the impact on crop growth and scientists talk about percentage pore space. A difference in the scale of observation was also revealed in the French study. Farmers, although aware of their own soils and fields, appear not to look at their farm or field in a landscape context or be aware of the state of their neighbours' fields and soils. Indeed farmers judge neighbouring fields by reference to their owners rather than the state of the fields themselves (see Table 1). In contrast researchers take a catchment perspective; they are acutely aware of catchment processes but regard farm boundaries as immaterial. The French study also revealed that farmers' awareness and understanding was restricted to what they could see, they were aware of run-off when they can see it but do not understand how it comes about. In the English study farmers observed soil erosion but did not make a connection with their own practices, as one advisor commented 'For soil protection, they're aware of most obvious things but most don't fully understand the topic'. In both studies there was a suggestion that run-off is something that is out of the farmers' control, a French farmer saying 'in any case, the water has to go down' and an England farmer commenting 'Nothing could be done about it'.

Table1 synthesises the results from the three studies described above and illustrates the difference between farmers and scientists in terms of the nature of the knowledge held, awareness and the depth of understanding, conception, meaning and language, the scale of observation, the methods of examination, and objectives.

These results can be explained theoretically in different ways. In the Swiss study farmers' and scientists' views are directed and shaped by different aims, methods and context of work. Farmers focus on production of foodstuffs while scientists focus on theories and principles of soil function and processes. These different aims obviously have to be achieved with completely different methods and in different contexts. Farmers work the soil by using the plough or direct drilling under field conditions. A scientist on the other hand quantifies certain soil properties by taking samples in the field and examining them under controlled conditions in the field or laboratory. The key problem facing scientists is how to standardise and generalise their achievements, in order that they are replicable in different local contexts (Clark and Murdoch 1997). On the other hand farmers face the problem of how to survive economically in a highly industrialised agriculture and how to cope with diseases, unpredictable weather conditions etc. While scientists can extrapolate measurements to a larger region – assuming that the measurements are comparable – farmers have an overview over the properties of their land and an impression of the state of the soil and their crops.

From this the view of the farmers can be characterised as 'broad', the view of scientists as 'deep' (Figure 2). This would reflect farmers main concerns better. While farmers are mainly concerned with maintaining soil for productive purposes under variable conditions - the level of action -, scientists, tend to focus on examining soil under controlled conditions – the level of observation. The scientists gain deep insight (large arrow) into their topic by neglecting the broader production-related connections made by farmers (smaller arrows). On the other hand the farmers need to know about the interactions between their actions, soil, plant growth and animal health. That is what they do and observe daily. That is why their view is more a broad overview (large arrow) by neglecting the deep insight in the several topics (smaller arrows). Farmers' knowledge is broad in the sense that it covers a range of aspects related to agricultural production goals although it could be argued that it is not broad in the context of other soil functions such as flood prevention or pollutant filtering. This broad understanding equips the farmers to understand the interactions between the factors that influence crop production but not necessarily other aspects of soil functioning. Equally scientists demonstrate in this research a deep and focused understanding of soil characteristics relevant to production and appear to be working to a deep, analytical model, however, it is acknowledged that scientists are increasingly taking a broader and more integrative view in other contexts (Holling 1998). The observations in the Swiss study are in line with those reported by sociologists who have demonstrated that scientific knowledge is socially constructed in a specific location, a laboratory, a trial site (eg Callon 1985), that it is local or situated knowledge (see Turnbull 1993). Farmers' knowledge, in the same way, has been described as contextual or 'situated' (Scoones and Thompson 1994).

This Swiss interpretation resonates with the notion of knowledge forms used to explain the nature of farmers' and advisors' knowledge in the English study. The farmers' considerable working knowledge of their own soils, learnt from experience, can be conceptualised as 'know how' (Lundvall and Johnson 1994) or 'practical knowledge' (Thrift 1985) which comprises skills and the capability to do something at a practical level. It has a significant tacit component, is part of their 'broad' view and is underpinned by their aims and by context. Their absence of understanding of 'the more subtle' things or not 'thinking about what they are doing' suggests that they lack what Lundvall and Johnson (1994) call 'know-why', know-why is an element of scientific knowledge, it is the knowledge of principles, rules and ideas of science and technology. Advisors in contrast seek the objectivity of scientific knowledge and look for explanation and understanding. They rely on field examination of the soil profile, as well as on scientifically derived codes and tools. This can be likened to the 'deep' view of the scientists in the Swiss study where they develop knowledge which helps them to understand, explain and quantify natural processes.
[INSET FIGURE 2]

In France, a social perspective is used to explain the different conceptions revealed between farmers and researchers (Weber 1956; Putnam, 1984). Putnam (1984) states that a society creates a system of thinking that is the result of breaking down reality as a function of its own experience. It is the way a social group creates categories and puts objects into these categories that provides the identity through which a person perceives an object. Consequently, 'two social groups that have different social positions and engage in different activities will have different conceptual systems.

Farmers and researchers in this study have been shown to have different activities and social positions and as such do not have the same vision of reality; they do not have the same representation of the world. They do not speak about soil in the same way, with the same words, the same categories, or the same features, nor at the same scale of observation (Darré, 1999, Darré and al, 2004). Inside a social group, be it farmers inside a catchment or researchers in a team, people talk together about the elements of reality (soil, crop and run-off and erosion) to resolve their own problems. At the same time, they create norms to act, and they transform the way they describe reality. The way farmers or scientists describe and conceive reality through words determines their respective actions.

These three theoretical explanations proposed should not be viewed in isolation but can be integrated to provide a theoretical overview of how farmers and scientists differ in their understanding of soil. The 'broad' view of farmers is linked to the social group norm, the values and the culture of being a farmer. Farmers' 'know-how' of working the land is also linked to this 'broad' view as the farmer intuitively relates his or her knowledge and experiences about cultivations to the weather and to agronomy, etc. The language of 'know-how' with words such as 'heavy' or 'light' is linked to the farmers' conception of reality and their proposed use of the soil. Conversely the 'deep' view of the scientist focuses on a narrow aspect of the farm. It is underpinned by precise language, method and measurement which are part of the world of being a scientist. Scientists like to 'know why' and explain things by understanding relationships and processes, they also like to reduce things to specific questions, they prioritise particular factors and examine specific sites. Farmers who demonstrate a 'broad' view and 'know-how' have their own distinctive language and view of reality which can be distinguished from that of the scientists who have a 'deep' view and 'know-why'. The two groups may talk of the same reality, which is under their feet, but, even if they use the same words, they do not refer to the same things. For example, for farmers the term 'neighbouring field' refers to the person who cultivates it but for scientists it refers to the state of the soil. To resolve any problems, farmers imagine how to negotiate with their neighbours, whereas scientists calculate the possible infiltration balance between the two fields. Their views are directed and shaped by different aims, methods and context of work which lead to different conceptions of reality.

Although the three studies used different theoretical terms to explain farmers' and scientists' understanding: knowledge, perception and conception - this analysis has shown that there are clear overlaps and linkages between these conceptualisations. As such, it proposed that the general term 'knowledge' can be applied in all three studies where knowledge is described as an interpretation which we can mobilise to give meaning to a practical situation (Leeuwis and van den Ban 2004). The common factor emerging from analysis of the three studies is that knowledge (in the broard sense described here) is contextual and cultural. It is socially constructed by the interaction with the environment and embedded in the practices and the epistemology of actors. Insights from all three studies show that knowledge held by farmers and scientists is not tightly bound in predefined notions of knowledge forms but emerges as part of the wider context, perspective, working practice and language, or culture of being a farmer or a scientist (advisor, researcher). Thus, the notion of knowledge cultures, as developed by Tsouvalis et al. (2000) with reference to previous work (Shotter 1985, 1997; Bordieu 1985; Foucault 1977), which recognises the contextual nature of the different understandings revealed in this analysis, offers a suitable collective conceptualisation for the three studies. Knowledge cultures, as defined by Tsouvalis et al. (2000, p. 912), are 'characterised by the practical understanding . . . referred to as ‘knowing from within. Such knowing provides a situated, conversationally derived knowledge rooted in a relational-responsive understanding of reality. It encompasses cognitive and experiential knowledge and is thoroughly social and embodied’. Knowledge cultures provide the value system on which the socio-technical practices of a farming style[4], in the case of farmers, and of applying science, in the case of scientists, are played out. Thus knowledge cultures, according to this definition, offer a broad framework in which to integrate and understand the theoretical and empirical analysis of the three studies presented here, where understanding of the soil is wrapped up in the context, habits, farming styles, language, aims, methods and meanings of being a farmer or being a scientist.

8. Conclusions

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The results from the study in England have revealed that farmers do possess considerable knowledge about soil however they have a broad and intuitive working knowledge drawn from experience, and lack a detailed understanding or ‘know-why’ of soil which the advisors possess. The results from Switzerland also show contrasting broad and deep knowledge held by farmers and scientists. They reveal a ‘different world’ when comparing how farmers and scientists talk and write about soils. Similarly in the French study, farmers’ and researchers’ conceptions of soil, their language and meaning differ. These quite different understandings revealed between farmers and scientists influence their perception of soil fundamentally and lead to different perspectives and language.

The results have provided evidence from three comparable studies of the differentiation between the understandings of soil held by farmers and scientists. In particular they have revealed the differences in forms of knowledge, the production of knowledge according to aims, methods and context, and the conceptions of reality. A common theme emerging from the results is that knowledge, in its broadest sense, is socially constructed, and as such contextual and cultural. The notion of ‘knowledge cultures’ offers a broad integrative conceptualisation for the three studies as it recognises the social, contextual and cultural elements of knowledge. In the context of soil management, the analysis has provided further insights into the nature of the difference between farmers’ and scientists’ understanding of soil and its management.

[4] Where a farming style is ‘a cultural repertoire, a composite of normative and strategic ideas about how farming should be done…’(van der Ploeg, 1993, p241).

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