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Can fuzzy cognitive mapping help in agricultural policy designand communication?

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Abstract

Agricultural environmental regulation often fails to deliver the desired effects because of farmers adopt-ing the related measures incorrectly or not at all. This is due to several barriers to the uptake of theprescribed environmentally beneficial farm management practices, most of which have been well estab-lished by social science research. Yet it is unclear why these barriers remain so difficult to overcomedespite numerous and persistent attempts at the design, communication and enforcement of relatedagricultural policies. This paper examines the potential of fuzzy cognitive mapping (FCM) as a tool to dis-entangle the underlying reasons of this persistent problem. We present the FCM methodology as adaptedto the application in a Scottish case study on how environmental regulation affects farmers and farmingpractice and what factors are important for compliance or non-compliance with this regulation. The studycompares the views of two different stakeholder groups on this matter using FCM network visualizationsthat were validated by interviews and a workshop session. There was a farmers group representing atypical mix of Scottish farming systems and a non-farmers group, the latter comprising professionalsfrom the fields of design, implementation, administration, consulting on and enforcement of agriculturalpolicies. Between the two groups, the FCM process reveals a very different perception of importance andinteraction of factors and strongly suggests that the problem lies in an institutional failure rather than ina simple unwillingness of farmers to obey the rules. FCM allows for a structured process of identifying areas of conflicting perceptions, but also areas where strongly differing groups of stakeholders might beable to gain common ground. In this way, FCM can help to identify anchoring points for targeted policydevelopment and has the potential of becoming a useful tool in agricultural policy design and communi-cation. Our results show the utility of FCM by pointing out how Scottish environmental regulation couldbe altered to increase compliance with the rules and where the reasons for the identified institutional failure might be sought.

Keywords: Agricultural policy; Agro-environmental measures; Fuzzy cognitive mapping (FCM); General Binding Rules; Stakeholder communication; Scottish agriculture

1 Introduction

During an inspection of Scottish watercourses as a first step in a national strategy to mitigate diffuse pollution, a significant number of breaches of formal regulations to prevent diffuse pollution were identified (SEPA. 2014a). Specifically for the case of keeping livestock from creating bank erosion (General Binding Rule (GBR) 19 in Scottish regulation (SEARS, 2009b)), breaches were found to occur on average once per kilometre of the examined waterways. These findings constituted a challenge to the regulatory framework of Scottish environmental and agricultural policies, including the obligatory GBR related cross compliance to receive European Common Agricultural Policy related subsidies (Scotland.gov.uk, 2013; SEPA, 2011) and the achievement of the good ecological status prescribed by the Water Framework Directive (WFD) (SEPA, 2013). The number of breaches of GBR 19 indicated that there might have been other breaches to the remaining GBRs taking place, such as regulation on use of fertilizer (SEARS, 2009a) and land cultivation (SEARS, 2009c). The problem could be framed as an issue of failure with regards to communicating landscape stewardship issues among Scottish farmers who either are not aware of regulations or actually choose to ignore them. But it might

also be interpreted as a case of institutional failure on behalf of the government. Instead of trying to point out responsibility to each of the two actors, government or farmers, it might be more fruitful to frame the issue as a matter of (not) reaching an alignment on what constitutes proper agricultural and landscape management between the perspectives of farmers and other relevant stakeholders involved in policy design and communication. . Dissonance in terms of perspectives or perception among heterogeneous stakeholders has been identified in many other contexts apart from Scotland. Examples include water management issues in Australia (Marshall, 2013), issues of multifunctional agriculture in the EU and Australia (Burton and Wilson, 2006; Elands and Præstholm, 2008; Wilson, 2004) as well as numerous studies within the field of social learning in relation to natural resource management across different EU member countries, as well as North America (Blackmore et al., 2007; Evely et al., 2008; Holling, 2001).

The context for the present paper is a case study on perceptions of the environmental regulatory framework and farm and landscape ecology among farmers and relevant stakeholders in rural Scotland. In this research, we refer to the later as non-farmers, which include those involved in the design, implementation, administration, consultancy/communication/advice on or enforcement of the regulation. In sum, non-farmers are not involved in the farm practices themselves, but that can influence, on a way or another, the way that regulation is designed or communicated to farmers. Starting from the hypothesis that there is a lack of alignment between farmers and non-farmer's perceptions on environmental regulation and factors determining compliance, the present study addresses the following research questions:

(1) Can Fuzzy Cognitive Mapping (FCM) help to diagnose and disentangle the (lack of) alignment of perceptions between the different groups (i.e. and therefore help corroborating or rejecting the hypothesis)?

(2) Can the insights gained from the use of FCM be used to provide input to how improving policy design and communication?

It is our ambition that this inquiry can lead to a better understanding of what may promote compliance or non-compliance of GBR, and thereby to derive recommendations for how to successfully adapt the agro-environmental regulation both in Scotland, and in general in all contexts in which diffuse pollution from agriculture remains a critical challenge. For this purpose, groups of Scottish farmers and non-farmers participated in a series of workshops, where they were asked to produce fuzzy cognitive maps based on the question "*How do environmental regulation affect farmers and farming practices and what is important for compliance or non-compliance with GBR (General Binding Rules)?*"

Firstly, the paper presents a brief introduction to FCM and its implementation in land use policy and planning. Secondly, a further development and adaptation of the FCM methodology is described in the form of a step by step procedure of its application in this research. Consequently, results from the Scottish case study are synthesized graphically in the form of Fuzzy Cognitive Maps over the central concepts identified as important to affect farmers and farming practices. Finally, the mapped differences between farmers and non-farmer's perceptions, and the relations between the different central concepts are discussed, and used to suggest recommendations for future policy development.

1.1 A brief history of Fuzzy Cognitive Mapping (FCM)

Fuzzy Cognitive Mapping originates in the work of Robert Axelrod (Axelrod, 1976) within the field of political science and the work of Bart Kosko (Kosko, 1986, 1988) within the field of information science. Axelrod introduced cognitive mapping as a distinct form of representing social scientific knowledge on causal relations. In his seminal work, Bart Kosko focused on cognitive maps as an approach to deal with uncertainty of causal knowledge, hence the term *fuzzy* cognitive mapping. More recent applications of Kosko's ideas have expanded

the range of contexts within which FCM have been applied. One particularly relevant field of inquiry in relation to our case is sustainable development (Dodouras and James, 2007). Dodouras and James have suggested FCM as an appropriate approach to address issues of sustainable development, where the aim is to "*reduce multidisciplinary conflicts, explain complex phenomena and lead to more informed decisions*" (Dodouras and James, 2007: 827). Other important objectives include the involvement of "*all interested parties in defining their current and future needs and priorities, and in identifying their own proposed solutions*" (Dodouras and James, 2007: 827).

Other approaches within the field of landscape ecology have expressed similar considerations. Özesmi and Özesmi states, in relation to a case study in Turkey, that "*..for successful conservation and sustainable development to occur, many stakeholder groups need to be involved in the process. Within this process, a rigorous scientific approach that can quantify the subjective perceptions of the different stakeholder groups can be useful. Such a method can be helpful both to obtain the support of the participants and to compare the similarities and differences among groups of stakeholders. Such a method may also make it easier for the groups to make decisions together and accept the results. Fuzzy Cognitive Mapping (FCM) offers such an analysis*" (Özesmi and Özesmi, 2003: 518). These authors suggest four types of problems where FCM is particularly useful (Özesmi and Özesmi, 2004). These problems include (1) where human actions affect ecosystems, and (2) where detailed scientific data are lacking but local knowledge or indigenous knowledge does exist. The third type of problems are (3) where problems are "wicked", meaning that there are many diverging perspectives on what constitutes the problem and that there are no optimal solutions to be found (Bouma et al., 2011; Norton, 2012; Rittel and Webber, 1972; Whyte and Thompson, 2012). The fourth type of problem is (4) where public involvement or intervention is desired or even mandated by law.

Our case in Scotland exhibits three of these attributes. First, it is a case of human action affecting the environment. Second, it is a case where there is a lack of knowledge, or to put it more precisely, a lack of integrated knowledge on the interaction between agricultural management and landscape development (in this case the ecological state of waterways). Third, our case also exhibits some attributes of being a "wicked" problem, as there is obviously heterogenous perceptions of what constitutes proper land management between farmers and non-farmers (Martin-Ortega, 2012). The fourth type characteristic suggested by Özesmi and Özesmi, matches the WFD's public participation principle. Although the expression "public participation" does not appear in the Directive, three forms of public participation with an increasing level of involvement are mentioned: i) information supply; ii) consultation; and iii) active involvement. According to the Directive, the first two are to be ensured, the latter should be encouraged (Martin-Ortega et al., 2014). The specific type of involvement on behalf of the government is up to national discretion (EC, 2003). The present study may serve as inspiration for governmental authorities (for example The Scottish Environmental Protection Agency SEPA or The Scottish Natural Heritage SNH) and policy makers (for example the Scottish Government or the European Commission) on how to improve the effect of agro-environmental policy measures, and avoid the failures described above. In either case, FCM offers an approach which allows different actors to map their own perception of causal relations between entities which are part of their life world.

1.2 Applications and adaptions of FCM

Among the various applications of FCM which can be found, different modalities of using FCM can be identified. In a study by Fairweather (2010), the FCM was adapted to reflect different perceptions of socio-ecological systems across different locations. A distinct feature of the study was that FCM was applied in a semi-structured manner, meaning that at least half of the factors which the participants should consider for the mapping process, was chosen by the researcher in advance. Another study by Fairweather and Hunt (2011) exhibits a similar approach. In this particular study, the aim was to explore how perceptions differ across

different groups of farmers. Again, the approach chosen here was to impose some degree of structuring of which concepts the participants were able to include in the mapping process.

Both of the approaches above serve as examples of one distinct modality of using FCM, which can be described as using cognitive mapping as a semi-structured approach to modelling causal relations. This mode of using FCM is primarily concerned with expanding scientific knowledge about causal phenomena, and less concerned with the implications of FCM in a planning context. For that reason, we suggest to term this first mode of using FCM as "normal" cognitive mapping, as the process of mapping is to a large degree oriented towards obtaining 'proper' descriptions of the phenomena in question. However, a "post-normal" approach to FCM emerges from various other studies, which are more concerned with utilising the potential of FCM as an integrated element of planning. In the "post-normal" mode of FCM, focus is on integration between different types of knowledge. Examples include the use of open-ended or 'grounded' inquiry in the elaboration of the FCM process (Hanafizadeh and Aliehyaei, 2011; Kontogianni et al., 2012a; Kontogianni et al., 2012b; Meliadou et al., 2012; Murungweni et al., 2011; Vanwindekens et al., 2013). Our application of FCM has been carried out in a "post-normal" mode, as the inquiry process, specifically identifying the variables or factors to consider in the mapping process, has been carried out in a grounded, open-ended manner.

2. Materials and Methodology

2.1 The FCM case study in Scotland

In order to address the research questions, the FCM process was divided into working with two different stakeholder groups, farmers and non-farmers, as defined in the introduction. The FCM process with non-farmers was carried out as part of a workshop in October 2011 (Vinten et al., 2011). The overall aim of the workshop was "*to develop effective approaches to achieving compliance with diffuse pollution regulations, with a focus on the general binding rules*" (Vinten et al., 2011: 10). The specific General Binding Rules in focus were:

- GBR 18 concerning fertilizer storage and application, which sets out minimum distances of fertilizer storage and application from watercourses as well as restrictions placed on fertilizer application on sloping land. It is divided into the categories organic and inorganic fertilizers. GBR 18 also defines requirements to weather conditions, application timings and general land management; additionally the underlying rationale is explained and practical steps are described (SEARS, 2009b)
- GBR 19 concerning the keeping of livestock, which defines livestock management requirements and sets out minimum distances regarding surface water as well as springs and uncapped wells that supply water for human consumption. Rationale and practical steps are described (SEARS, 2009c)
- GBR 20 concerning land cultivation, which sets out minimum distances regarding surface water as well as springs and uncapped wells that supply water for human consumption and additionally prohibits land cultivation on waterlogged land. Rationale and practical steps are described (SEARS, 2009c).

The nine non-farmer participants in the workshop came from different organisations and locations. The affiliations of the participants are listed in Table 1:

Table 1: Overview of affiliations of the nine participants in non-farmer workshop

Organisation	**Participant's role in organisation**
Scottish National Heritage (SNH)[1]	Consultant
Low Holehouse Farm, Ayrshire	Estate manager[2]
University of Stirling	Scientist
Scottish Government (SG)	Administrator/civil servant
Aarhus University, Denmark	Scientist

SAC Consulting, Scottish Rural College	Consultant
Scottish Environmental Protection Agency (SEPA)	Administrator/civil servant
National Farmers Union of Scotland (NFUS)	Consultant
The James Hutton Institute, Aberdeen	Scientist

[1] SNH is a Goverment organization aimed at conservation and sustainable use of the natural environment (SNH, 2014)

2 Estate is a privately own land-holding and management unit characteristic of Scotland (McKee et al., 2013)

Initially, the nine participants in the workshop were interviewed individually. The purpose of the individual interviews was to introduce the specific topic which the FCM process would investigate, to introduce the FCM method and to discuss their thoughts on the topic. The interviewees were asked to create a fuzzy cognitive map around the question 'How do environmental regulations affect farmers and farming practice and what is important for compliance/non-compliance with General Binding Rules (GBRs)?' Before creating the map they were shown a brief presentation demonstrating the FCM process while making use of a topic unrelated to the topic of the interview. They were asked to write a short list of concepts (using their own words), which they had mentioned during the interview. They were also informed that they could expand the number of concepts as much as they deemed necessary to complete their map. When the list of concepts (factors) was finished, they started the map creation. During the process of map creation following the interview, the interviewer sat back stating he needed to do some work on his laptop while placing the laptop screen between himself and the interviewee. The interviewee was not spoken to with the exception of answering technical questions. During the introduction, participants had been asked not to communicate with the other participants during map creation and only to pose technical questions. After completion, the map was validated by checking it for missing or unclear directional arrows, missing values and for readability. Immediate clarification was sought in in cases where the directional links were drawn in an unexpected way or at first glance did not make sense, avoiding any suggestion that the link had been wrongly placed or was nonsensical.

Also during October 2011, and based on the same question as presented to the non-farmers, FCMs were collected from a total of 8 farmers, selected to represent the major types of farming in Scotland (mixed livestock farming, arable farming and specialized livestock farming; both on uplands and lowlands). The FCM process was conducted as part of on-farm interviews and followed the same method as described for non-farmers.

2.2 FCM data handling

As an example of an unprocessed FCM, **Fig. 1** shows a map as drawn by one of the interviewed farmers.

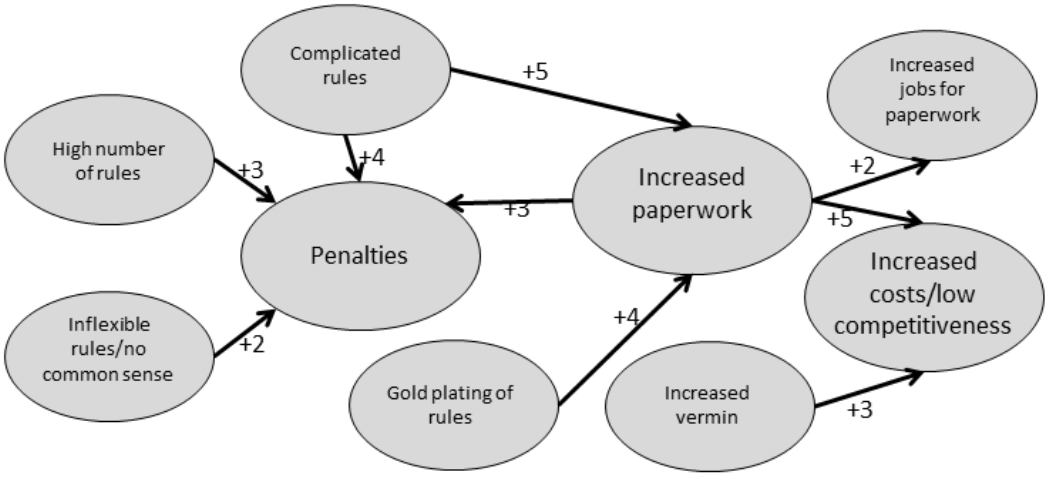

Fig. 1. Digitized version of an FCM drawn by a farmer. The arrows represent diminishing or increasing effects between concepts with a subjective rating by the farmer between -10 and +10 where 1 means very weak effect and 10 means very strong effect.

The different concepts that emerged in the FCMs were collected and processed separately for non-farmers and farmers and grouped into the emerging categories 'policy and regulation', 'farm economy and management', 'awareness and knowledge', 'attitude and behaviour', 'practical farming', 'natural resources' and 'natural risks and problems'. Categories were colour coded and the concepts assigned to the different categories were colour coded accordingly. Related concepts were then condensed into a single combined concept, using qualitative aggregation (Özesmi and Özesmi, 2003); for example the three concepts shown in figure 1 'complicated rules', 'high number of rules' and 'inflexible rules/no common sense' were combined to the single concept 'unwieldiness', retaining all linkages (**Table 2**).

Table 2
The concepts of Figure 1 condensed into fewer combined concepts encompassing the same basic meaning and sorted into their respective colour coded categories: 'policy and regulation' (light grey); 'economy and management' (medium grey) and 'natural risks and problems' (dark grey). Concept ID: concept number in the original FCM and concept number after condensation. Matrix ID: shows in which other FCMs a concept condensed into the combined concept also appeared. For example, concepts condensed into the combined concept 'bureaucracy' appeared in this FCM and in 6 others.

Concept ID	Concept	Matrix ID	Single Combined Concept	Category
1 (1)	Inflexible rules	6 (7)	**Unwieldiness**	Policy & regulation
2 (1)	High number of rules	6	**Unwieldiness**	Policy & regulation
3 (1)	Complicated rules	6	**Unwieldiness**	Policy & regulation
4 (1)	Gold plating of rules	6	**Unwieldiness**	Policy & regulation
5 (2)	Penalties	6 (5)	**Penalties**	Policy & regulation
6 (3)	Increased paperwork	6 (1,2,4,5,7,8)	**Bureaucracy**	Policy & regulation
7 (4)	Increased costs	6 (1,2,5,6,7,8)	**Cost**	Economy & management
8 (5)	Increased vermin	6	**Vermin**	Natural risks and problems
9 (6)	Increased paperwork jobs	6	**Employment**	Economy & management

The combined colour coded concepts were used to create an adjacency matrix (Özesmi and Özesmi, 2003) in MS Excel, in which the relationship values from the FCM links were inserted and added together whenever a concept appeared on more than one map (Table 3). If after adding all link values to the matrix nodes a matrix node exceeded the -10 +10 range, a matrix calculation operation was performed to normalize all values by the

highest value in the matrix. Values were then changed from between -10 and 10 to between -1 and 1 due to quantitative analysis software requirements

Table 3
Adjacency matrix based on condensedFCM from Fig. **1**. -1 represents strong diminishing effect, 1 represents strong increasing effect.

Concept	Unwieldiness	Penalties	Bureaucracy	Cost	Vermin	Employment
Unwieldiness		0.9	0.9			
Penalties						
Bureaucracy		0.3		0.5		0.2
Cost						
Vermin				0.3		
Employment						

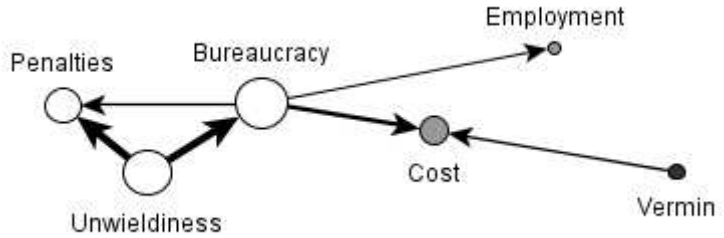

Fig. 2. Adjacency matrix from table 2 visualised as network. Size of arrow represents strength of effect; size of concept node represents centrality (the sum of incoming and outgoing link strength) of concept; colour represents category the concepts are grouped into.

The finished matrix was used in the MS Excel VBA based FCMapper (Bachhofer and Wildenberg, 2011) following the in-built guide to create a Pajek graph .net-file usable in the cognitive mapping analysis software Pajek (Batagel and Mrvar, 2013) or Visone (Visone, 2011). FCMapper was also used in the quantitative analysis as described in section 2.4. Visone was used for verifying the FCMapper calculations and for further processing following Visone's online manual (Visone, 2011): visualization of a combined, colour coded FCM for respectively non-farmers and farmers, using the metric Multidimensional Scaling (MDS) followed by stress minimization mode (both variations of the statistical method of multidimensional scaling as described in (Steyvers, 2006) as well as labelling and link routing in Visone's visualization panel.

Additionally, a visualization of the interconnections on a higher level between the categories ('policy and regulation', 'farm economy and management', 'awareness and knowledge', 'attitude and behaviour', 'practical farming', 'natural resources' and 'natural risks and problems') was created by making Visone draw an FCM of all concepts aggregated into their respective categories while retaining the visualization of all links.

2.4 FCM analysis

FCMs were analysed both qualitatively and quantitatively.

2.4.1 Quantitative analysis

The quantitative analysis was performed on the combined FCM matrix values for farmers, non-farmers and the combined matrix values of the whole study, analysing them separately for number of single (combined) concepts, number of links and number of self-loops, i.e. concepts that link to themselves on the adjacency

matrix. Other parameters looked at included concept indegree, outdegree and centrality. Indegree is the total amount of effects received by a concept irrespective of effect being diminishing or increasing. Outdegree shows the combined strength of effects a concept has on any number of other concepts. Centrality is the combined value of indegree and outdegree.

Number and percentage of transmitter, receiver and ordinary concepts were also identified (transmitter concepts have no indegree, receiver concepts have no outdegree and ordinary concepts have both an indegree and an outdegree). Density and complexity where also looked at. Density and complexity are graph theoretical indices describing connectivity between concepts (density) and ratio of receiver to transmitter concepts (complexity) of an FCM.

2.4.2 Qualitative analysis

The qualitative analysis looked for the underlying reasons of the results from the quantitative analysis, taking into account the differing viewpoints of the two groups by using the group workshop discussion and the farm interviews for verification. The qualitative analysis used the visualization of the combined matrix values as starting point. Choosing points of attention is a way of framing the inquiry which influences the outcome of the FCM process. Given that, choice of attention should be reflected carefully and in a transparent manner. In our case, the choice was informed by (1) policy relevance (focusing on issues addressed by Scottish agricultural policy) and (2) novelty (reflecting the need to pursue other options that the ones prescribed by current regulation).

3 Results

3.1 Quantitative analysis – farmers and non-farmers

There were 8 FCMs created by farmers, with a total of 89 concepts, equalling a mean of 11.1 concepts per map. The 89 concepts could be assigned to 7 categories and condensed into 43 single (combined) concepts.
In the non-farmers' group, 9 FCMs were created with a total of 95 concepts, equalling a mean of 10.6 concepts per map. The 95 concepts could be assigned to 7 categories and condensed into 41 single (combined) concepts.

Table 4 provides an overview of the FCM parameters analysed. The higher the density, the more links between concepts in a given map. A high complexity is typical for FCMs with many receiver variables as this indicates that the map creators have put much thought into the further implications of how their concepts interact (Özesmi and Özesmi, 2003).

Table 4. Overview of the two combined maps' FCM parameters.

FCM Parameter	Farmers	Non-farmers
Number of concepts:	43	41
Number of links:	105	136
Number of self-loops:	3	2
Transmitter concepts:	13 (30.2%)	7 (17.1%)
Receiver concepts:	8 (18.6%)	7 (17.1%)
Ordinary concepts:	22 (51.2%)	27 (65.9%)
FCM density index:	0,057	0.081
FCM complexity index:	0.615	1.000

The implications of the concept types' distribution (transmitter, receiver and ordinary) can be inferred as follows (Özesmi and Özesmi, 2003):

- Transmitter: A high number of transmitter concepts relative to the non-farmers indicates that the farmers tend to see the system as to a much higher degree under control from outside forces on which they have no influence than the non-farmers. Specific examples from the combined map of the farmers (see figure 3) include biological factors such as bad weather and vermin as well as social factors such as unwieldiness and (lacking) supportive approach, both of which are perceived to be beyond their influence.
- Receiver: Receiver concepts usually depict the further implications of the main network of concepts and give an indication of how well the map creators are capable of seeing the bigger picture their map (which represents the visual answer to a well-defined question) is embedded in. In this case, the two groups show no distinct difference in this concept type. The share of receiver concepts between different groups can reflect differences with regards to which level of complexity the involved stakeholders perceives.
- Ordinary: The higher the number of ordinary variables, the more the map creators thought of their map as an interconnected network where most concepts have an influence on many other concepts in the system. This makes the whole system susceptible to changes in the outdegree of a single concept as the changed outdegree has a higher influence through interconnectedness. The farmers' FCM was distinctly less interconnected than the non-farmers' FCM; this meaning that farmers perceive the situation as more fragmented or complex.

The most frequently mentioned concepts in the farmers' group (found on at least half of the individual maps and listed in their order of centrality) were bureaucracy, cost, business viability, biodiversity, time requirement, unwieldiness, financial support and regulation. The concept with the highest indegree was cost, the concept with the highest outdegree was unwieldiness and the most central concept was bureaucracy. The qualitative analysis presented next helps to unfold these concepts (as perceived by participants) and their interconnections.

3.2 Qualitative analysis – farmers

The farmers' combined FCM network is clustered around the four most central concepts of bureaucracy, cost, business viability and biodiversity (Fig 3). While the bureaucracy, cost and business viability were well defined in their common meaning to farmers, impact on each other and general importance, the concept of biodiversity had much more ambivalent meaning among the farmers; and its place in the network was not nearly as well defined despite its high centrality and, therefore, importance. This is reflected in some self-contradictions that occurred during farm interviews: for example, one of the interviewees stated that *"Biodiversity is really important… nature is, it's important to us farmers and our business. It's just something you do"*. When later creating the map, the only role the concept of biodiversity was assigned by the interviewee was as a transmitter concept increasing bureaucracy. These self-contradictions were absent from the other three main concepts.

The FCM in figure 3 contains three areas of special interest that allow insight into farmers' perceived role of knowledge dissemination by the authorities and their view of compliance issues (a;b;c). These areas were selected for their portrayal of negative feedback loops (vicious cycles) that were inferred from the one-on-one farm interviews and are visualised on the FCM.
The next set of areas identifies concepts and their sphere of influence where policy interventions or adaptations might be the most promising (anchoring concepts - d;e;f) that were inferred from the combined FCM. These anchoring concepts are transmitter concepts (no indegree) that are characterised by having a medium to strong influence (outdegree) on an important ordinary concept (a concept with both indegree and outdegree and a high centrality). Another important requirement for an anchoring concept is that farmers view its influence on the central ordinary concept as positive. Again, the one-on-one farm interviews are of

great importance to the map interpretation as the full meaning or perspective behind a concept may not be obvious just by looking at the map. The areas a;b;c and concepts d;e;f are explained in more detail next.

3.2.1 Identifying farmers' views on knowledge dissemination and compliance issues

Area a) centres on the concept of education (education in this context meaning exclusively environmental and best practice education offered by agricultural consultants and the government environmental agency). Education is portrayed as being pushed by general outside interference in day to day farm management, concrete regulatory demands like compulsory waste management plans and to a lesser degree by the promotion of precision farming; the latter portrayed as neutral influence in the farm interviews as opposed to the starkly negative perception of the other two concepts. The effect of education is perceived as increasing biodiversity which in turn increases bureaucracy; education also has a strong bias towards diminishing or reversing agricultural intensification in the mind of farmers. Pursuing intensification, a concept with increasing effect on business viability, will also increase outside interference in the form of pushing environmental education, closing a circle of effects that portrays farmers' opinion of environmental education as distinctly negative.

Area b) centres on the concept of awareness (in this context awareness of rules and regulations, possibilities for financial support and of environmental problems that can be addressed on a farm level). As long as the awareness is provided from outside sources with little demand on farmers' time, awareness of rules and regulations is seen as very positive due to its strong decreasing effect on costs and time requirement. At the same time it is portrayed as increasing the provision of ecosystem services from farmland (another concept with very inhomogeneous definitions and ambivalent meaning in the interviews) by following up on the rules and regulations or pro-actively changing land management to *"get SEPA[1] off my back";* which increases the bureaucracy-increasing biodiversity and strongly decreases business viability, both effects that very strongly increase time requirement and costs, closing another circle of effects. The perception of the concept of awareness therefore can be described as neither positive nor negative, making it unsuitable for a role as anchoring concept despite being a transmitter concept with a high outdegree.

Area c) centres on compliance (compliance with GBRs; not given a lot of attention on the FCM by the interviewees despite being asked about it directly during interviews and being part of the question central to the FCM process). The concept of compliance is of special interest due to its appearance of incomplete connectedness to the rest of the map when compared to the connections mentioned in the interviews. Linkages not drawn on any map although mentioned in 5 of the 8 interviews regard the concept of unwieldiness: a diminishing influence from timings for seasonal farm activities, again mainly dependent on weather; an increasing effect on costs incurred directly and a link from awareness as well as education that increase compliance. Instead the only increasing effects the farmers included on their maps are a weak link to bureaucracy and slightly stronger link from pressure (mainly from the environmental agency) as well as a strong decreasing link from bad weather. Compliance itself is depicted as increasing bureaucracy and decreasing farming's ability to ensure food security in general, something three of the interviewed farmers felt very strongly about *("this is why we are farmers… it's at the heart of our business"*). Overall, the farmers had a lot to say about compliance issues but seemingly had difficulties placing and linking the concept of compliance on the FCM.

3.2.2 Identifying anchoring concepts for policy interventions or adaptations

[1] Scottish Environmental Protection Agency, the government environmental regulator.

Area d) centres on precision farming, a transmitter concept that very strongly increases business viability. It has no negative connotations for the farmers mentioning it as the weak increasing effect on cost is seen as a very sensible investment if one can afford it. In the case of precision farming, the previously negatively portrayed concepts of biodiversity and environmental education are seen slightly positive: education tailored around precision farming helps to get the most out of the new technology while precision farming itself is also fulfilling obligations from the environmental agency that increase biodiversity as a side effect, with no extra time requirement for the farmer. In the context of precision farming, increased positive public perception due to biodiversity conservation (and due to the use of high-tech, modern farming technology) was mentioned as valuable in itself and for marketing purposes in three interviews. The same three farmers also stated anecdotally that they knew of other farmers who would engage in precision farming if they could get help with both the initial investment in new equipment required and a practical way to receive the necessary training.

Area e) centres on supportive approach, a transmitter concept that appears insignificant on the map but nevertheless was mentioned by all farmers in the interviews. Supportive in this case has no connotation with financial support but with helpfulness by regulators and their representatives. Four of the farmers expressed the wish not to be treated as "*environmental villains"* and asked for willingness to engage in environmental problem solving from an on-farm perspective that takes into account distinctly local features and issues. The main effect of increased supportiveness would be a strong diminishing effect on time requirement.

Area f) centres on unwieldiness, a transmitter concept that very strongly increases cost and bureaucracy and strongly increases time requirement and penalties. All farmers brought this up in the interviews in various forms as a very important cause of frustration surrounding environmental regulation. Unwieldiness was described in various forms, from e.g. "*gold plating of UK rules*" to "*inflexible dates with no regard for weather conditions*". From the farmers' perspective, reducing unwieldiness was seen as having the potential to go a long way towards increasing compliance. Especially the inflexibility of defined dates regarding farm operations is a major grievance. Decreasing unwieldiness would in the eyes of the farmers go the longest way to lessen negative perception of environmental regulations.

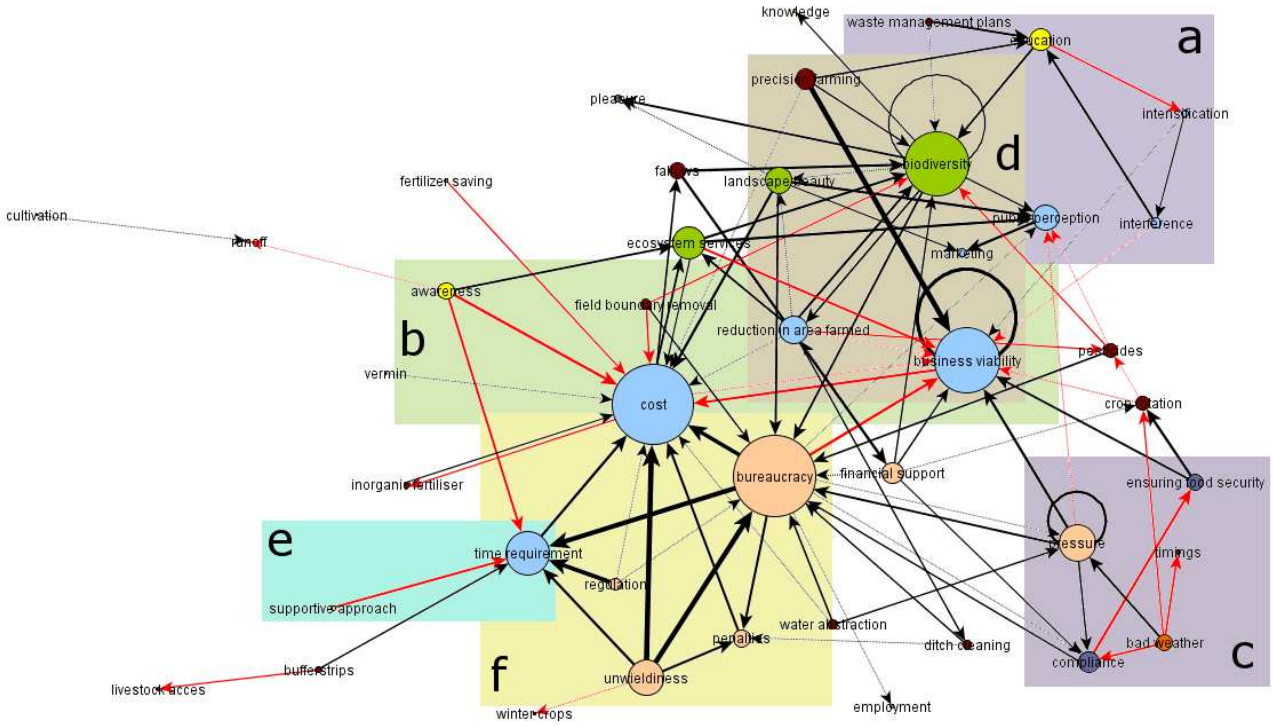

Fig. 3. Farmers' combined FCM adjacency matrix visualised as network. Area a; b; c: areas providing insight into farmers' perceived role of knowledge dissemination by the authorities and their view of compliance issues. Area d; e; f: concepts and their sphere of influence where policy interventions or adaptations might be the most promising. Colour coding as in Fig 7. Link colour: red = diminishing effect, black = increasing effect. Link width and layout: scaled to link strength (0.1 – 1.0), strength 0.1 – 0.3 depicted as dotted line

The network can also be visualised as a category network (Fig 4) showing the overarching causalities. The category network is created by grouping all concepts in their respective categories while retaining the links. The farmers' category network shows economy and management to be the main theme of the FCMs. Economy and management receives very strong one-sided links from policy and regulation and has strong two-way links to practical farming and natural resources.

Policy and regulation appears to only have little influence on practical farming and none on natural resources or awareness and knowledge. It has some influence on attitude and behaviour.

Awareness and knowledge's main effects in this visualisation appear to be strong diminishing effects on economy and management concepts and increasing effects on natural resources concepts. It has no links to policy and regulation and attitude and behaviour.

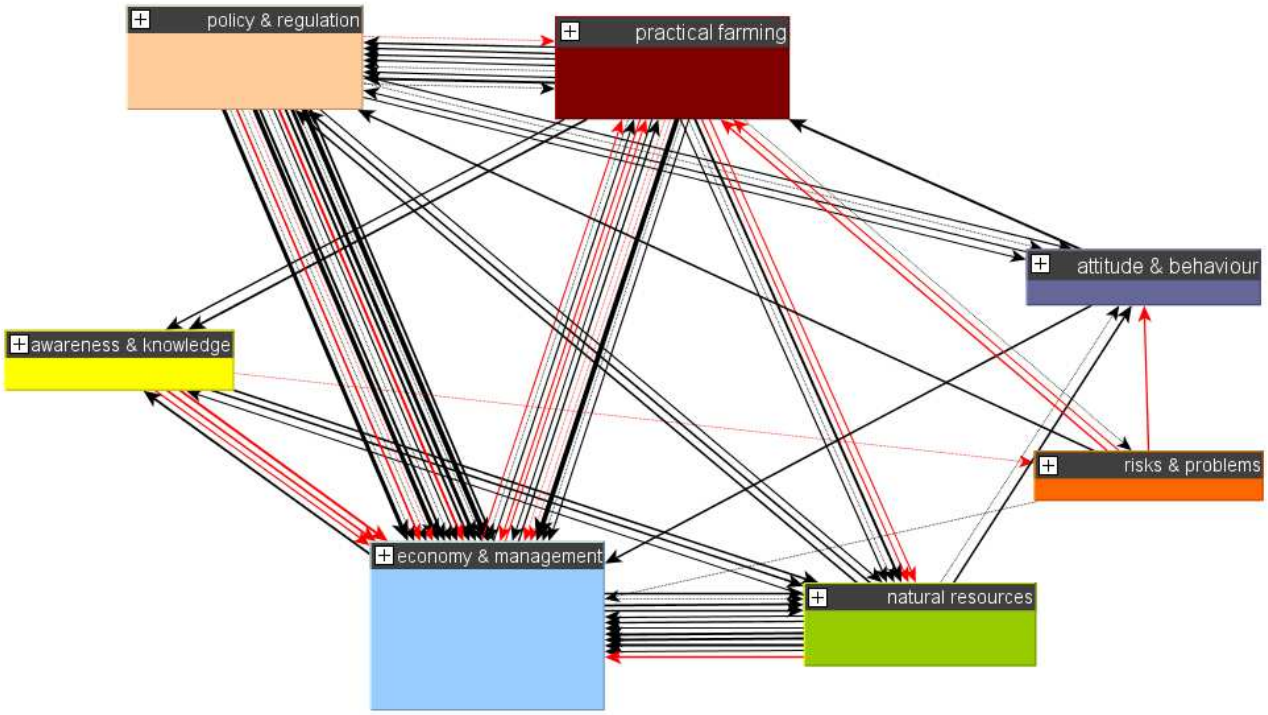

Fig. 4. Farmers' combined FCM network presented as category network. Farmers' combined FCM network presented as category network. Category size: weighted after combined centrality. Link colour: red = diminishing effect, black = increasing effect. Link width and layout: scaled to link strength (0.1 – 1.0), strength 0.1 – 0.3 depicted as dotted line.

3.3 Qualitative analysis – non-farmers

The non-farmers' combined FCM (Fig 5) was analysed for its divergence from the farmers' FCM (Fig 3) and to single out concepts with distinctly different weighting or concepts found in the farmers' FCM that were absent. The analysis shows a very different perspective on the identical question the farmers were asked. The purple and blue areas (a; b) show map regions of special importance to the network that differ substantially from the farmers' network while the yellow rectangles (1; 2; 3) highlight concepts weighted in a considerably different way in comparison.

3.3.1 Differing perspectives on the same question

Area a) in figure 5 centres on compliance, by far the most central concept on the map. Its centrality score of 10.97 is more than five times higher than the 1.80 on the farmers' map. The concept dominates the FCM and is linked to most other concepts within area a); additionally, all concepts in the category 'policy and regulation' link to compliance where their impact is not depicted in such a centralised manner on the farmers' map. The concept of supportive approach also illustrates the differing perspectives as it has only one link on the farmers' map: strongly diminishing time requirement. On the non-farmers map it is linked to compliance, farmer attitude, education and knowledge; concepts that have a negative connotation or are missing on the farmers' map. The remaining concepts from the category 'attitude and behaviour' also play prominent roles on the non-farmers' map whereas they are largely missing from the farmers' map.

Area b) centres on the three concepts of awareness, education and knowledge that are given substantial weight and also have a very positive connotation as they are perceived to have a strong increasing influence on the most important concept of compliance. This is in marked contrast to the farmers' map where the concepts are depicted as ambiguous (awareness), mainly negative (education) or insignificant (knowledge) and also not linked to compliance in any way.

3.3.2 *Concepts with distinctly differing weightings*

Concept 1, biodiversity; it has (for a concept mentioned frequently by non-farmers during the workshop) low connectedness, low centrality (1.74) and a low outdegree (0.97). Additionally it lacks connections to concepts from the categories policy and regulation, awareness and knowledge and risks and problems; this was unexpected due to biodiversity conservation supposedly being a key aim of environmental regulation and therefore important to non-farmers. On the farmers' map, it is the fourth most central concept (centrality 5.55) with a high connectedness to concepts of most other categories except risks and problems; additionally its outdgree of 2.20 is also much higher.

Concept 2, bureaucracy; the most central concept on the farmers' map (centrality 7.15) does not play an important role on the non-farmers' map (centrality 1.35). Here its main connections are to concepts of the category attitude and behaviour whereas on the farmers' map it is very strongly connected to the categories farm economy and management, policy and regulation and practical farming. The respective outdegrees are 3.05 and 1.19, reflecting the much higher impact farmers assign to the concept.

Concept 3, reduction in area farmed; the concept has the same indegree on both maps (0.55) but differs substantially in its connectedness (3 links on the non-farmers' map and 9 links on the farmers' map) and in its respective outdegree of 0.26 and 1.90. It was hardly mentioned in the non-farmer workshop but came across as very important during the farm interviews, with many farmers expressing hurt feelings in regard to being prevented from using their land in the way they saw fit.

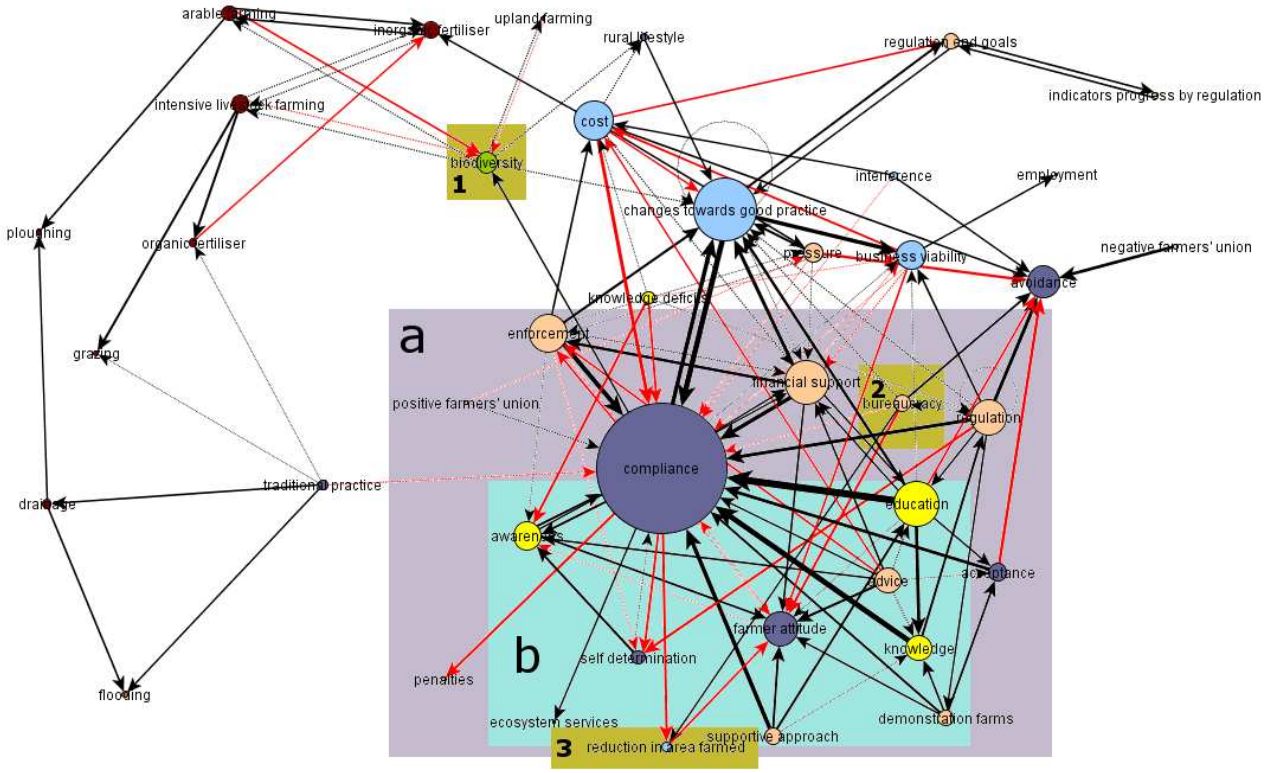

Fig. 5. Non-farmers' combined FCM adjacency matrix visualised as network. Area a; b: the different map regions of the non-farmer's network that differ substantially from the farmers' network. Yellow rectangles (1; 2; 3): concepts weighted differently in the same comparison. Colour coding as in Fig 7. Link colour: red = diminishing effect, black = increasing effect. Link width and layout: scaled to link strength (0.1 – 1.0), strength 0.1 – 0.3 depicted as dotted line.

The non-farmers' category network shows attitude and behaviour being the most important category together with policy and regulation, the two having very strong connections to each other although these are mainly one-sided towards attitude and behaviour. This is in marked contrast to the farmers' map that depicts a weak two-way link between the two. The category also has strong two-way links to economy and management (only a single link on the farmers' map) and awareness and knowledge (none on the farmers' map) while the links to the remaining concepts are very few.

Policy and regulation additionally has strong two-way links to awareness and knowledge and economy and management but none at all to practical farming, natural resources and risks and problems. The farmers' map on the other hand depicts the category as having no links at all to awareness and knowledge, only few links to economy and management, a few links to practical farming, natural resources and risks and problems but none to attitude and behaviour.

Economy and management has strong two-way links to policy and regulation and attitude and behaviour but despite having a few links to the concepts of awareness and knowledge and natural resources has no influence on them. The farmers' network in comparison also shows strong two-way links to policy and regulation but additionally strong two-way links to practical farming, natural resources and awareness and knowledge; it also has link to risks and problems. In contrast, there is only one link to attitude and behaviour and it exerts no influence on the other concept.

All in all the farmers' category network appears much more balanced and interconnected than the non-farmers' category network.

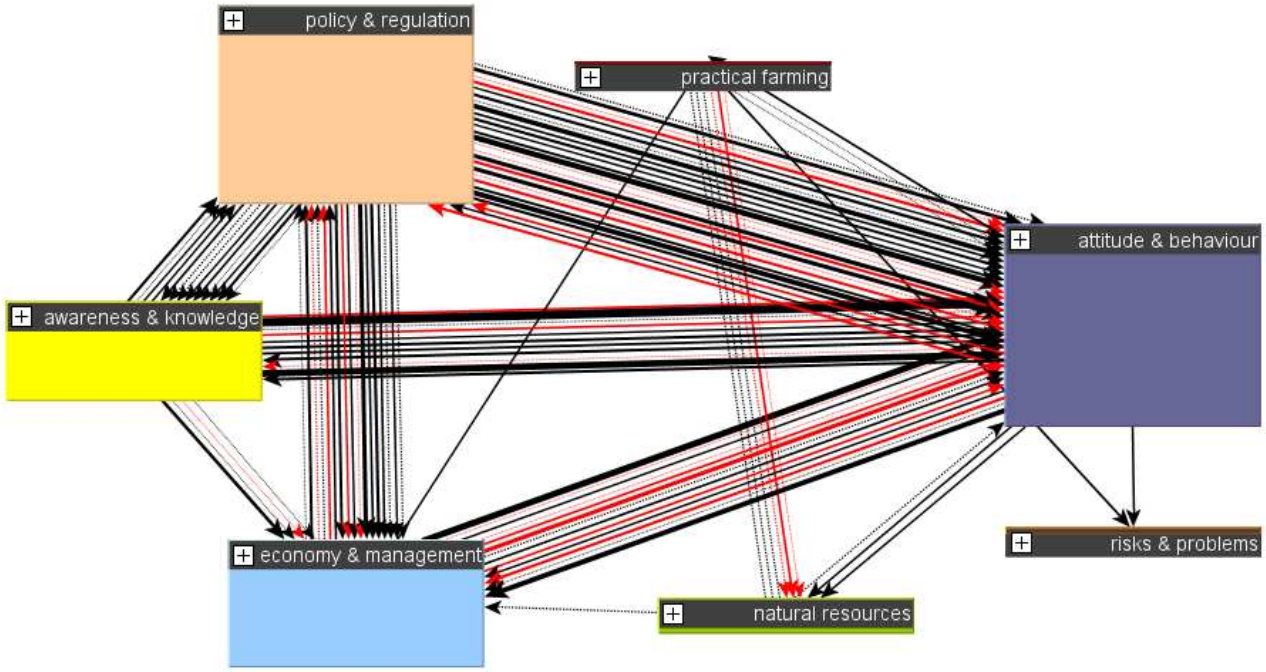

Fig. 6. Non-farmers' combined FCM network presented as category network. Category size: weighted after combined centrality. Link colour: red = diminishing effect, black = increasing effect. Link width and layout: scaled to link strength (0.1 – 1.0), strength 0.1 – 0.3 depicted as dotted line.

4 Discussion

Diffuse pollution from agriculture remains a significant challenge to many countries. In the Scottish context, the initial hypothesis for our study was that the issue in question can be framed as a case of not reaching an

alignment of perspectives of farmers and non-farmers stakeholders involved in the design and communication of diffuse pollution regulation. The initial hypothesis was confirmed by the results, as the perceptions between farmers and non-farmers exhibit considerable differences (table 5).

Table 5
Most central perceptions for farmers and non-farmers regarding factors of importance for the initial question about how environmental regulation affects farming practices and the compliance or non-compliance with General Binding Rules

Non-farmers	Farmers
Compliance	Bureaucracy
Changes towards good practice	Cost
Education	Business viability
Financial support	Biodiversity
Cost	Time requirement

The farmers perceive bureaucracy and costs as being a major concern, coupled with concerns about maintaining business viability. This is consistent with findings by Martin-Ortega and Holstead (2013) based on the review of recent research on barriers for implementation of measures to improve water quality in Scotland. The FCM approach reveals that biodiversity [which has a less clearly defined meaning] was perceived as being a mostly negative factor, as it was perceived to lead to an increase in bureaucracy and thus also an increase in time requirement. The non-farmers perceive compliance, or rather the lack of compliance, as the most central concept. They also emphasize education as an important factor, in the sense that improving farmer education would lead to improvements regarding achieving a higher degree of compliance. The overall picture is that perceptions are heterogeneous across the two groups, which supports the assumption that the issue is a 'wicked' problem (Gray and Gill, 2009; Norton, 2012; Whyte and Thompson, 2012). The review carried out by Martin-Ortega and Holsted in the Scottish context supports this point by highlighting that different world-views from different stakeholders represent barriers to implementation of environmental conservation measures (Martin-Ortega and Holstead, 2013).

The FCM approach helps to disentangle this finding by pinning it down to the actual different perceptions. Perceptions of causality did also exhibit considerable differences across the two groups. As illustrated in figure 4, farmer perceptions can be mapped as a network of relations being particularly dense regarding interactions between policy and regulation, farm economy and management, and practical farming. They attributed less frequency of interaction to attitudes and behavior, as well as awareness and knowledge. As illustrated in figure 6, non-farmers perceptions can be mapped as a network of relations with a radically different density pattern. Here, the emphasis is on interactions between policy and regulation, attitude and behaviour, and farm economy and management. Practical farming is not being perceived as having much importance. It could be argued that the question which was posed to the participants in the FCM process might have induced greater variation between the maps of farmers and non-farmers, as it is a rather lengthy question which can be seen as two separate questions (one about how farmers are affected by regulation, and one about what is importance for compliance). Still, the individuals' conceptions and perceptions underlying the maps were teased out in the qualitative analysis of the interviews, and diversity of perceptions add to the impression that the issue is indeed a 'wicked' problem.

A significant part of the 'wickedness' of this problem is that the results do not indicate any self-reflectivity on behalf of non-farmers regarding the role of bureaucracy in relation to adoption of regulation. Several other studies have emphasized that bureaucracy, costs, complexity with regards to accessing funds and concerns regarding maintaining business viability are critical barriers for uptake of measures from the side of farmers (Martin-Ortega and Holstead, 2013). Given that, it is surprising that there is so little awareness on these issues

among non-farmers. Part of the explanation might be that knowledge on the social factors affecting adoption is limited among non-farmers. This is even more surprising, given that insight into the social factors affecting adoption is a core theme in established research areas like social learning (Ison et al., 2013; Rodela, 2011) or adaptive co-management (Armitage, 2009; Holling, 2001; Plummer, 2009), to mention a few. It is also worthnoticing that even though it is well established that information does not necessarily lead to action, non-farmers perceive that 'education' of the farmers will lead to a higher degree compliance. The results of the present study point at an urgent need for improving communication between non-farmers and social scientists to make scientific findings on behavioural and social factors policy-relevant.

So far, it is difficult to identify possibilities for reaching an alignment of perspectives between farmers and non-farmers. Is institutional failure unavoidable, given the diversity of perceptions? Some contributions on natural resource management, such as Luhmann's work on ecological communication (Luhmann, 1989), have emphasized the inevitability of institutional failure. In Luhmann's perspective, differentiated social systems will seek to establish organizational closure (self-reference) in relation to their surroundings, which will make it difficult to establish common ground on as environmental issues. However, this rather bleak account have been contradicted by recent work on social learning in relation to natural resource management as well as adaptive co-management approaches (Armitage et al., 2007; Armitage et al., 2007 ; Armitage, 2009; Folke, 2006; Holling, 2001; Westley, 2002; Westley et al., 2002). A common thread across social learning and adaptive co-management approaches is that alignment between perspectives is possible, given adequate social, institutional, ecological and cognitive resources are available. As we will discuss in the remaining part, FCM is capable of identifying common factors of importance between different groups of stakeholders. Specifically, FCM provides a detailed picture of perceived factors of importance as well as perceptions of how these factors interact. As the results so far show, it is not possible to identify any common factors of importance between the two groups, which could suggest that there is no possibility of alignment of perspectives. Instead, a closer look at the perceptions of interactions between factors reveals some promising aspects. FCM yields a detailed picture of perceptions of how factors interact. Some of the factors are perceived to interact in negative or vicious cycles, with biodiversity as one prominent example, whereas others are perceived to interact in virtuous cycles. With regards to establishing anchoring points, it is important to look for how vicious cycles can be reduced, or how virtuous cycles can be enhanced.

In this regard, FCM enables a structured inquiry into how anchoring points can be established. In our case, the anchoring points could be farmer perceptions of concepts which are perceived as not being part of a vicious cycle, as in the case of biodiversity. They should also be transmitter concepts (no indegree) as this infers that farmers don't view the concepts as being influenced by their own actions, therefore requiring no additional effort from their side. Designing or altering environmental regulation policies in a way that increase the importance of these concepts and their positive influence on central concepts has the potential to increase GBR compliance: from the farmers' point of view, there would not only be no negative effects associated with compliance but, on the contrary, compliance would be beneficial to the farmer and his business.

The first anchoring point to consider is thus precision farming (see figure 4). Precision farming is not a central concept for the farmers, but the point is that precision farming is perceived to have a positive influence on business viability. Precision farming is also perceived as requiring education, but given the positive impact on business viability, the interaction between precision farming, education and farm business viability can be described as a virtuous cycle rather than a vicious cycle.

Another possible anchoring point is farmer perception of the benefits of a supportive approach on behalf of government. Again, the concept is not by any means central, but according to the map (figure 4) it could be an important element in a positive development. A supportive approach by the government would reduce time requirements, which again will reduce costs. If a supportive approach also would include reducing

568 bureaucracy, there would, according to farmer perception, be an overall positive effect on business viability as
569 well as costs. It is important to point out that for farmers, a supportive approach does not equal financial
570 assistance but consists of localized support in implementation of measures, advice on how to receive grants
571 and targeted consulting and also to be treated in a friendly and supportive way. A third anchoring point could
572 be unwieldiness, especially prescribed timings of farming activities and overly complicated rules and
573 procedures. If unwieldiness could be reduced, it would lead to reductions in the level of bureaucracy, time
574 requirements and costs.

575 In order for these anchoring points to function as such, they need to be aligned with perceptions on behalf of
576 non-farmers. When considering the network mapped in figure 6, it is rather obvious that non-farmer
577 perception of the importance of education could establish an alignment between perspectives on either side.
578 Farmers might conceive education in a different manner, e.g. in relation to acquiring specific skills in relation
579 to precision farming. In order for education to serve as anchoring point on behalf of the government, it will
580 require an alignment of the objectives for learning, which accommodates the two perspectives.

581 Another possible anchoring point among the perceptions of non-farmers is, like for farmers, the notion of a
582 supportive approach; though as in the case of education, supportive approach holds a different meaning for
583 non-farmers than for farmers: the qualitative interviews indicate that non-farmers typically perceive supportive
584 approaches having to do with financial support and not necessarily as having to do with changing practices
585 within the regulatory process itself. In addition, non-farmers might not perceive supportive approaches as
586 having to do with addressing the issue of unwieldiness, which is not perceived as an issue at all among non-
587 farmers. It is also worth noticing, that bureaucracy is also not perceived as being an issue among non-farmers.
588 Some of the interviewees might work with GBR compliance issues on a regular basis within an administrative
589 setting, which might explain why it is not a subject of reflection among them. This might be the most coherent
590 attribute of the group of non-farmers. We made the conclusion earlier that the farmers' category network
591 appeared more balanced and interconnected than in the case of non-farmers. The larger degree of coherence
592 among farmers might reflect that they, even though they manage different farming systems, have more in
593 common with regard to perception than non-farmers among themselves. The internal differences within the
594 group of non-farmers are not surprising, since they are a much more heterogeneous group in terms of their
595 affiliations. These institutions differ in terms of the type of tasks they carry out and in terms of worldview. In
596 all, they can be expected to exhibit considerable diversity with regards to how they are embedded within their
597 surroundings, both in terms of social, cultural, economical and territorial dimensions (Hess, 2004). This is
598 simply a reflect of the complex reality of the range of actors influencing design and communication and
599 regulation and something to take into account, i.e. regulations and messages regarding that regulation come
600 from a diverse range of sources, that can eventually even produce conflicting or inconsistent messages.

601 To sum up, the concepts of education and supportive approaches might be able to serve as anchoring points
602 among non-farmers. They should stand a decent chance, whereas other central concepts among non-farmers
603 such as knowledge and awareness are far less likely to serve as anchoring points. One of the reasons might be
604 that these two concepts do not resonate among farmer perceptions in the same manner as the two preceding
605 concepts, which should be able to facilitate positive dynamics. Conflicting and changing policy messages also
606 have created scepticism among farmers that can also act as a barrier to uptake.

607 **5. Conclusions**

608 The Scottish study shows that fuzzy cognitive mapping can be a good tool to disentangle the different world
609 views of farmers and non-farmers (i.e. other stakeholders involved in the design and communication of
610 regulation) that represent a barrier to compliance with agricultural environmental regulations (research
611 question 1). Our application of FCM does demonstrate that the approach is able to enhance the capacity to

inquire into wicked problems by pointing out which anchoring points can be established among heterogeneous perceptions between Scottish farmers and non-farmers. The latter are defined as relevant stakeholders involved in designing, implementing, administrating, consulting on or enforcing regulation but themselves typically without involvement in practical farming.

In this case we were able to pinpoint three specific anchoring points (transmitter concepts with a strong effect on a central concept where the effect has a distinctly positive connotation in the farmers' view) for which policy development could be further developed in this case, namely precision farming, supportive approach and unwieldiness; hereby exemplifying the utility of the FCM approach. The supportive approach could be fitted within SEPA's current two tiered approach to mitigate diffuse pollution (SEPA, 2014a). This includes a targeted approach in so-called priority catchments, involving one-to-one visits to farmers in which specific advice is given to specific breaches of general binding rules. SEPA is currently developing a sophisticated auditing and monitoring system which has the potential for undertaking tailored awareness raising, engagement and audit and further support for land managers, as the ones suggested here (SEPA, 2014b). Evidence of the positive effects of this supportive approach is starting to emerge, as expressed in SEPA's Diffuse Pollution Management Advisory Group meetings (SEPA, 2014a).

The potential for precision farming in Scotland has been studied by Macgregor & Warren (2006). Moreover, the list of the most central perceptions for farmers and non-farmers (Table 5) showed little overlap between factors of importance for the initial question about how environmental regulation affects farming practices and the compliance or non-compliance with general binding rules. Only costs were among the most central factors for both farmers and non-farmers, but from different perspectives.

FCM does allow for a structured process of identifying both areas of conflicting perceptions, but also areas where stakeholders with different interests might be able to gain common ground. Finally, in relation to policy development (research question 2), FCM offers a critical, reflexive approach to how a regulatory process can be conceived (and thus changed), based on the relevant stakeholders' own perceptions. Our study does indicate that if the insights gathered during the study were utilized in future developments of policy, it would be an important element in avoiding future institutional failures regarding regulating human impact on ecosystems. Our final conclusion is that FCM can help identifying the (lack of) alignment of perceptions and serve as a basis for recommendations for improving policy design and communication.

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