Soil Use and Management

Soil Use and Management, March 2016, **32,** 36–44 doi: 10.1111/sum.12244

Using mental models to understand soil management

K. Prager[1] & M. Curfs[2]
[1]*The James Hutton Institute, Craigiebuckler, Macaulay Drive, Aberdeen AB15 8QH, UK, and* [2]*3D-EC Environmental Change, Curtiuslaan 14, 1851 AM Heiloo, The Netherlands*

Abstract

Soil degradation continues to be a serious issue. This is partially due to the specific characteristics of soil and degradation, many of which are linked to how humans perceive their environment. How a person perceives soil degradation will influence how they interpret this phenomenon, what attitude they adopt towards it, and how they will ultimately decide to act. Mental models are understood as constructed by the human mind as a result of perception, experience, attitudes and knowledge, and the comprehension of discourse. Applying the concept of mental models allows an understanding of land manager decision-making with regard to soil management, linking perceptions, attitudes and beliefs with behaviour. We show how mental models can help identify consistencies and differences of perceptions of different soil-related stakeholders, such as farmers, scientists, administrators, advisors and policy makers. In a practical test of the concept, a diagram-based representation of mental models was applied in south-western Spain. We found that the occurrences of overlap in the mental model of soil-related stakeholders are the areas where communication should focus. It is in these areas where strategies to address the problem of soil degradation can be developed.

Keywords: Cognitive maps, mindset, mentality, behaviour change, technology adoption

Introduction

Over a decade ago, Stocking & Murnaghan (2001, p25) stated that ‘although land degradation is a physical process, its underlying causes are firmly rooted in the socio-economic, political and cultural environment in which land users operate’. Researchers have recognized the importance of the human dimension in soil degradation and investigated socio-economic, institutional, and political factors influencing soil conservation (Prager *et al*., 2011).

There is an abundance of concepts in the environmental management literature that explain human behaviour and in particular factors influencing land manager decision-making. The psychological perspective offers concepts such as mental models, mindset, mentality and cognitive maps. However, these concepts are rarely well defined and there is a mix ranging from everyday usage to scientific theories and models. This study is intended to introduce ‘mental models’ and further their constructive application in understanding soil management. After highlighting the specifics of soil degradation and discussing why it is important to consider mental models, we define the concept of mental models and distinguish it from related approaches. This is followed by a description of a tool for eliciting and representing mental models in diagrams, which is then applied to soil management in a Mediterranean environment to illustrate how they aid in understanding farmer decision-making. This study presents ideas around a concept not yet widely known among land degradation researchers which we hope will stimulate discussion and further thinking on the relevance of mental models.

Correspondence: K. Prager. E-mail: katrin.prager@hutton.ac.uk
Received July 2015; accepted after revision November 2015

Background: The human dimension of soil degradation

Among scientists, it is generally accepted that soil degradation is a global threat impacting almost all countries in the world (MEA, 2005). Nevertheless, soil degradation continues. It is therefore referred to as a ‘wicked problem’ (Weber & Khademian, 2008) or an ‘intractable environmental problem’ (Putnam & Wondolleck, 2003). The characteristics that make soil degradation so difficult to address include poor visibility (Bouma, 2005) and slow rates of change leading to long time frames over which on- and off-site impacts become evident (Hey & Baron, 2008). In addition, soil degradation is a complex problem (Eswaran *et al*., 2001) without a straightforward ‘solution’ but several possible ways to address the problem, often dependent on which soil functions are deemed most important and who makes the judgment (Reed *et al*., 2013). Finally, soil degradation is rarely perceived as a serious problem by the public at large, and often not even by land managers (Montgomery, 2007) resulting in low political priority.

The social aspects of soil degradation are often investigated as socio-economic drivers (Boardman *et al*., 2003) but rarely as psychological drivers. To successfully address wicked problems, we suggest that more attention needs to be paid to how land managers and other stakeholders[1] perceive and understand soil. Mental models offer a way to shed light on these factors. Kaplan & Kaplan (1983) argue that a person's reaction to and feelings about an environment are as much a function of how that environment is known, that is of the mental construct one has of it. A person's background (upbringing, culture, knowledge, experience) determines what they perceive of the environment around them.

Different cultures hold different relationships with their environment and therefore interact with it in different ways (Pretty *et al*., 2009). Empirical studies have shown that understanding is cultural and contextual. For example, the understanding of soil differs considerably between scientists, advisors and farmers (Ingram *et al*., 2010). Similarly, Sillitoe (1998) stresses that soil perceptions of scientists and local land users match poorly. How a person perceives soil degradation will influence how they interpret this phenomenon, what attitude they adopt towards it, and how they will ultimately decide to act. Differing but justifiable perceptions and attitudes make finding common ground on how to best approach soil management difficult. In addition, what is seen as a 'solution' to soil degradation will depend on the respective stakeholder's aims, that is which soil functions they want to enhance or protect. With regard to 'wicked environmental problems', Kearney & Kaplan (1997, p579) state that making explicit and visualizing mental models – so that they might be examined, compared, and discussed – 'can expand people's conceptualizations of the problem, pinpoint areas of disagreement, highlight areas of potential agreement, and provide a foundation on which to base a discussion and, ultimately, a decision'. This suggests that there is benefit in making explicit not only land managers' mental models, but also those of scientists or administrators involved in recommending practices or implementing policy to address soil degradation.

Application of mental models

Definition of mental models

Concepts that help to understand land manager decision-making include mental models, cognitive maps, mindset and mentality. These are used interchangeably in the literature, and often without definitions, which on one hand helps to express an interpretation without further detail but on the other hand creates confusion about what is really meant (for a detailed critique see Doyle & Ford (1998)). Generally speaking, mindset and mentality express a general state of mind, and are typically mentioned in passing without further definition, for example 'cultural mindset' (Hardeman & Jochemsen, 2012) and 'dependency mentality' (Bizoza, 2014). In contrast, mental models and cognitive maps are concepts with a scientific background and are constructed from theory.

The theoretical underpinnings of mental models trace back to Kenneth Craik's psychological research in the 1940s (Zaksek & Arvai, 2004; Johnson-Laird, 2013). In parallel, a school of thought developed around the term 'cognitive map' (Tolman, 1948; Doyle & Ford, 1999). Kitchin (1994) gives a detailed description of the history, use and definitions of cognitive maps. He refers to Kaplan (1973) who described a cognitive map as 'a mental construct which we use to understand and know the environment', thereby indicating a possible link between mental models and cognitive maps. The varying definitions of cognitive mapping are the result of its diverse base in multiple disciplines, including psychology, geography, sociology, planning, system dynamics and political science (Kitchin (1994). The same applies to mental models, with the result that there is no united theoretical base for either concept.

Here, we take cognitive maps to be the umbrella term, and mental models as a specific form of cognitive maps. A cognitive map is a hypothetical construct that enables the individual to establish a matrix of environmental experience into which a new experience can be integrated (Kitchin, 1994). To some authors, cognitive maps involve the integration of images, information and attitudes about an environment (Spencer & Blades, 1986).

Attitudes, along with expressed beliefs and perceptions, are an important feature of mental models (Wood *et al*., 2012). A well-founded, annotated definition is suggested by Doyle & Ford (1999, p414): 'A mental model of a dynamic system is a relatively enduring and accessible, but limited, internal conceptual representation of an external system (historical, existing or projected) whose structure is analogous to the perceived structure of that system'. Here, we take mental models as a conceptual representation constructed by the human mind as a result of perception, experience, attitudes, knowledge and the comprehension of discourse.

Tools for diagram-based representation of mental models

The intertwined nature of cognitive maps and mental models is apparent in Wood *et al*. (2012) who compiled several 'cognitive mapping tools and approaches', which they collectively term 'diagram-based representations of mental

[1]Soil-related stakeholders are people with a stake in soil management, which – depending on the issue – can include non-farming land managers, foresters, NGOs and public authorities who own or manage land, and even the general public.

models' (such as belief networks, semantic webs, concept maps or influence diagrams). Diagram-based representations have several benefits such as the visualization of consistencies or conflicts between perceptions and beliefs of individuals or groups (Wood *et al*., 2012).

Mental models cannot be captured or even measured like natural phenomena (amount of soil eroded, amount of nitrate leached). Instead, a mental model is 'fuzzy', 'incomplete' and most likely 'imprecisely stated' when trying to elicit it from an individual (Forrester, 1971). Furthermore, 'within one individual, a mental model changes with time and even during the flow of a single conversation' (Forrester, 1971; p213). This is not problematic in social sciences because the perceptions as expressed by the individual are taken as what they are at the time of interviewing, without judging them to be true or false (Moon & Blackman, 2014).

Two of the diagram-based representation tools will be introduced briefly, the decision-based mental modelling and semantic web analysis, as we tested a combination of these for eliciting the mental models in our practical application. The diagrams can be 'elicited directly from respondents, be derived from respondents' verbalizations, can be inferred from respondents' decisions or actions, or can be produced based on some combination of these approaches' (Wood *et al*., 2012, p1335). Each approach has its advantages and disadvantages so it is important to be clear on what the purpose of the research is, whose mental models are to be elicited, and what the diagrams are to be used for.

Decision-based mental modelling. Decision-based mental models can be created following a four-step approach described by Bostrom *et al*. (1992):

1. Experts create an influence diagram (called an 'expert model'), for example for a soil-related problem; either constructed by a group of experts, or pieced together from the literature.
2. Lay mental models are constructed by the researcher using semi-structured interviews to elicit lay beliefs.
3. Lay beliefs are then mapped onto the expert influence diagram. Alignments, misalignments (e.g. misconceptions held by laypersons) and knowledge gaps are described.
4. The mapping is analysed using different metrics (e.g. frequency of beliefs in larger populations collected through questionnaires).

This approach has been widely used in risk analysis (Zaksek & Arvai, 2004; Wagner, 2007; Schoell & Binder, 2009). We disagree with an underlying value judgement of this tool, that is that 'expert' mental models are used as a starting point onto which 'layperson' mental models are then mapped in order to identify gaps. This suggests that expert mental models are superior to, more complete and valid than layperson mental models. We argue that in the context of soil management, some land managers are more of an expert on their particular soils than an academic with more general knowledge. According to Bouma (2005), farmers can provide valuable knowledge but there is also information that they cannot possibly possess and it would not be fair to suggest otherwise. It is also possible that misconceptions are held by academic experts, by administrators or other soil-related stakeholders.

Semantic web analysis. This method is more qualitative in nature than the decision-based mental model. It provides nuanced descriptions of relations between concepts that do not readily lend themselves to quantification. Interviews are used to produce a diagram with concepts (nouns) represented as nodes in a network diagram. Directional arrows are labelled with relationship terms (mostly verbs) that show relatedness between concept nodes (Wood *et al*., 2012). Interview participants could be asked to think about the topic of interest (e.g. soil management) and then report what would happen if the scenario changed in some way (e.g. stopped ploughing).

According to Wood *et al*. (2012), semantic web diagrams have been coded to provide an overall knowledge score that takes into account misconceptions and a measure of complexity. As with the method of decision-based mental models, we reject the notion that there are right or wrong conceptions (i.e. misconceptions) or that a measure of complexity indicates quality or usefulness of a mental model. To our understanding, semantic webs provide rich visualizations of an individual's mental model regarding a specific issue, producing outputs that can be similar to those from a social-anthropological approach (Mathieu & Joannon, 2003).

Practical test of the concept

Mental models are not yet widely used in soil degradation research. Eckert & Bell (2005) found that prior experience, values and beliefs, and knowledge influenced a farmer's current mental model of farming. Turner *et al*.'s (2014) study of land ethics held by farmers and ranchers in South Dakota supported this. Wagner (2007) compared mental models of scientist and local residents regarding flash floods and landslides, and showed that personal experience and the visibility of processes are two main factors explaining the content of mental models. In relation to soil management, it can thus be argued that the visible factors such as landslides or erosion features can be influential in the decision-making process. Less visible factors such as soil health, organic matter decline or compaction would be less influential.

In Spain, soils in olive groves are increasingly at risk from erosion and loss of soil organic matter (Vanwalleghem *et al*., 2011). In the past, 'the soil below olive trees was often cultivated for the production of crops for non-farm use (...). Nowadays, the normal practice is simply to control spontaneous grasses and other vegetation by seasonal ploughing or harrowing, sometimes preceded by grazing or cutting. Soil erosion is a major problem associated with olive plantations, which has been exacerbated by the practice of keeping bare soils' (Lefebvre *et al*., 2012, p51). Attempts to promote permanent soil cover and its benefit for reducing soil erosion and increasing soil organic matter have had only limited success. To illustrate how mental models can be used and what kind of insights they yield, we elicited and compared an interdisciplinary scientist's mental model with a farmer's mental model of soil management in olive groves in south-western Spain.

Method

We followed a grounded theory approach (Strauss & Corbin, 1998) for gathering and analysing data and developing theory from it. For the construction of a hypothetical scientist's mental model, we drew on our own mental models as scientists, on conceptualizations that we considered to be common among land degradation researchers based on personal encounters and joint working in different projects and contexts, and complemented these with ideas from economics (costs, yields) and institutional analysis (EU policy) from the literature.

The empirical data from which we constructed the farmer mental model were collected in the Western Andévalo, Huelva province, in south-western Spain during

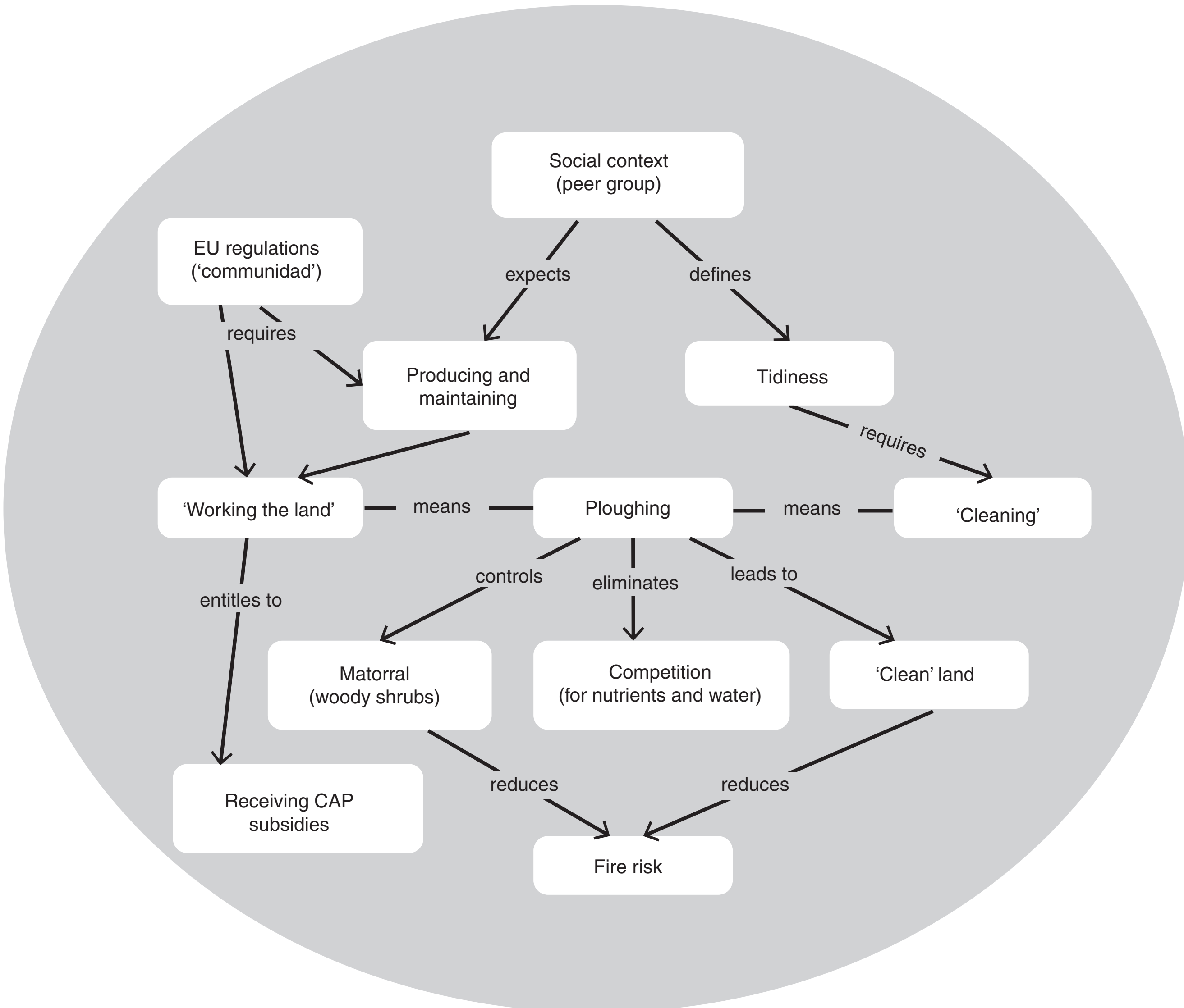

Figure 1 Mental model of an Andalusian farmer.

2010–2014. We conducted a total of 16 semi-structured interviews in the local language with agricultural advisors, regional and local authorities, researchers from the University of Huelva working in the area and private consultants. The interviews served to establish the multifacetted environmental and social context of the soil degradation problem. In addition, action research and participant observation (Kindon *et al.*, 2007) as part of being a farmer in the area was carried out by one of the authors. On at least 20 occasions, practices relating to soil management were discussed with different farmers in the field. Topics covered when, why and how often a farmer ploughed; local customs of what kind of crops or trees to plant (when, where and why); frequency and effects of chemical or organic fertilizer application; the notion of soil, erosion, soil degradation, and reasons and practices for protecting soil. The resulting mental model (Figure 1) represents a typical farmer in the region. For explanation of concepts and relationships, we used some information from the other interviews.

A farmer's mental model

We found that soil and soil management are not necessarily part of every farmer's mental model. Soil management can occur and is performed without it being labelled or perceived as soil management. For the farmer, the action of ploughing is not primarily targeted at soil management. Ploughing is performed in olive orchards several times a year, albeit without the intention to sow or plant crops in between the trees. The main intention of the farmer is to control the spread of matorral (woody shrubs), to eliminate competition for nutrients and water by weeds, and to maintain 'clean land' under his olive trees, complying with a notion of tidiness. In the farmer's mental model, 'clean land' is associated with reduced fire risk; hence, by ploughing he

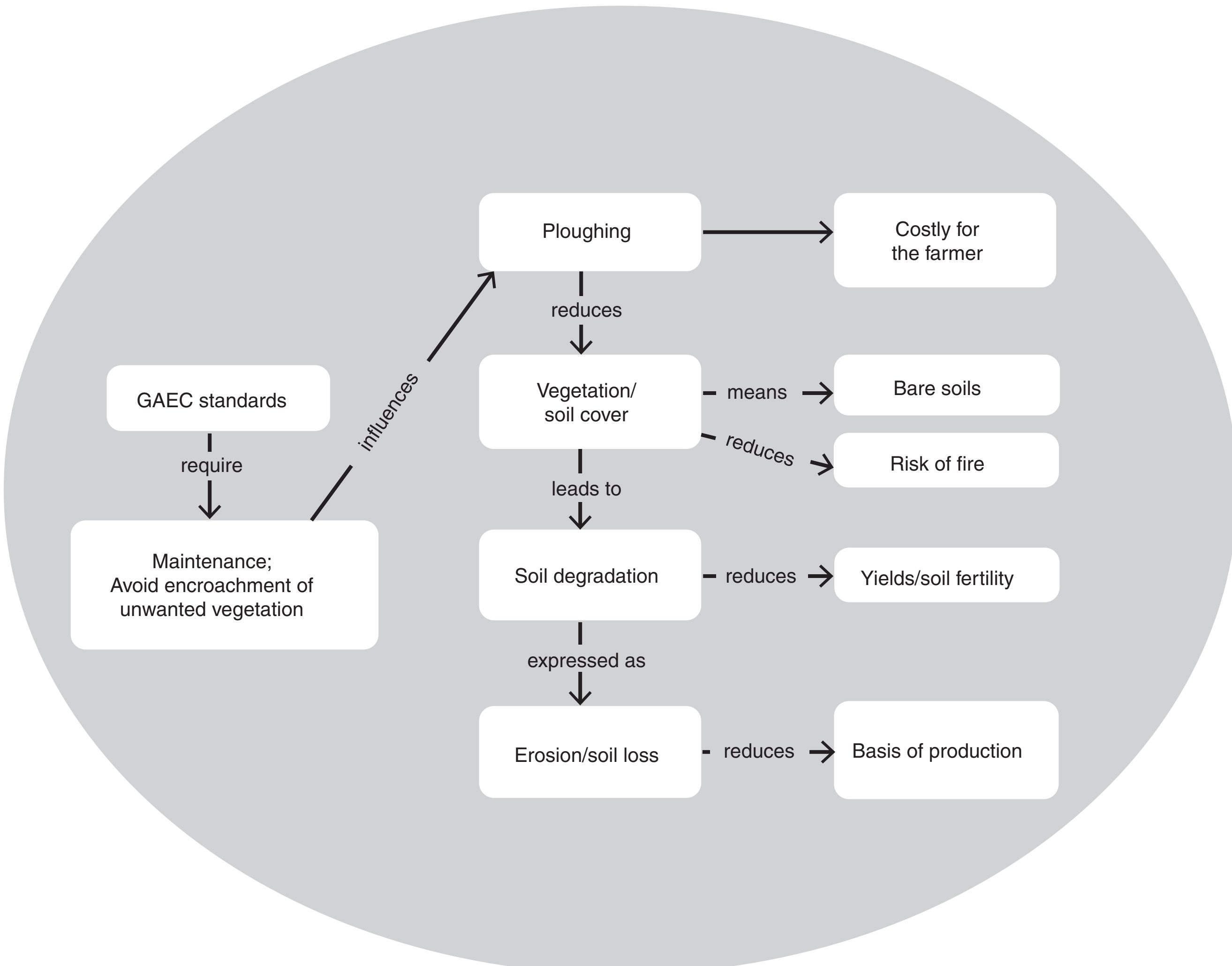

Figure 2 Mental model of a hypothetical interdisciplinary scientist.

keeps his area safe. Among the peer group of farmers, but also in the wider social context, tidiness of fields is a desirable feature. In the Spanish language, ploughing is commonly referred to as *limpiar* (cleaning), as well as *labrar* (working). There is an association that to properly work the land, a farmer has to plough. In addition, there is an element of habit: the farmer had performed this ploughing regime in the olive grove for decades. In addition, the EU regulations (referred to by the farmer as the 'communidad') require him to work the land in order to receive subsidies.

A scientist's mental model

To the interdisciplinary scientist, ploughing is responsible for loss of soil cover (leaving soils bare but also lowering fire risk), which in turn increases vulnerability to soil degradation and erosion (Figure 2). Degraded soils reduce yields, and eroding soils mean that farmers are losing their basis of production. Ploughing creates a cost for the farmer (fuel, time or payment to a contractor). The EU Common Agricultural Policy (CAP) prescribes standards for Good Agricultural and Environmental Condition (GAEC). With regard to soil, they require that a minimum level of maintenance is ensured and encroachment of unwanted vegetation is avoided (Table 1).

Member states are required to adjust the generic GAEC standard to their specific circumstances at national or regional level 'taking account of the specific characteristics of the areas concerned' (European Union, 2009, Prologue 4). In Spain, this is the regional level; in our case the province of Andalucía. Table 1 shows the EU GAEC standards and the corresponding rules in Andalucia, the *Buenas Condiciones Agrarias y Medioambientales (BCAM)*. The latter include the general statement: 'on cultivated land, avoid the encroachment of matorral, and spontaneous undesired vegetation' (Junta de Andalucia, 2014). BCAM are structured different to EU GAEC standards (Junta de Andalucia, 2009). The Andalusian BCAM make no reference to the management of perennial cultivations on land with less than 10% slope, that is there are no rules for the land manager concerning ploughing in olive groves on flat land.

Table 1 EU GAEC standards and the corresponding soil-related rules in Andalucia, Spain. Translation by the authors

Issue	EU GAEC Compulsory and optional standard relating to soil management	BCAM in Andalucia (*Buenas Condiciones Agrarias y Medioambientales*)
Soil erosion: Protect soil through appropriate measures	Compulsory standards • Minimum soil cover • Minimum land management reflecting site-specific conditions	**1.** Management of fallow and set aside land In fallow and set aside land, local traditional agricultural practices will be performed; including minimum ploughing, maintaining an adequate vegetation cover through spontaneous vegetation, or through sowing of beneficial species, all of which have as purpose to minimize the erosion risk, fire risk and the invasion of weeds or undesired vegetation, the occurrence of plagues and diseases, and to maintain the productive capacity of the soil and favouring the increase of biodiversity. (...) **2.** Management of permanent cultures In olive orchards with slopes of more than 10%, in which the soil is kept bare in between the olive trees through the application of herbicides, it is necessary to maintain a vegetative cover alive or inert, that may include pruning material and/or stones, with a width of 1 metre following the contour lines, and cross-contour lines if the design of the parcel or the irrigation system impedes their establishment along contour lines. The elimination of the cover can be realized from the moment that the herbaceous cover starts to compete with the cultivation, using chemical and mechanical methods, it may be incorporated into the soil by superficial ploughing respecting in all forms the norms from article 4.2b (4.2 b concerns slopes with more than 15%)
Minimum level of maintenance: Ensure a minimum level of maintenance and avoid the deterioration of habitats	Compulsory standard • Avoiding the encroachment of unwanted vegetation on agricultural land Optional standard • Maintenance of olive groves and vines in good vegetative condition	

Discussion

When comparing the mental model of the scientist with that of the farmer, we notice that there is limited overlap. The action of ploughing appears in both diagrams but is associated with different concepts. There is overlap in the concept of weeds, which appears as ‘unwanted vegetation’ (a GAEC requirement) in the scientist’s model, and as ‘matorral’ in the farmer’s model. The third area of overlap is fire risk; both models desire to reduce fire risk and link it to the amount of vegetation.

We argue that these occurrences of overlap are the areas where communication between scientist and farmer should focus, and where strategies to address the problem can be developed. Discussions between the author (scientist) and the farmer in the field about ploughing as a cause for erosion, the impact of soil degradation, and even pointing out the costs of ploughing to the farmer (core concepts in the scientist’s mental model), had no effect on the farmer’s ploughing regime. In the farmer’s mental model, tidiness overruled the notion of reducing erosion or reducing costs. Then, grazing was introduced on this farm by mutual arrangement with a neighbour, which kept the vegetation short. From one day to the other, the farmer subsequently made the decision not to plough based on his perception that the vegetation was sufficiently controlled by the grazing.

By understanding the mental model of the farmer, in this case the notion of tidiness and offering a management alternative that equally addressed the farmer’s aim of a tidy farm proved successful in reducing tillage erosion. The fire risk was seen to be sufficiently controlled by keeping the vegetation low through grazing, hence ‘clean land’ (achieved by ploughing = limpiar) was not absolutely essential anymore. We infer that discussions that focussed on reducing soil degradation were not successful because this concept was not part of the farmer’s mental model.

Importantly, farmers are not a homogeneous group. The mental model of a modern, specialized, highly educated farmer will be different to that of a semi-subsistence farmer with basic education; the former may actually be similar to a scientist mental model. However, the principle remains valid that focussing on areas of overlap between mental models of different stakeholders is likely to yield best results.

Scientists are in a challenging position, in particular if they want to adopt transdisciplinary ways of working to address wicked problems (Bouma, 2015). They have to deal with tensions between their own (tacit) and professional knowledge, farmer knowledge, and the requirements of the regulatory context. For many, it may be tempting to just focus on professional knowledge even though this is less appropriate in times of increasing knowledge levels and critical attitudes of the public.

In this paper, we illustrated how mental models provide insights into the motivations for a certain behaviour (soil management practice) and help understanding underlying perceptions and beliefs. Our findings resonate with Wood *et al.* (2012) and Kearney & Kaplan (1997) who state that mental models can help identifying consistencies and conflicts between perceptions and beliefs of different individual and collective actors (land managers, scientists, administrators, advisors, policy makers). Disparate views can be summarized and compared, forming a basis for discussion, improving mutual understanding and learning, and even offering the opportunity to identify where misinformation might have been built into a mental model.

Conclusion

Although the empirical research involved in constructing mental models comes at a cost, the findings will help channel investment in research to areas where the chances of recommendations being adopted are highest. Mental models can also be of benefit to policy makers and administrators who must make judgments about the best policy or course of action to take, given imperfect information about the beliefs and perceptions of several stakeholder groups (Wood *et al.*, 2012).

Mental models can range from simple to very detailed, they can be constructed for few or many different stakeholders, and they can be aggregated by type of stakeholder. The use of quantitative metrics and an extrapolation to a larger target population is not useful or necessary in all cases. The choice of method will depend on the objective pursued in the respective context. Special attention needs to be paid to the nuances of language. Depending on the areas of overlap that can be identified from mental models, strategies would need to align to those concepts that the respective stakeholders consider important. Ultimately, we encourage the use of mental models to support systems thinking and the integration of different understandings in developing strategies to address soil degradation, while respecting underlying perceptions and beliefs.

Acknowledgements

Michiel Curfs’ empirical research was partially funded by LEDDRA (EU FP7 Grant Agreement number 243857). Katrin Prager’s writing retreat in Spain was funded by the Scottish Government’s RESAS research programme 2011-16.

References

Bizoza, A.R. 2014. Three-stage analysis of the adoption of soil and water conservation in the highlands of Rwanda. *Land Degradation & Development*, **25**, 360–372.

Boardman, J., Poesen, J. & Evans, R. 2003. Socio-economic factors in soil erosion and conservation. *Environmental Science & Policy*, **6**, 1–6.

Bostrom, A., Fischhoff, B. & Morgan, M.G. 1992. Characterizing mental models of hazardous processes: a methodology and an application to radon. *Journal of Social Issues*, **48**, 85–100.

Bouma, J. 2005. Soil scientists in a changing world. *Advances in Agronomy*, **88**, 67–96.

Bouma, J. 2015. Engaging soil science in transdisciplinary research facing wicked problems in the information society. *Soil Science Society of America Journal*, **79**, 454–458.

Doyle, J.K. & Ford, D.N. 1998. Mental models concepts for system dynamics research. *System Dynamics Review*, **14**, 3–29.

Doyle, J.K. & Ford, D.N. 1999. Mental models concepts revisited: some clarifications and a reply to Lane. *System Dynamics Review*, **15**, 411–415.

Eckert, E. & Bell, A.A. 2005. Invisible force: Farmers' mental models and how they influence learning and actions. *Journal of Extension*, **43**. Available at: http://www.joe.org/joe/2005june/a2.php

Eswaran, H., Lal, R. & Reich, P.F., 2001. Land degradation: an overview. In: *Response to Land Degradation* (eds E.M. Bridges, I.D. Hannam, L.R. Oldeman, F.W.T. de Pening Vries, S.J. Scherr & S. Sompatpanit), pp. 20–35. Science Publishers, Enfield, New Hampshire.

European Union, 2009. COUNCIL REGULATION (EC) No 73/2009 of 19 January 2009 establishing common rules for direct support schemes for farmers under the common agricultural policy.

Forrester, J. 1971. Counterintuitive behavior of social systems. In: *Collected Papers of J. W. Forrester* (eds J.W. Forrester), pp. 211–244. Wright-Allen Press, Cambridge, MA.

Hardeman, E. & Jochemsen, H. 2012. Are there ideological aspects to the modernization of agriculture? *Journal of Agricultural & Environmental Ethics*, **25**, 657–674.

Hey, C. & Baron, M. 2008. Bodenschutz aus politikwissenschaftlicher Perspektive. *International Symposium "Soil Protection in Europe – Key Questions for Sustainable Soil Protection"*, 21–22 January 2008, European Academy of the Urban Environment, Berlin Germany.

Ingram, J., Fry, P. & Mathieu, A. 2010. Revealing different understandings of soil held by scientists and farmers in the context of soil protection and management. *Land Use Policy*, **27**, 51–60.

Johnson-Laird, P.N. 2013. Mental models and cognitive change. *Journal of Cognitive Psychology*, **25**, 131–138.

Junta de Andalucia, 2009. Boletin Oficial de la Junta Andalucia **130**, pp. 92–115.

Junta de Andalucia, 2014. Condicionalidad nociones basicas. Available at: http://www.juntadeandalucia.es/agriculturaypesca/cocow/condicionalidad_nociones.html#BCAM accessed 29 Oct 2015.

Kaplan, S. 1973. Cognitive maps in perception and thought. In: *Image and Environment* (eds R.M. Downs & D. Stea), pp. 63–78. Aldine, Chicago, Illinois.

Kaplan, S. & Kaplan, R. 1983. *Cognition and Environment: Functioning in an Uncertain World*. Ulrich's bookstore, Michigan.

Kearney, A.R. & Kaplan, S. 1997. Toward a methodology for the measurement of knowledge structures of ordinary people: the conceptual content cognitive map. *Environment and Behaviour*, **29**, 579–601.

Kindon, S., Pain, R. & Kesby, M. 2007. *Participatory Action Research. Approaches and Methods*. Routledge, Oxon.

Kitchin, R.M. 1994. Cognitive maps: what are they and why study them? *Journal of Environmental Psychology*, **14**, 1–19.

Lefebvre, M., Espinosa, M. & Gomez y Paloma, S., 2012. The influence of the Common Agricultural Policy on agricultural landscapes, JRC Scientific and Policy Reports, Report EUR 25459 EN, Sevilla.

Mathieu, A. & Joannon, A. 2003. How farmers view their job in Pays de Caux, France: consequences for grassland in water erosion. *Environmental Science & Policy*, **6**, 29–36.

MEA 2005. *Millennium Ecosystem Assessment*. Global Assessment Reports. Island Press, Washington, DC, Ecosystems and Human Well-Being.

Montgomery, D.R. 2007. *Dirt -The Erosion of Civilizations*. University of California Press, California. 294 pp.

Moon, K. & Blackman, D., 2014. A Guide to Understanding Social Science Research for Natural Scientists. Conservation Biology Article first published online: 24 JUN 2014.

Prager, K., Schuler, J., Helming, K., Zander, P., Ratinger, T. & Hagedorn, K. 2011. Soil degradation, farming practices, institutions and policy responses: an analytical framework. *Land Degradation & Development*, **22**, 32–46.

Pretty, J., Pilgrim, S., Adams, B., Berkes, F., de Athayde, S.F., Dudley, N. & Vintinnerk, E. 2009. The intersections of biological diversity and cultural diversity: towards integration. *Conservation and Society*, **7**, 100–112.

Putnam, L.L. & Wondolleck, J.M., 2003. Intractability: definitions, dimensions, and distinctions. In: *Making Sense of Intractable Environmental Conflicts: Concepts and Cases* (eds R.L. Lewicki, B. Gray & M. Elliott), pp. 35–59. Island Press, Washington D.C.

Reed, M.S., Fazey, I., Stringer, L.C., Raymond, C.M., Akhtar-Schuster, M., Begni, G., Bigas, H., Brehm, S., Briggs, J., Bryce, R., Buckmaster, S., Chanda, R., Davies, J., Diez, E., Essahli, W., Evely, A., Geeson, N., Hartmann, I., Holden, J., Hubacek, K., Ioris, A.A.R., Kruger, B., Laureano, P., Phillipson, J., Prell, C., Quinn, C.H., Reeves, A.D., Seely, M., Thomas, R., dervan Werff Ten Bosch, M.J., Vergunst, P. & Wagner, L., 2013. Knowledge management for land degradation monitoring and assessment: an analysis of contemporary thinking. *Land Degradation & Development* **24**, 307–322.

Schoell, R. & Binder, C.R. 2009. System perspectives of experts and farmers regarding the role of livelihood assets in risk perception: results from the structured mental model approach. *Risk Analysis*, **29**, 205–222.

Sillitoe, P. 1998. Knowing the land: soil and land resource evaluation and indigenous knowledge. *Soil Use and Management*, **14**, 188–193.

Spencer, C. & Blades, M. 1986. Pattern and process: a review essay on the relationship between behavioural geography and environmental psychology. *Progress in Human Geography*, **10**, 229–248.

Stocking, M.A. & Murnaghan, N. 2001. *Handbook for the Field Assessment of Land Degradation*. Earthscan, London.

Strauss, A. & Corbin, J. 1998. *Basics of Qualitative Research Techniques and Procedures for Developing Grounded Theory*, 2nd edn. Sage Publications, London.

Tolman, E.C. 1948. Cognitive maps in rats and men. *Psychological Review*, **55**, 189–208.

Turner, B.L., Wuellner, M., Nichols, T. & Gates, R. 2014. Dueling land ethics: uncovering agricultural stakeholder mental models to better understand recent land use conversion. *Journal of Agricultural and Environmental Ethics*, **27**, 1–26.

Vanwalleghem, T., Amate, J.I., de Molina, M.G., Fernández, D.S. & Gómez, J.A. 2011. Quantifying the effect of historical soil management on soil erosion rates in Mediterranean olive orchards. *Agriculture, Ecosystems & Environment*, **142**, 341–351.

Wagner, K. 2007. Mental models of flash floods and landslides. *Risk Analysis*, **27**, 671–682.

Weber, E.P. & Khademian, A.M. 2008. Wicked problems, knowledge challenges, and collaborative capacity builders in network settings. *Public Administration Review*, **68**, 334–349.

Wood, M.D., Bostrom, A., Bridges, T. & Linkov, I. 2012. Cognitive mapping tools: review and risk management needs. *Risk Analysis*, **32**, 1333–1348.

Zaksek, M. & Arvai, J.L. 2004. Toward improved communication about wildland fire: mental models research to identify information needs for natural resource management. *Risk Analysis*, **24**, 1503–1514.