Can Fuzzy Cognitive Mapping Help in Agricultural policy design and communication?

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ABSTRACT

Agricultural environmental regulation often fails to deliver the desired effects because of farmers adopting the related measures incorrectly or not at all. This is due to several barriers to the uptake of the prescribed environmentally beneficial farm management practices, most of which have been well established by social science research. Yet it is unclear why these barriers remain so difficult to overcome despite numerous and persistent attempts at the design, communication and enforcement of related agricultural policies.

This paper examines the potential of fuzzy cognitive mapping (FCM) as a tool to disentangle the underlying reasons of this persistent problem. We present the FCM methodology as adapted to the application in a Scottish case study on how environmental regulation affects farmers and farming practice and what factors are important for compliance or non-compliance with this regulation. The study compares the views of two different stakeholder groups on this matter using FCM network visualizations that were validated by interviews and a workshop session. There was a farmers group representing a typical mix of Scottish farming systems and a non-farmers group, the latter comprising process professionals from the fields of design, implementation, administration, consulting on and enforcement of agricultural policies.

Between the two groups, the FCM process reveals a very different perception of importance and interaction of factors and strongly suggests that the problem lies in an institutional failure rather than in a 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 be able to gain common ground. In this way, FCM can help to identify anchoring points for targeted policy development and has the potential of becoming an effective tool in agricultural policy design and, due to its inherently visual nature, communication. Our results show the utility of FCM by pointing out how Scottish environmental regulation could be altered to increase compliance with the rules and where the reasons for the identified institutional failure might be sought.

1 Introduction

During a recent inspection of Scottish watercourses (Vinten et al., 2011), a significant number of breaches of formal regulations to prevent diffuse pollution were identified. 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 at least once per kilometre of the examined waterways. These findings constitute a challenge to current regulation 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 indicates that present regulation might be inadequate and in addition there might be many other breaches to the remaining GBRs taking place, such as regulation on use of fertilizer (SEARS, 2009a) and land cultivation (SEARS, 2009c), as well as others. Given the number of breaches, the problem can be framed as an issue of failure with regards to communicating landscape stewardship issues among Scottish farmers who either aren't 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 non-farmers (process professionals[1]). 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 environmental regulation and farm and landscape ecology among farmers and relevant stakeholders in rural Scotland. 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 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 the present policy failure with a critically high number of GBR breaches, and thereby to 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 adaption 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)

[1] Relevant stakeholders involved in designing, implementing, administrating, consulting on or enforcing regulation but themselves typically without involvement in practical farming; further on referred to as 'non-farmers' in the context of this paper

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 dynamics of agricultural and landscape management. 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). Regarding the fourth type of problem suggested by Özesmi and Özesmi, the involvement of government to facilitate farmers' compliance with the GBR's and similar agro-environmental regulations are mandated by law, as part of the overall compliance with the WFD's public participation principle (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 these approaches 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

The FCM process was divided into working with two stakeholder groups, namely farmers and non-farmers. The latter included estate managers, consultants, scientists, as well as representatives of NGOs, Farmer's Union, SEPA (Scottish Environment Protection Agency) and from the Scottish Government.

In October 2011, in a combination of interviews and a workshops nine non-farmers representing different institutional affiliations and regions in Scotland were interviewed and asked to create an FCM 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)?' The focus in both activities was on three Diffuse Pollution General Binding Rules:

- 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).

Before creating the map they were shown a brief presentation explaining the FCM process while making use of a topic unrelated to the topic of the interview. A short list of concepts (in their own words) they had mentioned in respectively the interviews and workshop and which they could expand on as much as they felt they needed to complete their map was provided prior to starting the map creation. During the process of map creation following the two interviews, 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. At the workshop, participants were asked not to

communicate with the other participants during map creation and only technical questions were answered as well. 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.

During the same period, 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 the final 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, figure 1 shows an FCM as drawn by one of the interviewed farmers.

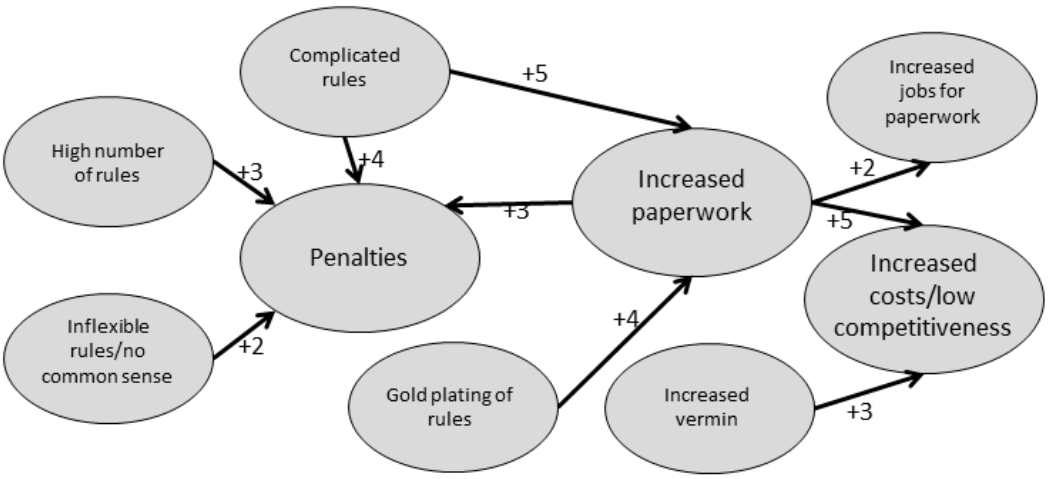

Fig. 1. Digitized version of an FCM drawn by a farmer. The arrows represent diminishing or increasing effects between concepts with a subjective rating by the farmer between -10 and +10 where 1 means very weak effect and 10 means very strong effect.

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 1).

Table 1
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	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 (Figure 2, Table 2). The worksheet was set to highlight values exceeding -1.0 or +1.0. If a matrix node exceeded this range after adding all link values to the matrix nodes, a matrix calculation operation was performed to normalize all values by the highest value in the matrix.

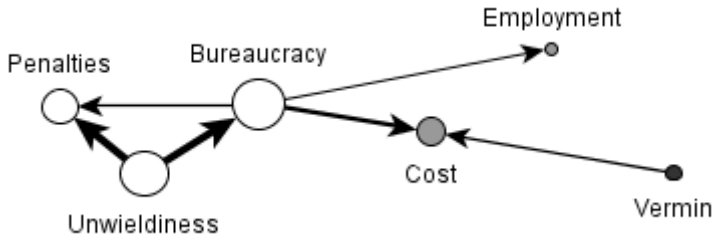

Fig. 2. Adjacency matrix from table 2 visualised as network. Size of arrow represents strength of effect; size of concept node represents centrality (the sum of incoming and outgoing link strength) of concept; colour represents category the concepts are grouped into.

Table 2
Adjacency matrix based on condensed (Figure 2) FCM from figure 1. Values changed from between -10 and 10 to between -1 and 1 due to quantitative analysis software requirements. -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						

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 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 (Figure 2).

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 (Figure 3).

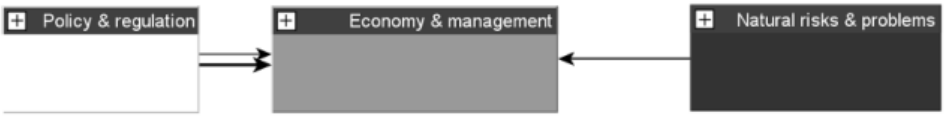

Fig. 3. Network view based on concept categories showing the amount and strength of links between different groups of concepts (Network in Figure 2 visualised on category level).

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 concepts
- Number of links
- Number of self-loops: concepts that link to themselves on the adjacency matrix
- Number and percentage of transmitter, receiver and ordinary concepts: transmitter concepts have no indegree, receiver concepts have no outdegree and ordinary concepts have both an indegree and an outdegree
- FCM density index (connectivity): number of links *L* divided by number of concepts *C* to the power of 2 (L/C^2): the lower the number the lower the density
- FCM complexity index: number of receiver concepts *R* divided by the number of transmitter concepts *T* (R/T): the lower the number, the higher the complexity
- 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.

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. Rather than basing the analysis on the matrix values like 2.4.1, the qualitative analysis used the visualization of the combined matrix values as starting point. Special attention was given to concepts targeted by current Scottish agricultural policy and concepts with a high outdegree and also currently not prioritized by policymakers. The concept category maps (Fig. 3) were used to describe causality between categories.

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 unique 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 unique concepts.

The two combined maps were analysed for their number of unique concepts; the number of links between the concepts; the number of concepts exhibiting self-loops; density and complexity. Density and complexity are graph theoretical indices describing connectivity between concepts (density) and ratio of receiver to transmitter concepts (complexity) of an FCM. (Table 4). 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.
- 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. The two groups show no distinct difference in this concept type.
- 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.

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 4). 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 4 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[2] of 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

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

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

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.

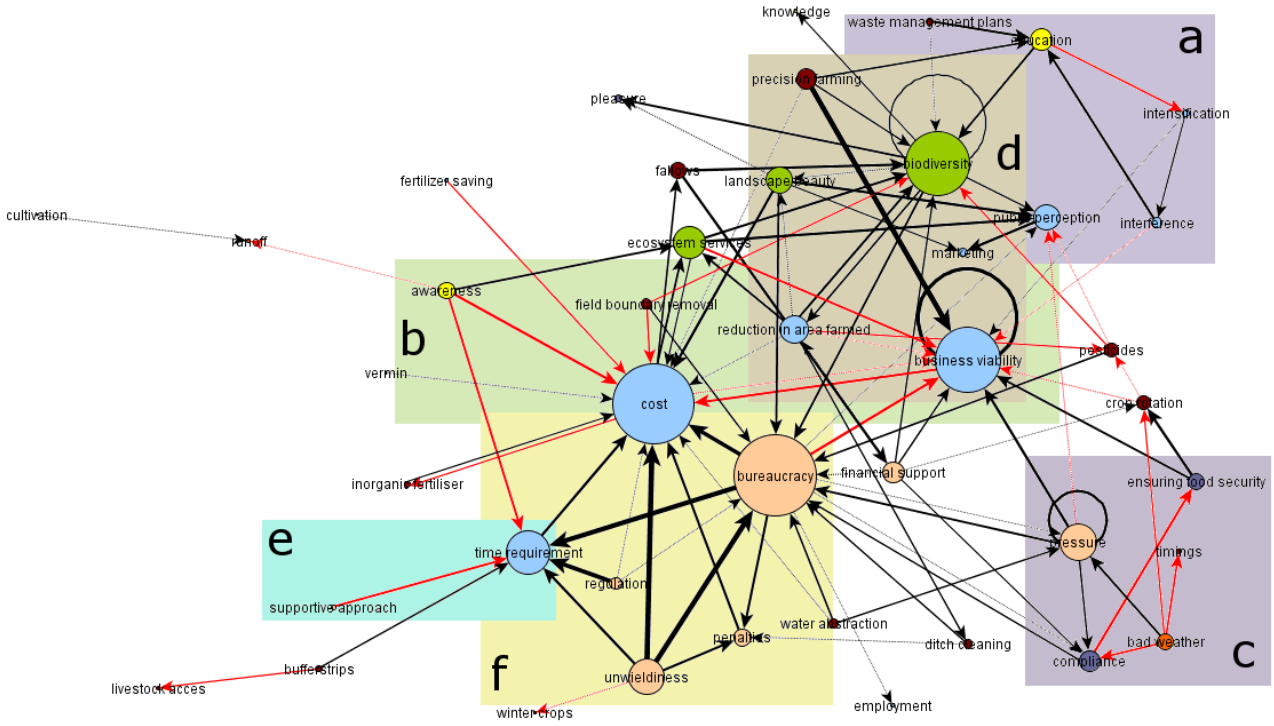

Fig. 4. Farmers' combined FCM adjacency matrix visualised as network. Area a; b; c: areas providing insight into farmers' perceived role of knowledge dissemination by the authorities and their view of compliance issues. Area d; e; f: concepts and their sphere of influence where policy interventions or 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 5) 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.

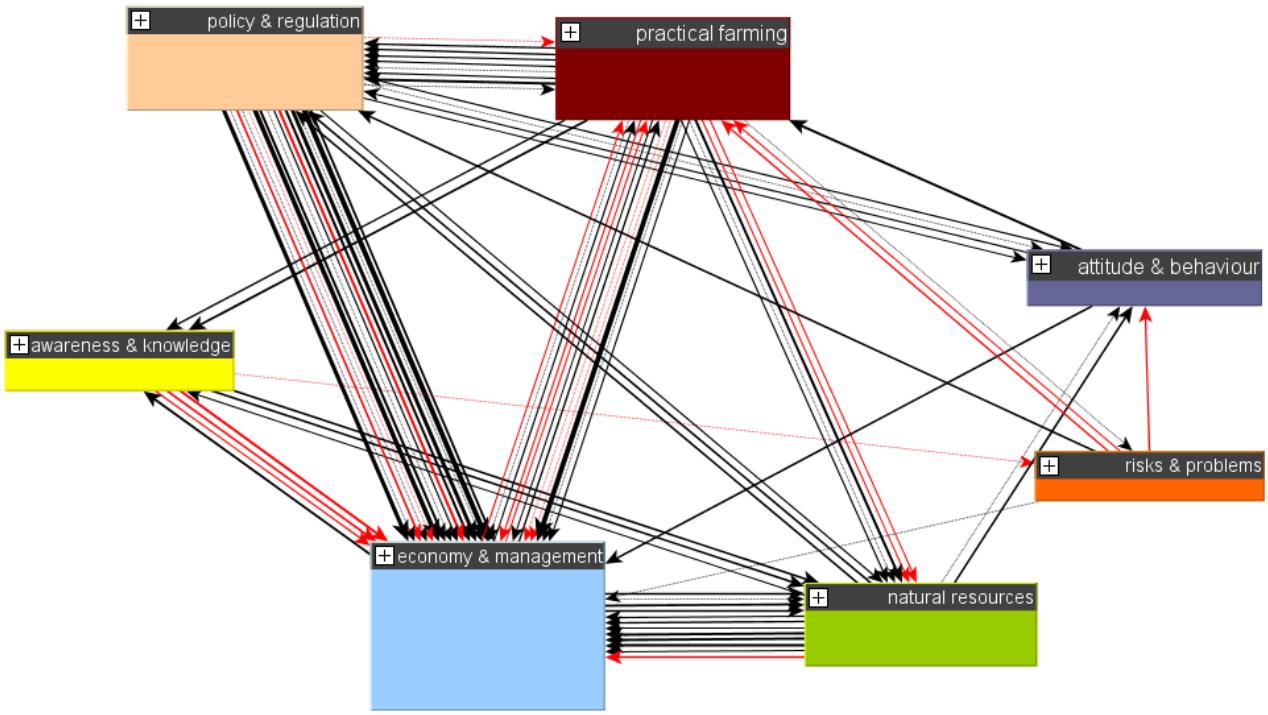

Fig. 5. Farmers' combined FCM network presented as category network. Farmers' combined FCM network presented as category network. Category size: weighted after combined centrality. Link colour: red = diminishing effect, black = increasing effect. Link width and layout: scaled to link strength (0.1 – 1.0), strength 0.1 – 0.3 depicted as dotted line. 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 6) was analysed for its divergence from the farmers' FCM (Fig 4) 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 6 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, as expected from non-farmers who work with GBR compliance issues on a regular basis. 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.

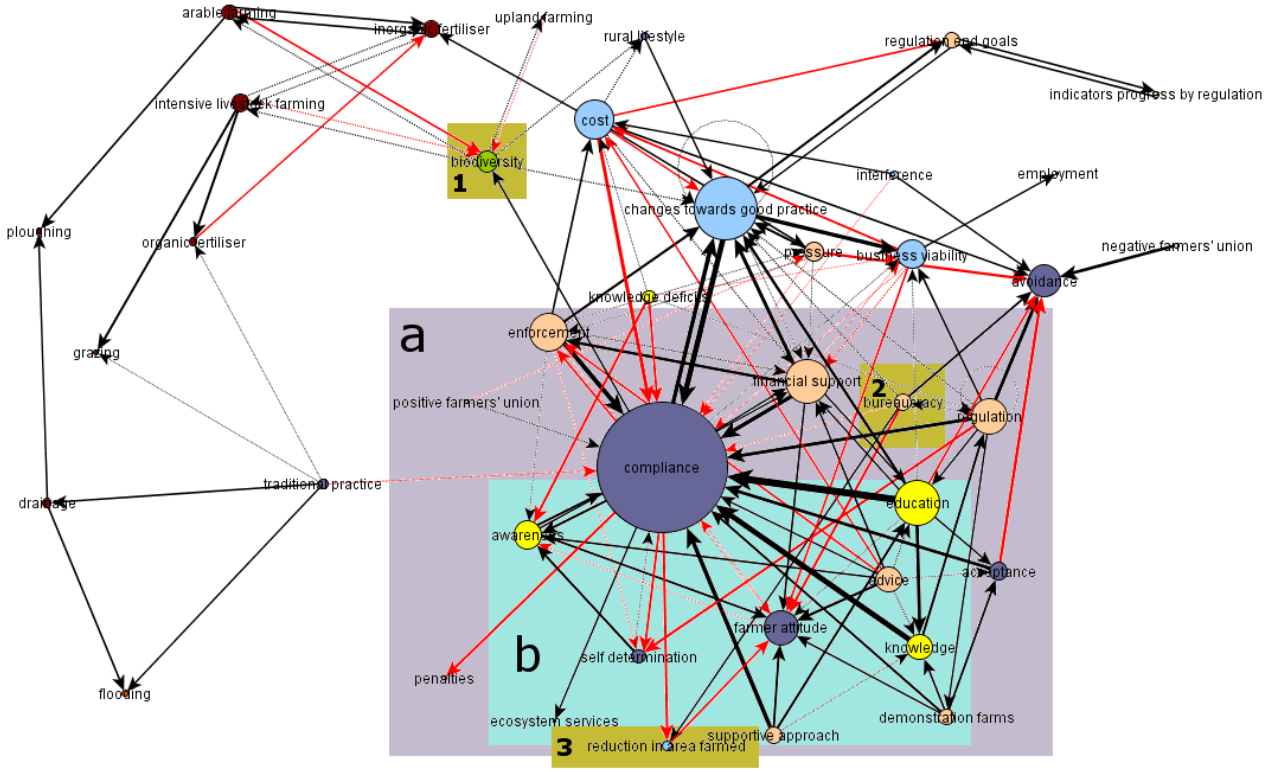

Fig. 6. Non-farmers' combined FCM adjacency matrix visualised as network. Area a; b: the different map regions of the non-farmer's network that differ substantially from the farmers' network. Yellow rectangles (1; 2; 3): concepts weighted differently in the same comparison. Colour coding as in Fig 7. 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.

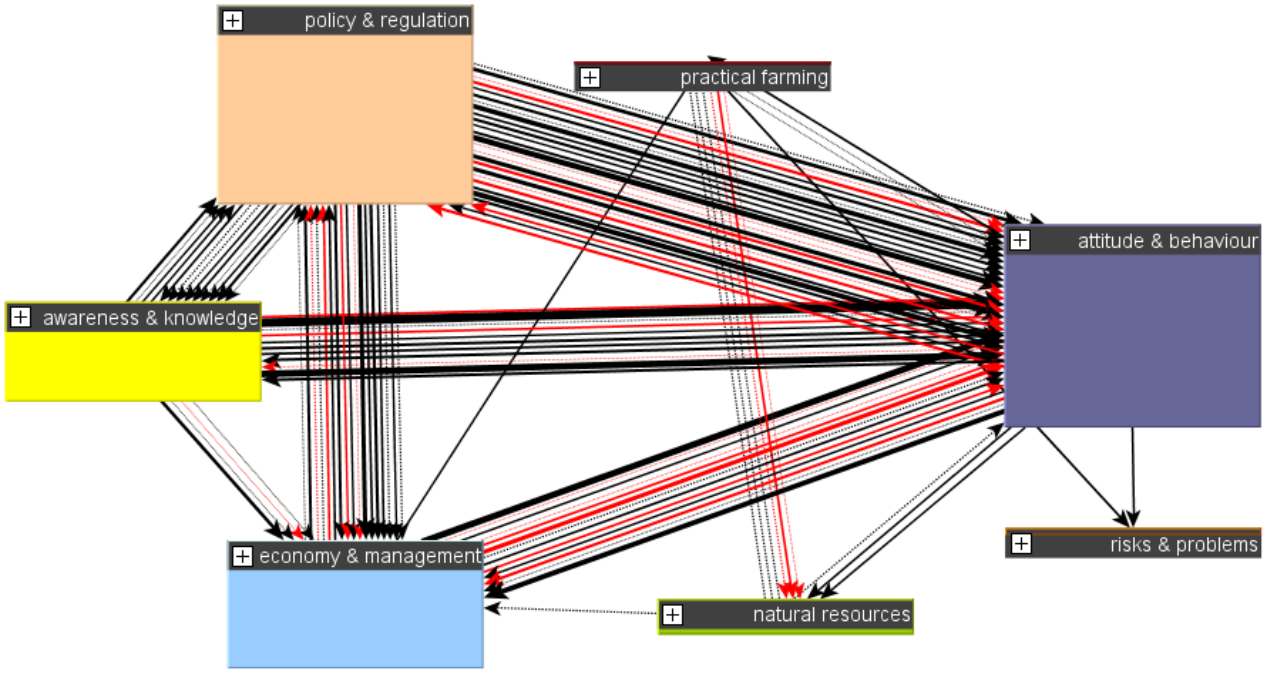

Fig. 7. Non-farmers' combined FCM network presented as category network. Category size: weighted after combined centrality. Link colour: red = diminishing effect, black = increasing effect. Link width and layout: scaled to link strength (0.1 – 1.0), strength 0.1 – 0.3 depicted as dotted line.

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. 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 between 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 (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 and this goes also for natural resources, which is quite a paradox given that natural resources should be a core concern for policy makers. These 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. 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.

Our conclusion with regard to the combined adjacency matrix is that our application of FCM confirms the initial hypothesis that there is a lack of alignment of perceptions. Given that many other studies are able to confirm these results, it is relevant to address the first research question regarding how FCM can diagnose and disentangle the lack of alignment between perspectives.

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 of the classical contributions on natural resource management, such as 'the tragedy of the commons' hypothesis would confirm that conclusion (Hardin, 1968). Other, more recent approaches, such as Luhmann's work on ecological communication (Luhmann, 1989), have also emphasized the inevitability of institutional failure. However, these rather bleak accounts (particularly in the case of Luhmann) 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 also capable of facilitating processes of alignment. A very important aspect in that regard is that 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. It is not possible to identify any common factors of importance between the two groups, which could suggest that there is not 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 form 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 bureaucracy, there would, according to farmer perception, be an overall positive effect on business viability as well as costs. It is important to point out that for farmers, a supportive approach does not equal financial assistance but consists of localized support in implementation of measures, advice on how to receive grants and targeted consulting and also to be treated in a friendly and supportive way. A third anchoring point could be unwieldiness, especially prescribed timings of farming activities and overly complicated rules and procedures. If unwieldiness could be reduced, it would lead to reductions in the level of bureaucracy, time requirements and costs.

In order for these anchoring points to function as such, they need to be aligned with perceptions on behalf of non-farmers. When considering the network mapped in figure 6, it is rather obvious that non-farmer perception of the importance of education could establish an alignment between perspectives on either side. However, education is perceived by non-farmers to have a positive influence on compliance. Farmers might conceive education in a different manner, e.g. in relation to acquiring specific skills in relation to precision farming. In order for education to serve as anchoring point on behalf of the government, it will require an alignment of the objectives for learning, which accommodates the two perspectives. Another possible anchoring point among the perceptions of non-farmers is, like for farmers, the notion of a supportive approach; though as in the case of education, supportive approach holds a different meaning for non-farmers than for farmers: the qualitative interviews indicate that non-farmers typically perceive supportive approaches having to do with financial support and not necessarily as having to do with changing practices within the regulatory process itself. In addition, non-farmers might not perceive supportive approaches as having to do with addressing the issue of unwieldiness, which is not perceived as an issue at all among non-farmers. It is also worth noticing, that bureaucracy is also not perceived as being an issue among non-farmers. In their case, that is what they do and it is not a subject of reflection among them. To sum up, the concepts of education and supportive approaches might also be able to serve as anchoring points among non-farmers. They should stand a decent chance, whereas other central concepts among non-farmers such as knowledge and awareness are far less likely to serve as anchoring points. One of the reasons might be that these two concepts do not resonate among farmer perceptions in the same manner as the two preceding concepts, which should be able to

facilitate positive dynamics. Conflicting and changing policy messages also have created scepticism among farmers that can also act as a barrier to uptake.

5. Conclusions

The Scottish study shows that fuzzy cognitive mapping can be a good tool to disentangle the different world views of farmers and non-farmers that represent a barrier to compliance with agricultural environmental regulations (research 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 process professionals (non-farmers) which 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 (precision farming, supportive approach, and unwieldiness) hereby exemplifying the utility of the FCM approach. 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. It is also worth emphasizing that FCM is an inherently visual approach, which allows for effective, targeted communication among different groups of stakeholders. 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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Appendices: