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Are farmers in England equipped to meet the knowledge challenge of sustainable soil management? An analysis of advisor and farmer views.

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ABSTRACT

Concern about the agricultural soil resource in England has led to the introduction of a range of measures which potentially challenge farmers' knowledge about the soil and its management. Our understanding however of how well equipped farmers are with regard to effectively carrying out more complex and knowledge intensive sustainable soil management practices is limited. Specifically, by drawing on the concept of scientific and tacit forms of knowledge, this paper examines the knowledge of soils held by farmers through analysis of data collected from semi-structured interviews with farmers and agricultural advisors and supplemented with data from an extensive postal questionnaire survey of advisors. The data indicate that, while farmers are technically well informed, they can often lack the in-depth scientific knowledge required to implement more complex practices such as using the nutrient value of manures. They also reveal that, while most farmers have good knowledge of their own soils, their tacit knowledge of soil management can be weak, notably in relation to cultivation. The paper concludes that although farmers' knowledge about soil and its sustainable management appears in general to be well developed there are some areas which need to be significantly enhanced and as such require both a policy response and further research effort.

Key words: scientific knowledge, tacit knowledge, farmer, agricultural advisor, soil management, best management practice, diffuse pollution, cultivation.

1. INTRODUCTION

The centrality of knowledge to agriculture has been highlighted by a number of commentators (Winter 1997; Morgan and Murdoch 2000), with knowledge described as the 'fourth factor of production' because of the widely differing knowledge, skills and aptitudes farmers need for producing food (Winter 1997). This is the case today more than ever before with the emergence of policies encouraging more sustainable farming practices, which are considered to be more complex and more demanding on the skills and knowledge of farmers than conventional farming (Kloppenburg 1991; Röling and Jiggins 1994). Mounting evidence of threats to the agricultural soil resource have brought calls for more sustainable management of this vital resource and recent policy developments in Europe and in England mean that demands on farmers' soil management competencies will increase. However our understanding of the nature and extent of knowledge about this crucial resource held by farmers in England is poorly developed, particularly in comparison with our appreciation of how they manage, and impact, other natural resources such as water, nature and landscape (Lowe et al. 1997; Morris and Potter 1995; Harrison et al. 1998).

As such, this paper reports the findings of research into the nature and extent of farmers' knowledge about soils through analysis of data collected from semi-structured interviews with farmers and agricultural advisors drawn primarily from those interacting with two projects in England[1] promoting soil management practices: the UK-wide Soil Management Initiative and the Landcare partnership in the south-west of the country. The interviews were supplemented with data from an extensive postal questionnaire survey of advisors.

2. INCREASING DEMANDS ON FARMERS BY POLICY MAKERS

Decline in soil quality in the UK has been largely attributed to intensive arable farming. Subsidies provided as part of the Common Agricultural Policy (CAP) through the 1970-80s encouraged continuous arable cropping, winter cereals, increased cultivation with heavier machinery, ploughing up of pasture, minimal rotations, the inappropriate use of marginal lands, and overgrazing in upland areas all resulting in negative consequences for the soil (Boardman 1990; Baldock and Mitchell 1995; DETR 1998; Joint Nature Conservation Council 2002). More recent reports suggest that these practices are continuing and the farming community have been urged to improve their understanding and husbandry of soil (Environment Agency 2004a,b).

Following calls for more sustainable use of soil (Royal Commission on Environmental Pollution 1996; Defra 2002a,b) a number of policy initiatives have emerged in an attempt to counter the increasing threats to the agricultural soil resource both in Europe and in England (DETR 2001;Commission of the European Communities 2002). These include ‘The First Soil Action Plan for England’ (Defra 2004a); the requirements for farmers to prepare a Soil Management Plan as a condition of receiving the Single Farm Payment[2] (Defra 2005); and in some cases for payment under the new Environmental Stewardship Scheme. These, together with the introduction of catchment sensitive farming as part of implementation of the EC’s Water Framework Directive (Defra 2004b), all herald a new era of policy concern for soil in England. The farmers’ responsibility in achieving the goals associated with these policies is clear, as stated in a popular farming press magazine ‘Soil management is something no farmer can afford to ignore’ (Farmers Weekly 2004a).

These policies build on previous initiatives which have promoted more sustainable 'best management practice' of soil to farmers (MAFF 1998;1999a,b; ADAS et al. 2000; Environment Agency 2001). Best management practices for soil are based on a number of fundamental principles of good soil husbandry including: maintenance of soil structure through enhanced soil organic matter content and protection from compaction, overworking and runoff; as well as the management of soil as a buffer for nutrients by using artificial and organic fertilisers effectively and efficiently. Farmers can lack familiarity and experience with such practices (Park et al. 1997) which are considered to be more knowledge intensive than conventional practices in that they are non-prescriptive and demand attention to detail, observation, as well as an understanding of the scientific principles on which they are based (Röling and Jiggins 1994; OECD 2001). Clearly knowledge is particularly significant given the complexity of the practices and the need for farmers to adapt them to their own soil types. It is to the issue of farmers' knowledge that the discussion now turns.

3. FARMERS' KNOWLEDGE ABOUT SOIL AND ITS SUSTAINABLE MANAGEMENT

Whilst it is accepted that farmers' knowledge of soil management is important little is known about the nature and extent of such knowledge. It has long been recognised that farmers need new knowledge and skills to take on the demands of sustainable agriculture (Winter 1997) but the suggestion has been that such knowledge is poorly developed due to the continued 'productivist modes of thinking' within the farming community (Curry 1997; Pyrovetsi and Daoutopoulos 1999; Wilson 2001). Today concern remains about whether farmers have the right skills set to deliver the

Government's goals for sustainable farming (Defra 2004c; University of Reading 2005).

Potentially at least this knowledge and skills inadequacy extends to soil management. Scientific and policy reports highlighting the degradation of agricultural soils clearly imply that farmers are not managing them sustainably (Boardman et al. 2003; Environment Agency 2004a,b). A poor knowledge base coupled with lack of experience of complex new technologies and practices has been highlighted as a constraint to more sustainable management of the soil. This has been demonstrated for other knowledge demanding practices which provide soil and environmental benefits such as integrated farming systems (Morris and Winter 1999), reduced tillage (Tebrugge and Bohrnsen 2001; Davies and Finney 2002; Coughenour 2003), managing nutrients in manures (Smith et al. 2000, 2001) and organic farming (Burton et al. 1999). Concerns expressed in 1970 about farmers' lack of awareness of soil condition when cultivating (MAFF 1970) appear to be still valid (Davies and Finney 2002) while today farmers are reported to have insufficient understanding of the reasons and techniques for soil management (Central Science Laboratory 2004).

However this negative view of farmers' competence is questioned by the farming industry who claim that soil is managed sustainably (National Farmers' Union 1994) and is in 'good heart', arguing that agricultural activities in the UK are synonymous with stewardship and conservation of the resources they rely upon (Ward 1995). Such nurturing and stewardship are seen to be part of being a 'good' and knowledgeable farmer (McEachern 1992; Burton 2004). More generally farmers regard their own knowledge in managing the environment as very important and often undervalued

(Wilson 1997; Harrison et al.1998; Seymour et al.1998). They place high value on their experience and use this as their primary source of knowledge for management decisions (Contant 1990; Fearne 1991; Lyon 1996;Tsouvalis et al. 2000). A growing literature in other countries (Romig et al. 1995; Walter et al. 1997; Bruyn and Abbey 2003) also demonstrates that farmers have considerable knowledge of their own soil, are able to identify characteristics of soil quality and have developed a rich vocabulary to describe it (van der Ploeg 1989; Liebig and Doran 1999; Romig et al. 1995; Tsouvalis et al. 2000; van Rompaey 2001; Curtis et al. 2003).

These different accounts demonstrate the range of views held about farmers' ability to hold and apply knowledge about soil and in part reflect the heterogeneous mix of farmers and their practices. Indeed the temporally and spatially diverse way in which farmers know and understand their farming systems has already been identified (Raedeke and Rikoon 1997). It is clear however that there is a lack of evidence about farmers' knowledge of soil in England and about their capacity to implement more complex sustainable soil management practices that policy is now demanding.

4. THEORETICAL CONSIDERATIONS

Conceptual approaches to understanding farmers' knowledge in relation to natural resource management have a broad base drawing both on behavioural (Napier et al. 1984; Lichtenberg and Zimmerman 1999; Ryan et al. 2003) and cultural approaches (Carr and Tait 1991; Long 1992; McEachern 1992; Harrison et al 1998; Tsouvalis et al. 2000; Burton 2004); as well as on perspectives that relate knowledge to social and experiential learning (Lyon 1996; Röling and Wagemaker 2000; Russell and Ison 2001).

Developments in sustainable agriculture have brought new understandings of knowledge in the context of farming. A number of commentators have developed the notion that sustainable agriculture is knowledge intensive involving the adoption of technologies that require a high level of management skills, with an emphasis on observation, monitoring and judgement (Röling and Jiggins 1994; Park et al. 1997; Tebrugge and Bohrnsen 2001; Coughenour 2003). Implementing these highly technical practices is thought to require some understanding of the underpinning scientific principles and physical processes (Vanclay and Lawrence 1994; Pretty 1995). At the same time it is considered that sustainable systems and practices are highly dependent upon traditional local and 'ecosystem sensitive' knowledge, with general principles applied in a site-specific way (MacRae et al. 1989; Kloppenburg 1991; Norgaard 1992). Arguably, then, the knowledge farmers need for sustainable soil management must consist of both a technical understanding of the principles of soil management or 'scientific knowledge', as well as an intuitive, local or 'tacit knowledge', or at least an ability to interpret technical knowledge in a local context drawing on experience, through observation and monitoring.

The notion of knowledge comprising of scientific and tacit knowledge elements provides a useful framework for this research, where scientific knowledge[3] is understood to be universal, objective and decontextualised and tacit knowledge[4] implicit, indigenous and context dependent resulting from talents, experience and abilities. Scientific knowledge is itself, in part, comprised of what Lundvall and Johnson (1994) call 'know- why'[5], which is the knowledge of principles, rules and ideas of science and technology, it therefore concerns application. 'Know how'[6]

(Lundvall and Johnson 1994) and 'practical knowledge' (Thrift 1985) share many features of tacit knowledge, being informal and learnt from experience of watching and doing. Characteristics of both scientific and tacit knowledge are highly relevant to soil management, the former because understanding and managing soil requires technical application of scientific principles and decontextualised generalities and the latter because soil is a spatially heterogeneous material 'rooted to place' and is intimately linked through cultivation to farm practices.

Tacit knowledge is fundamentally linked to direct experience and the practical, sensuous and personal skill that develops with attention to a specific place (Hassanein and Kloppenburg 1995). It is frequently claimed that farmers have an intimate and intuitive tacit knowledge of the soil on their farms and a refined understanding of local spatial and temporal processes, gained through years of walking and cultivating the land (Winklerprins 1999). Descriptions interpreted through the local environment have been explored and soil quality assessments are firmly established by farmers in observational field experiences using senses of touch, taste, sight and smell; while soil physical properties become 'known' to farmers through in-field experiences (Romig et al. 1995; Walter et al. 1997; McCallister and Nowak 1998). Winklerprins (1999, p151) explores this idea defining 'local soil knowledge' simply as 'knowledge of soil properties and management possessed by people living in a particular environment for some period of time'. Such tacit or local knowledge is considered to be more relevant to sustainable agriculture (Kloppenburg 1991; Murdoch and Clark 1994).

However, others claim that such local tacit knowledge is exaggerated and distorted and warn against mythologising it suggesting that it can often be nothing more than a set of improvisational capacities summoned by needs (Molnar et al. 1992; Richards 1993). It has also been argued that indigenous soil knowledge, although still of great value in developing countries (Sillitoe 1998), has no relevance to modern agriculture where farmers have come to rely heavily on scientific applications in agriculture (Morgan and Murdoch (2000). For many, science is just as capable, or more capable of finding sustainable solutions (Molnar et al. 1992; Murdoch and Clark 1994). Farmers in western countries have arguably been assimilating scientific information into their own knowledge for decades. They operate highly technical arable systems incorporating advanced technologies (Ward 1995; Tsouvalis et al. 2000) and demonstrate adaptations, practical solutions and produce experimental knowledge, sometimes using scientific method (Wilson 1997; Harrison et al. 1998; Tsouvalis et al. 2000).

Debates about the respective value of scientific and tacit forms of knowledge have lead many researchers to criticise this categorisation and argue that these knowledge forms are fundamentally complementary (Romig et al. 1995; Walter et al. 1997) and that knowledge is comprised of blends of all knowledge forms, that it is heterogeneously constituted (Long 1992; Murdoch and Clark 1994; Clarke and Murdoch 1997). Thus knowledge that farmers hold, or need to hold, about soil and its management is arguably a mixture of both scientific and tacit knowledge as it needs to combine an understanding of new technologies with a new awareness and sensitivity of natural resource management (Röling and Jiggins 1994; Pretty 1995). The extent to which farmers are 'equipped' with this blend of knowledge for sustainable soil management is a central concern of this study.

5. METHODOLOGY

The qualitative and quantitative data on farmers' knowledge of soils, which are presented in this section, are derived from interviews with a selected group of farmers and agricultural advisors supplemented by an extensive postal questionnaire survey of a range of advisors. Semi-structured interviews were undertaken with farmers and advisors in the context of two soil management initiatives in England. The UK Soil Management Initiative (SMI) is an independent organisation which aims to address the problems of soil compaction, structural degradation and erosion by promoting the management of soil structure through appropriate cultivations and practices such as revised plough tillage, well managed reduced or conservation tillage[7] and removal of sub-/surface compaction. The Landcare Partnership, a project piloted by the Environment Agency in the Upper Hampshire Avon catchment in the south-west of England, promotes Better Farming Practices (BFP) to control diffuse farm pollution. Untimely cultivation; maize with late cultivation and often excessive manure application; outdoor pigs; inappropriate manure applications; and lack of nutrient budgeting have all been identified as high risk practices particularly in the areas of more erosive Greensand and of Weald clay, which are exposed in some valleys in this mainly chalk catchment. The BFP proposed all aim to restrict run-off of sediment and loss of nutrients primarily through promoting appropriate cultivation techniques and the use of nutrient management plans to allow for manure nutrient content[8]. The catchment is one of 40 priority catchments recently designated for delivery of catchment sensitive farming by the government.

Selection and sampling of farmers for interviews within both projects was based on attendance at demonstration days and involvement in the project. For SMI all farmers (15 in total) who had attended two recent demonstration days were approached and of these eight agreed to be interviewed. These comprise arable farmers typically from large arable units (>500 acres) in the East and East Midlands regions. In addition two farmers from the SMI board were interviewed. For Landcare all farmers (eight in total) who had recently attended a recent demonstration event were contacted and five agreed to be interviewed. Their farms are typically mixed with cereal, dairy cattle and sheep and some pig rearing. Two farmers who had provided demonstration sites for the project were also interviewed. Interview details are given in Table 1 (all Tables at end of paper). The aim of farmer selection was not to extrapolate from a representative sample but to explore through detailed analysis and descriptive narrative the defining characteristics of farmer knowledge, for this reason there is no attempt to typologise the interviewees in the following analysis.

Selection and sampling of advisors for interviews was based on attendance at demonstration days, involvement and potential interaction with the project. For SMI all advisors listed as members (seven in total) and all those who had attended recent events (eight in total) were interviewed. In addition a sample of 20 advisors were selected for their specialism in combinable crops, cultivation or soil management from the directories of the Association of Independent Crop consultants (AICC) (120 members) and British Institute of Agricultural Consultants (BIAC) (280 members). All Landcare advisor partners (ten in total) were interviewed as were those who had attended a recent demonstration event (four in total). In addition, of the 20 agronomists, seed merchants, farm management companies and consultants operating within the catchment identified using the AICC and BIAC directories, and the local telephone directory, 15 agreed to be interviewed.

The interviews with farmers and advisors were ‘semi-structured’ in that they were conversations informed by common themes relevant to the issues addressed by the initiatives rather than specific questions (listed in Table 1). Questions were open ended to allow deeper exploration of topics. The interview schedule provided structure and ensured the same issues were discussed in each case, it was supported with reference to relevant publications[9].

Qualitative data from interviews were complemented by quantitative data from an extensive questionnaire of advisors. Questionnaires were sent to 304 individual advisors in five categories as follows: conservation advisors[10]; Rural Development Service agri-environment scheme advisors[11]; independent agronomists; ADAS[12] advisors and distributor (commercial) agronomists (FACTS)[13]. Due to the different approaches to identifying potential advisors non-probability sampling was used to target certain sectors. In total 163 questionnaires were returned with an average response rate of 40% for the first four categories. It was not possible to estimate a response rate for the FACTS respondents[14].

In total 17 farmers and 64 advisors were interviewed within the two projects and 163 advisors surveyed nationally. Advisors were used as the main key informant due to restricted farm access following an outbreak of foot and mouth disease at the time of the study. Advisors are arguably well placed to provide a balanced and well informed opinion about farmers. They have a good understanding of, and regular contact with, farmers; they observe their activities frequently and have one of the closest relationships with farmers and their farms (Angell et al. 1997; Ingram and Morris 2007). Each advisor can also draw from their experience of advising a number of farmers, typically up to 20 farmers each within a relatively wide geographical area, enabling them to develop a broad impression of the farming community. This contrasts to individual farmers whose experiences are narrower, being tied to a particular farm environment and business. Advisors also arguably provide a more objective view of what is happening on-farm as farmers may be reluctant to own up to poor knowledge and practice. Interviewing advisors as well as farmers also provides different accounts and interpretations which can triangulate and complement each other. The nation-wide survey results add to the multiple sources of evidence and assist in the triangulation of qualitative material.

In the sections presenting the empirical material, the scientific knowledge element of farmers' soil knowledge will be examined, that is, their understanding of the requirements and principles of soil best management practice. The extent of farmers' engagement with using nutrients in manures from interviews in the Landcare initiative gives a more detailed measure of their scientific understanding. Insights into the tacit element of farmer soil knowledge are gained by examining farmer and advisor views of about farmer local knowledge of their fields and their experience, skills and competence in practical soil management. Detailed consideration is given to tacit knowledge of cultivation practices drawing on the interviews from the SMI initiative. Although results are presented separately below it is understood that the two knowledge forms are in reality intimately linked.

6. FARMERS' SCIENTIFIC KNOWLEDGE OF SOIL

6.1 Farmers' scientific knowledge of soil in relation to soil best management practice

The interviews revealed that there is a range of competencies amongst farmers in relation to scientific knowledge. Many of those interviewed are professional, highly skilled, intelligent graduates, with one farmer FACTS and BASIS[12] trained, and three farmers holding responsible positions within national agricultural organisations. They are competent in preparing their own fertiliser recommendations, using and interpreting research station results and can grasp difficult issues such as the soil nitrogen dynamics. Some advisors' views confirm this, they consider farmers to be technically knowledgeable and as having an understanding of principles that underpin best management practice. As one independent agronomist (A) said *'Most farmers I* deal with are aware of good husbandry techniques and go to great lengths to keep soil in good order'. For them there is clear evidence of good techniques being used. However this view is not shared by all advisors, as one distributor agronomist's (RP) remark demonstrates: 'They are appalling at soil husbandry, they take their soils for *granted and don't necessarily look after them as much as they should do'.* This lack of consensus among advisors about this aspect of farmers' knowledge is reflected in the questionnaire responses with only an average of 40% of all advisors agreeing that farmers are technically well informed about soil management (Table 2). Views among advisors and farmers explored in interviews suggest that, although in a very broad sense farmers practice good husbandry, it is the depth of farmers' technical understanding of soil management that is limited, as one agri-environment scheme advisor (F) explained:

They are aware of gross errors of management but not aware of more subtle things they can do. There's awareness that the problem exists on one level but not yet sufficient awareness of issues leading to that.

Advisors claim that farmers, although aware of problems, do not necessarily tie them down to their own practise. This was borne out in the Landcare 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 (P) remark epitomises this view, *'I've seen water* run of 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'*.

Soil management is seen by advisors as quite a complicated issue which a number of farmers do not fully understand, particularly with more demanding techniques being introduced. They consider that, although a very important issue, soil management is frequently ignored due to lack of knowledge by farmer. Indeed the majority of advisors (average 74%) responding to the questionnaire thought that lack of knowledge and skills about soil management options was important in explaining farmers' failure to use more sustainable practices (Table 3). Without the knowledge or acquired skill farmers are thought by some advisors to give up and drop back to more familiar intensive production methods:

I would entirely agree that for more environmentally favourable practices for soil you *need more knowledge and skill and if you don't have that or don't develop it quickly* then you will give it up and drop back to intensive production methods which have been tried and tested (Farm Manager/Agronomist V).

Some farmers accept they are ignorant in this respect as one (Farmer B) remarked 'I know everything about machinery, a little about crops, but very little about the soil. Eve*n though I work the land, I still don't know enough about soil*'. For many realisation that they lack such understanding was part of their motivation for attending the demonstration days provided by the projects.

6.2 Farmers' scientific knowledge of soil in relation to managing nutrients in manure

A large part of the promotion of soil best management practice in the Landcare initiative has been aimed at using manures as part of the nutrient budget for the farm. This requires some understanding the principles of nutrient dynamics in the soil and being able to estimate amounts, and the nutrient content, of manure so that artificial fertiliser rates can be adjusted accordingly. Interviews with farmers and advisors working in the catchment revealed that this is still very challenging and involves unfamiliar skills for farmers who often lack the experience of high fertility situations. As one independent agronomist (EB) remarked '*What we're doing, advisors and farmers alike, we're all scratching our heads asking* how much should we allow for that [manure]?' A large number of advisors (some 19 out of the 29 interviewed) within the catchment see ignorance of the value of manures as an obstacle claiming that the majority of farmers, dairy farmers in particular, still regard it as a waste product that has to be disposed of rather than as a valuable source of nutrients. They argue that the farmers they work with are often unable or reluctant to measure the amounts of manure used and that manure applications are roughly estimated, spreaders are uneven and manures are often mixed from different animal sources, an agri-environment scheme advisor (F) supports this view:

They don't know what's in it in many cases, haven't a clue what the analysis is, they are reluctant to do analyses whether slurry or solid, they haven't got a clue as to how much they put on. The whole thing is very hit and miss.

Four farmers interviewed in the catchment confirmed this view accepting that they still view manure as a waste product, rather than an asset, this was particularly the case with dairy and small mixed farms where maize becomes a dumping ground for manure. They also tend to regard nutrient budgeting as a complex process beyond their capabilities. However progressive and bigger farmers were described by some advisors interviewed in the catchment as more disciplined about accounting for manure, measuring its value as part of their nutritional programme and using more sophisticated spreading machinery. They are understood to be gaining knowledge about the nutrient value of manure, and are increasingly using or, if arable-only, buying in manure, sewage sludge or poultry manure, and have seen benefits to soil structure as well as realised the economic sense of the practice. Three of the farmers (two from mixed farms of about 500 acres) interviewed in the catchment had started to incorporate manures into their nutrient budgeting; one described the benefits:

Yes definitely we estimate how many tonnes of manure and where it went on. Where I *put a lot of manure on last year, I put a lot less N top dressing on, so it's helping me again and saving me money. I'm sure manure is all good for the so*il structure and composition (Farmer MF).

However, although some farmers are beginning to utilise manure nutrients, an agri-environment scheme advisor for the area suggested that nutrient budgeting is a 'closed book' to 95% of farmers with only the larger arable farmers taking an interest, with perhaps only 5% of farmers and 15% of land being subject to a nutrient balance.

These results suggest that the extent of farmers' scientific knowledge concerning soil management is variable and in some cases not fully developed. Many farmers and advisors interviewed and surveyed point to good husbandry and good technical knowledge as evidence of knowledge about soil management. However interviews revealed that the depth of this knowledge about soil can be limited. Although advisors suggest that there is 'considerable understanding of the soil', they consider that farmers remain ignorant about the more subtle things, in particular farmers do not always have sufficient knowledge to make the link between certain practices and their consequences suggesting lack of understanding of underpinning principles or 'know-why'. This might explain why only 40% of advisors surveyed (Table 2) agreed that farmer are technically well informed about soil management. In terms of having or acquiring the scientific knowledge needed to incorporate nutrient budgeting into managing manures the larger more progressive farmers appear most likely to be accounting for manures, since it is thought they can afford advice and analysis and are more likely to be experienced, from their arable practices, in nutrient budgeting.

Advisors consider that for many farmers this is still a challenge, that they ‘haven’t got a clue’. Farmers tend to agree, particularly smaller dairy and mixed farmers who are constrained by the size of arable land on which they can spread manure, the condition of the often heavier soil, and their own lack of experience of nutrient budgeting. Given these constraints they are less likely to seek out and develop knowledge on the value of manure.

7. FARMERS’ TACIT KNOWLEDGE OF SOIL

7.1 Farmers’ tacit knowledge of soil in relation to soil best management practice

All the farmers interviewed had some knowledge of soils in terms of their spatial heterogeneity, physical properties and response under different cultivation practices. In support of this an average of 65% agreed that farmers had a good knowledge and understanding of their soils (Table 4). All farmers interviewed appear to have some knowledge of how the soils differ in their fields in terms of depth, texture and drainage, although the level of detail they used varied. Farmers described variation using either a local term, a textural (eg sandy, silty) or geological reference, and in some cases a formal classification. While some used vague terms such as ‘thick bits’ and ‘thin bits’ others, notably those implementing reduced tillage, knew their fields intimately, even to the point of contesting the soil series map, and some held extensive records of yield for different soil types.

All farmers interviewed also appear to have developed a practical ‘working knowledge’ of their soils through regular cultivation which enables them to judge its structure and condition. Accordingly soils were often described by farmers in terms of their ease of cultivation, with terms such as ‘light and easy’ 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. One farmer who practices reduced tillage emphasised the significance of the weather to these properties:

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 fo*rce 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).

In describing farmer knowledge of soil, terms and phrases such as 'intuitive knowledge', 'being in tune with the soil', or 'understanding the soils', which express a less tangible form of knowledge, were commonly used by farmers and advisors. 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.' Those more knowledgeable farmers described experience, long term observation and record keeping as contributing towards this intuitive or tacit knowledge.

Some advisors and farmers however dispute that farmers have any such attachment or intuitive knowledge of soil. Farmers who consider themselves to be good soil managers are very critical of other farmers, for example, one (Farmer L) said 'They *don't have any intuitive feel, no they don't. I don't think they have the slightest* interest, not the ones I know anyway!' A number of advisors also claim that continued poor practice and abuse of soil is evidence of a lack of such knowledge. In accordance with these sentiments, but in contrast to previous comments in favour of farmers' knowledge of their soils, an average of 54% advisors surveyed agreed that most farmers they advised are not concerned with good agricultural practice for soil management (Table 5) supporting one advisor's view that 'Farmers battle on *regardless, not really working with soil and the conditions'.* Also an average 79% consider that soil degradation is a problem in English agriculture (Table 6). In support of this more than 55% advisors on average had observed severe compaction, water erosion, capping and poor drainage in the last two years which they attributed to poor soil management (Figure 1), although most respondents stressed the localised and irregular nature of these incidences with their occurrence often coincident with very wet conditions. Advisor observations and opinions will clearly be influenced by the type of client, his farming system and soil type, however these figures do suggest that a large number of advisors drawn from a national sample have concerns about soil management, and do concur with interviewee comments.

7.2 Farmers' tacit knowledge of soil in relation to cultivation

The nature and extent of tacit knowledge of soil can be explored through farmers' cultivation since these operations bring the farmer into direct sensual contact, through sight, feel and smell, with the soil. Farmers and advisors interviewed within the SMI project provide an interesting view on the nature of this knowledge. There is universal agreement amongst them that cultivation is a very skilled activity, with important decisions needing to be made about the timing, and the interval between subsequent successive cultivations, as well as the choice of machine. Poor cultivation decisions and practices are regarded by the majority of advisors as the main reason for soil structural degradation including compaction and surface capping which lead to erosion. This is attributed to lack of thought, as one advisor said 'My view is the level of competence in terms of cultivation is not necessarily that great because farmers *don't think about what they are doing'*. 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 SMI, is that 'they do not know how to examine their soil *to determine how much cultivation is required'*. This lack of inspection is compounded by the pressures to get crops drilled, even when weather conditions are unsuitable, coupled with the availability of very powerful machinery, which compact the soil and cultivate deeper than necessary:

It's one almighty rush. 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).

For those that do have the time or the interest to inspect soils, advisors consider that a further problem arises because farmers are often ill equipped to interpret what they see. The farmers interviewed who had attended the SMI demonstration days agreed that they had limited experience in inspecting the soil and benefited in particular from this element of the demonstration event. Although most of the time farmers are seen to get cultivations right, advisors consider that when things go wrong they can have quite a visible impact both agronomically and environmentally:

In the days with horse and plough they knew it intimately and couldn't do much damage, now with huge machinery they can do a lot of damage very quickly before they have gained the experience. Even the most in tune farmers can make those mistakes on a big scale (Independent agronomist J).

This is verified by the advisors' comments and survey respondents' observations of localised compaction and water erosion (Figure 1). Farmers themselves recognise the problems brought by larger machinery, and the pressures soils are under, as one (Farmer P) remarked 'We have huge tractors now and see the damage we are actually doing to the soils'. There was a suggestion from a number of advisors (nine out of 31) that farmers are more removed from the soil than they used to be. With farms getting bigger, labour a constraint, and the demands of paper work, farmers have less opportunity to visit their fields, many leaving cultivations to their tractor drivers and field walking to their advisors:

No farmers don't know their soils intimately, they're hopeless. The generation of farmer who knew their soil are those that spent a lot of time in their fields walking up *and down but they don't now, they haven't got time for that nor the interest.* (Independent agronomist DG).

The inference is that use of large machinery is threatening their knowledge of the soil since this technology removes their physical and sensual contact with the soil, obscuring any visible signs of problems with the subsoil which may have been detected earlier by someone on foot. However some farmers defend themselves against such claims, suggesting that it is only on larger farms with hired labour where this is a problem, as one (Farmer M) remarked 'It all depends how much you leave to your agronomist. A lot of farmers, myself included, still like to get out there and walk *across the field'* .

In contrast to the farmers described above who fail to examine and understand their soils, three farmers interviewed who have been practicing reduced tillage were notable exceptions. Reduced tillage systems require close and regular observation of the surface and subsoil condition and demands a new understanding and awareness of soil. As such these farmers demonstrate an appreciation and an intimate knowledge of their soils. One described his 'awakening' in understanding the soil through inspection and moving away from performing operations through habit:

Speaking personally ten years ago I never even thought about it. I didn't look at the soil, I didn't dig holes, I didn't look for earth worms. We would subsoil every year before we planted oil seed rape and we wasted thousands of pounds doing that and probably did more harm than good because that was the thing you did, it was habit (Farmer L).

These represent an interesting cohort of farmers who are both knowledgeable about their soils and enthusiastic about the methods they have discovered to manage them sustainably. These farmers tend to be characterised not by type of farm enterprise or farm size but by their commitment and readiness to observe, experiment and learn, which enables them to build up invaluable knowledge over time.

This analysis presents a complex picture of farmers' tacit soil knowledge. Although the advisors surveyed largely agree that farmers are knowledgeable about their own soils, the majority also agree that farmers are not concerned about soil. This might suggest that knowledge of soil does not automatically qualify farmers to be interested in its protection or husbandry or that other factors prevent knowledgeable farmers from demonstrating concern. Advisor interviews reflect this division of views with some considering that farmers do have tacit knowledge, describing them as being 'in tune' or having 'intuitive knowledge' of soil, referring to it as their 'livelihood' or their 'birthright' and others describing farmers as disinterested, not 'in tune with', 'not working with the soil' and not knowing their soils intimately. Farmers themselves tend to acknowledge that, when it comes to soil management, as with any other aspect of farming, there are good farmers and bad farmers. Evidence from farmer interviews reveal that whilst all farmers could offer a description of their soils, these were at different levels of detail, some making very general and sometimes vague comments about variable texture and 'workability', others demonstrating an intimate knowledge. Many acknowledged that, although they knew the spatial patterns of their soils, they lacked a full understanding of soil particularly in relation to its examination and cultivation and accepted that problems occurred, none however accepted that they were 'hopeless' as suggested by some advisors.

Advisors considered that lack of intuitive knowledge particularly concerning soil structure was demonstrated by poor competence in cultivation and consequent soil degradation. Clearly the potential for farmers to damage the soil using larger machinery is a recurring theme and this is attributed to lack of inspection, and poor interpretation, of soil and to the habit of carrying out degrading operations without thinking about the consequences. The loss of connection with the land and the pressure to complete operations compounds the problem. Farmers who have experience of reduced tillage however do demonstrate an appreciation of the soil brought about by learning through examination, observation and monitoring. They have a greater tacit knowledge and a detailed understanding of how their soils behave under cultivation and/or changing weather. These farmers are highly critical of other farmers' lack of interest and degrading practices.

8. DISCUSSION

This paper describes the views advisors and farmers hold about the nature and extent of farmers' soil knowledge in England. Although the research exposes some conflicting opinions, both within and between the farmer and advisor communities, there is a general consensus that, although farmers are largely knowledgeable, many appear to lack the in-depth scientific and tacit knowledge necessary for carrying out more complex sustainable soil management practices.

The survey results provided a general picture of the extent of advisors' views about farmer soil knowledge while the advisor and farmer interview data elaborate on these views in more depth, exploring the nature of this knowledge in the context of the two projects. The advisors were a valuable and informed source of comment for this research. Their range of views reflect the diversity of situations that they deal with, in terms of their clients, their systems, environment and soil types. They also reflect their own knowledge, standards and interpretations of what constitutes degradation and good soil management. However, correspondence between the views of the different types of advisors who responded to the survey suggest that advisors have a largely unified view about farmers' knowledge. This is with the exception of conservation advisors who are less involved in practical farming matters on the farm and therefore arguably less aware.

Farmers interviewed as part of the SMI initiative represent predominantly larger arable farmers from the eastern parts of the country who are seeking to understand soil management in the context of reducing crop establishment costs through reduced tillage techniques. The Landcare farmers from the south-west have a more diverse farming background and are looking for practices that will lead to both reduced sediment and nutrient loss in response to pressure from the Environment Agency, fisheries and the local public. As such their interests differ, however some commonalties have been revealed. Farmers from both projects are knowledgeable about their own soils however they acknowledge that they are challenged by practices such as managing manures and appropriate cultivations which they recognise as very skilled activities. It is particularly interesting to note that even within a sample of self-selected farmers drawn from those who had attended demonstrations, i.e. motivated individuals, the majority in both projects accept that soil is still a resource they do fully understand and indeed that is why they are seeking knowledge about its management.

The research has shown that the relationship between the different knowledge forms is complex and that scientific knowledge relies considerably on tacit knowledge for interpretation particularly at the level of local farm implementation. Cultivation practices involve highly skilled operations using technical and scientific knowledge but this knowledge needs to be combined with local knowledge of soil and weather conditions to be effective. Similarly experience is central to tacit knowledge and yet it contributes to farmers being able to confidently apply scientific knowledge as with nutrient budgeting. Results suggest that only by having a full complement of scientific and tacit can farmers be fully 'equipped' to implement soil best management practice. However for both forms of knowledge there is a sense that farmers have some knowledge but not enough, they are 'in tune but equally ….there is considerable ignorance' or 'they are aware of gross errors of management but not aware of more subtle things they can do' or 'there is an enormous amount of understanding about the soil but where farmers fall down is they won't examine it'. This highlights the fact that in many cases farmers do not have sufficient in-depth knowledge that sustainable soil management demands. This lack of knowledge is considered by the majority of advisors surveyed to be important in explaining poor uptake of best soil management practices.

The potential for damage done by larger machinery and poor cultivation decisions is a recurring theme. Back in the 1970s the Strutt report remarked that farmers' lack of knowledge of the composition of the subsoil was leading to mistakes and to unjustified risk taking' (MAFF 1970), it appears that this continues to be the case today as machinery capable of damaging the soil structure is used without sufficient thought given to the subsoil condition. Because of the risks even the most ‘in tune’ farmers are thought to be ‘very capable of making big mistakes’.

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Failure to examine the condition of the soil prior to cultivation is seen as a major underlying cause of poor cultivation decisions. Many farmers appear to no longer have the time to walk their fields or inspect the soil and inability to interpret what they see compounds the problem. It has been argued that, before the advent of the productivist era and associated technological evolution, farmers usually had an intimate knowledge of their land holding, its fertility and composition through practices of rotation and ploughing, with local knowledge attuned to the rhythms of nature and tied to the farm and the local ecosystem, of which soil is a central component (Morgan and Murdoch 2000). The suggestion is that during the intensification of UK agriculture in the period 1950-1980 this farmers’ local knowledge base was replaced by specialised and commodified agricultural inputs. This research suggests that the farmers’ soil knowledge base may also have been eroded throughout this transition; that the use of hi-tech machinery, compounded by time and labour constraints on the farm, has displaced the traditional relationship farmers had with their soil landscape. Previously ‘in the day with horse and plough they knew the soil intimately’ but ‘the generation of farmers who knew their soil and spent a lot of time in their fields walking up and down’ has been replaced by those who rarely walk the farm and have lost connection with the land. This is with the exception of those SMI farmers who, through the practices of reduced tillage, are rediscovering the soil; they are arguably forgetting the old habits of cultivating without inspection and relearning how to examine and interpret soil conditions, processes that Morgan and Murdoch (2000) claim are necessary to acquire knowledge for sustainable farming. This analysis of course is based on advisors views and, although accepted by some farmers interviewed, was contested by others who claim to walk their fields regularly. However the prospects for UK agriculture, with continued reduction in farm income support, declining crop prices and consequent re-structuring and adjustment, mean that farmers will have less resources, time and labour to address soil management matters. They are also more likely, in striving for efficient systems, to use larger machines or employ contractors to undertake their operations, thereby diminishing their connection with the land even further (GFA-Race and IEEP 2004).

In conclusion there is evidence of some farmers being well equipped to carry out sustainable soil management, however some areas will have to be significantly enhanced and standardised to meet the new policy challenges, specifically improvement of the ‘know-why’ element of scientific knowledge, relating poor management practice to consequences, and improvement of the ‘know-how’ element of tacit knowledge that enables farmers to examine soil and interpret what they see. Achieving these improvements will require different approaches. Enhancing scientific knowledge requires explanation through training and demonstration, as provided by the new BASIS certificate in soil and water management offered to farmers (Farmers Weekly 2004b), publications (Defra 2005), and workshops and demonstration events, such as those offered by SMI and Landcare. Enhancing tacit knowledge requires farmers to learn through practice. Practical demonstrations are a popular method for showing farmers how to examine and interpret soil condition, however this research has revealed the value of experience gained on-farm. Although this has to be an individual endeavour it could be facilitated by competent practitioners. This research has shown that individuals within the farming and advisory communities are well informed, concerned and knowledgeable about soil and as such could support on-farm learning either through farmer discussion groups or one to one advice. Ultimately farmers need to be encouraged to attend training courses and demonstrations, to seek assistance from advisors and to learn for themselves. Policy demands will provide an impetus for some while the cost savings offered by practices such as reduced tillage and managing manure will provide incentives for others who are searching for ways of surviving in a competitive industry (UK SMI 2002; Defra 2004d; Environment Agency 2005). Enthusiastic farmers, such as those practising reduced tillage, also have a role to play as ‘champions’ or ‘influencers’ of good soil management within the farming community.

It has long been recognised that farmers need new skills to take on the new demands of sustainable agriculture but little has been known about soil, this research has gone some way to address this gap in the English context. It will be important to build on this research in the future by consulting a larger sample of farmers to elaborate further the extent and nature of their knowledge about soil and to inform policy by identifying constraints and opportunities for improving this knowledge.

EXPLANATORY NOTES

1. The focus on England rather than the UK as a whole is justified as policy making is devolved to the agricultural departments of the constitutive countries i.e. England, Wales, Scotland and Northern Ireland

2. As part Common Agricultural Policy (CAP) reforms implemented in 2005, farmers will have to meet new 'cross-compliance' standards designed to protect the environment before they receive their Single Farm Payment.

3. 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).

4. Tacit knowledge is also referred to as local/lay/indigenous/informal and traditional. 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).

5. In Lundvall and Johnson's (1994) typology 'know-what' refers to knowledge about facts, which is largely codified. 'Know-why' is the knowledge of principles, rules and ideas of science and technology.

6. 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.

7. Reduced tillage and conservation tillage refer to non-inversion tillage. The former also called 'minimum or minimal tillage' is 'shallow tillage' (<100 mm without inversion), the latter describes any non inversion tillage which leaves at least a third of the soil surface covered by crop residues; it includes direct drilling, shallow and deep tillage (Davies and Finney 2002). Both are considered by some commentators (UK SMI 2002) to improve soil structure, biota, soil organic matter and reduce erosion.

8. To manage manures effectively farmers need to know the nutrient content of applied manures; apply manures evenly and at known rates; rapidly incorporate manures (where appropriate) or use an application technique that will minimise ammonia losses; apply manures in spring (where possible) to reduce nitrate leaching losses; take the nutrient supply from manures into account when calculating inorganic fertiliser additions; and ensure total N per year does not exceed 250kg/ha.

9. Publications referred to during the interviews for definitions, explanations and lists of best management practice included: Managing Livestock Manure booklets (ADAS et al. 2000); MANNER (MANure Nitrogen Evaluation Routine) a PC decision tool; Best Farming Practices: Profiting from a Good Environment

(Environment Agency 2001); A Guide to Managing Crop (SMI 2002) and Visual Soil Assessment (SMI 2005).

10. Conservation advisors, mostly in the NGO ‘Farming and Wildlife Advisory Group’, are farm conservation specialists.

11. Defra’s Rural Development Service project officers manage and administer government funded agri-environment schemes.

12. ADAS, formerly the government advisory service, was privatised in 1997 and now operates as a consultancy, although it still undertakes environmental protection dissemination work for the government.

13. FACTS provides a national training syllabus and accreditation for arable advisors and farmers. Training includes soil and nutrient management.

14. Questionnaires were emailed on behalf of the author through the FACTS organisation to an unknown number and sector of the membership.

15. BASIS is an Independent Registration Scheme for the Pesticide Industry and oversees FACTS.

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Table 1. Characteristics of farmers and advisors interviewed and themes discussed

LANDCARE PARTNERSHIP	SOIL MANAGEMENT INITIATIVE
Farmers interviewed (N=7)	**Farmers interviewed (N=10)**
1. Mainly arable farm on chalk with winter wheat and arable break crops (field beans and oil seed rape). Some sheep. 500 acres	1. Arable farm, Leicestershire. Combinable crops on loams. 440 acres
2. Arable farm on chalk with winter wheat, oil seed rape and field beans. 350 acres	2. Arable farm, Herts. Combinable crops on chalky soils, Boulder clay. 750 acres.
3. Mixed farm on chalk. Arable rotations with spring barley; suckler cows, indoor pigs. 200 acres	3. Arable farm, Cleveland. Combinable crops on light soils, loams. 520 acres.
4. Mixed farm bordering chalk and Pewsey Vale clay, suckler cows, sheep and arable. 250 acres	4. Arable farm, Rutland. Combinable crops on clayey soils. Reduced tillage. 800 acres
5. Dairy farm, with forage maize and grass silage. 180 acres. Clayey soils, some Greensand.	5. Arable farm, Leicestershire. Loamy soils. Cereals with break crops. 300 acres.
6. Arable farm on mainly chalk with winter wheat, break crops, also sheep. 550 acres	6. Arable farm Leicestershire. Clays with sandy loams. Cereals with break crops (peas or beans). 40 head suckler herd. 450 acres
7. Dairy farmer with some forage maize and grass silage. Clay with some Greensand. 150 acres	7. Arable farm, Kent. Cereals with break crops plus sheep. 1200 acres
	8. Arable farm, Leicestershire. Cereals with break crops (peas or beans). 660 acres
	9. Arable farm, Worcs. Clay loam over clay. Reduced tillage. 600 acres.
	10. Arable farm, Warwickshire. Some sheep. Reduced tillage on Evesham clays. 1000 acres.
7 farmers	**10 farmers**
Advisors interviewed (N=29)	**Advisors interviewed (N=35)**
10 partners (agronomists, RDS advisors, conservation advisors etc)	7 board members
4 event attendees	8 event attendees
15 local agronomists, merchants, consultants etc	20 agronomists/consultants
Themes discussed in interview	**Themes discussed in interview**
What is the nature and extent of farmer knowledge about:	What is the nature and extent of farmer knowledge about:
• managing manures and their nutrients • practices leading to erosion • best management practices to prevent run-off • sources of information • the aims of the project	• soil structure and its examination • cultivations/appropriate cultivations • reduced tillage • causes of problems • sources of information • the aims of the project

Table 2. Advisors' response to the question: To what extent do you agree that most farmers you advise are technically well informed about soil management?

	% of respondents within each advisor category					% average
	Conservation	DEFRA RDS	Independent agronomists	Distributor agronomists	ADAS	
Agree	15	41	44	54	48	40
Neither agree nor disagree	50	50	29	23	39	38
Disagree	35	9	26	23	13	22
No. of valid respondents	32	22	71	13	23	Total 161

Table 3. Advisors' response to the question: How important is lack of knowledge and skills about soil management options as a factor in explaining poor uptake of soil best management practices?

	% of respondents within each advisor category					% average
	Conservation	DEFRA RDS	Independent agronomists	Distributor agronomists	ADAS	
Not important	3	14	13	9	2	8
Neither important nor not important	9	24	24	7	26	18
Important	88	62	63	84	72	74
No. of valid respondents	32	21	70	13	23	Total 159

Table 4. Advisors' response to the question: To what extent do you agree that most farmers you advise have a good knowledge and understanding of soils on their farm?

	% of respondents within each advisor category					% average
	Conservation	DEFRA RDS	Independent agronomists	Distributor agronomists	ADAS	
Agree	41	73	63	77	70	65
Neither agree nor disagree	50	27	22	23	30	30
Disagree	9	0	15	0	0	5
No. of valid respondents	32	22	71	13	23	Total 161

Table 5. Advisors' response to the question: To what extent do you agree that most farmers you advise are not concerned with good agricultural practice for soil management

	% of respondents within each advisor category					% average
	Conservation	DEFRA RDS	Independent agronomists	Distributor agronomists	ADAS	
Agree	28	59	70	69	44	54
Neither agree nor disagree	50	41	23	23	52	38
Disagree	22	0	7	8	4	8
No. of valid respondents	32	22	71	13	23	Total 161

Table 6 Advisors' response to the question: To what extent do you think soil degradation is a problem in English agriculture?

	% of respondents within each advisor category					% average
	Conservation	DEFRA RDS	Independent agronomists	Distributor agronomists	ADAS	
No problem exists	0	0	18	0	4	4
Don't know	0	17	17	25	26	17
Yes problem exists	100	83	65	75	70	79
No. of valid respondents	32	23	71	12	23	Total 161

Figure 1. Advisors response to the question: Indicate the severity of any incidences of degradation which you have observed in the course of your work over the last 2 years which can be attributed to inappropriate land use or poor soil management?