Farmers' perceptions on ecosystem services and their management

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ABSTRACT

Agriculture is the largest terrestrial land use outside protected areas and both has a great potential and an urgent need for increased ecosystem services (ES) delivery in land sharing scenarios. Farmers are directly responsible for the management of their agroecosystem and therefore determine the level of ecosystem services provision. It is important to understand farmers' perception on ecosystem services, to be able to design sustainable farming systems, using local knowledge. Ecosystem services and their management are based on a complex interaction of interconnected social and ecological factors. No model exists until so far which integrates the assessment of multi-agroecosystem services with management. We propose to use fuzzy cognitive maps (FCM) as a tool to address this research gap. The tool is applied to a compare the perception on ecosystem services and their management between agroecological family farmers, conventional family farmers and large scale farmers. Agroecological farmers were found to have more complex perceptions of their agroecosystems, based on the number of connections and intermediate ES in their fuzzy cognitive maps and recognise a higher number of benefits from on farm trees. Conventional and large scale farmers rely more on external inputs than agroecological farmers. Additional agrobiodiversity indicators were collected per farm which showed that agroecological farmers have a higher crop diversity and number of products sold, which correlated with the perception of more complex farming systems. Both agroecological and conventional family farmers have a strong peasant identity, recognising more direct ES than large farmers and relying more on production for consumption. The fuzzy cognitive maps proofed to be a useful tool for mapping the perceptions of farmers on the complex social-ecological interactions of ecosystem services and their management.

INTRODUCTION

Farmers have a great potential to influence the global provision of ecosystem services (ES), which are broadly defined as the benefits people obtain from nature (MEA 2005). About 40% of the global terrestrial surface is occupied by croplands and pastures managed by farmers and represents the largest land-use outside protected areas (Foley et al. 2005). The variety and quantity of benefits obtained from nature will depend on the type of management of the landscape. While nature reserves are essential for the conservation of rare, endemic, specialized, or area-demanding species, most biodiversity is found outside of protected areas, in production landscapes (Baudron and Giller 2014). Increasing biodiversity augments the delivery and especially the variety of ES (de Bello et al. 2010, Harrison et al. 2014), even though the debate surrounding these linkages remains contested (Schröter et al. 2014). Farmers make continuous decisions on how to manage diversity based on their perceived opportunities and constraints (Vandermeer et al. 1998). Farmers' understanding and valuing of ES determine their management of a farming system and consequently the provision of ES, following a complex interaction between the agroecosystem and the farmer (Lescourret et al. 2015). Previous studies tended to be refrained by a theoretical approach to address the complex feedback loops between the ecological and social systems to explain ES provision (Diaz et al. 2011) and identified a lack of studies and adequate tools for studying farmers' understanding and management of ES in practice (Lamarque et al. 2014, Smith and Sullivan 2014, Lescourret et al. 2015). This study uses fuzzy cognitive maps (FCM) as an integrated research tool to understand the perception of farmers on ES and their management, and applies it on a comparison between agroecological family farmers, conventional family farmers and large scale farmers.

The analysis of ES, biodiversity and human actions requires an interdisciplinary framework for integrating the social and ecological interactions. Diaz et al. (2011) proposed a framework that connects social systems to ecological systems, mediated through land use decisions and ES provision. In agroecosystems, the management by farmers influences the ecological system such as land cover, functional biodiversity and ecosystem properties, which then determines the provision of multiple ES, of which farmers are the direct beneficiaries closing the continuous feedback loop. Farmers also look back and reflect upon the ES provision to determine their perception on ES, to continue adjusting their management. The interactions between social actors and ecological components can be both positively and negatively reinforcing, for example resulting in further reduction of diversity with intensified monocultures or the development of more complex agroecosystems on the contrary, depending on the priorities and decisions of the social actors. Farm management is strongly influenced by social institutions such as belief systems, traditions, farmer organisations, regulations and market demands (Spangenberg et al. 2014). Ecological components are also influenced by outside forces, such as climate change and neighbouring ecosystems, in addition to the management component described above. This research investigates how farmers perceive the entire package of multiple and interconnected ES on one hand and how this influences their management of the agroecosystem on the other hand, following the conceptual framework based on Diaz et al. (2011) and specifically adopted to agroecosystems (Lescourret et al. 2015).

It is essential to include farmers' perceptions in order to (re)-design more sustainable farming systems. Farmers have substantial and invaluable experimental knowledge about their systems, which they manage as a whole. Scientists on the contrary continue to consider ES as separate units (Smith and Sullivan 2014, Tancoigne et al. 2014). Within the context of the ES framework (MEA 2005), provisioning services have received most attention in research, as well as the monetary quantification of these services. However, little research has been conducted on the social-cultural valuing of ES, which is especially relevant for the multiple supporting, regulating and cultural ES (Diaz et al. 2011, Chan et al. 2012, Cáceres et al. 2015). These are more difficult to quantify economically than provisioning services and vary strongly with the perceptions of different social actors along spatial and temporal scales (Hein et al. 2016). Yet, the stakeholder perception and valuation are critical to a farmer's decision-making process to adopt certain agricultural practices. Farmers must consider the management of simultaneous ES, which "is challenging, because of the multiple positive (synergies), negative (trade-offs) and non-linear relationships between services and the multiple levels at which management can be applied" (Lescourret et al. 2015 p. 69).

In order to capture the complexity and non-linear interactions between the social system and the ecological system, the tool fuzzy cognitive maps (FCM) has been used as a method to capture the perception of farmers and how they manage their agroecosystems. FCM is a semi-quantitative modelling tool that has been developed to assess and compare knowledge from non-technical experts (Özesmi and Özesmi 2004). Important and relevant features of the tool are: to make certain implicit assumptions, such as mental models, explicit; to consider the multivariate interactions that result in nonlinear interactions; and to bridge the gap between storylines and quantitative models, integrating social and ecological sciences (Kok 2009, Papageorgiou and Salmeron 2013, Jetter and Kok 2014). As a participatory methodology, FCM are simple to use and easy to explain and can be conducted in the field with farmer families in a short period of time (van Vliet et al. 2010). The FCM concept seems to be a particularly well suited methodology to deal with the ES concept that is inherently complex (Reyers et al. 2013) and subjective (Chan et al. 2012, Maier and Feest 2015). Nobody has ever used FCM for capturing farmers' perception on ES and their management. FCM allows for the mapping of the subjective valuing and the interactions of multiple services using a single tool. If proven effective, this will provide an answer to the need identified by Lescourret et al. (2015 p. 73) stating that "No models of multiple agro-ecosystem services explicitly including management option effects are available". In addition to conducting the FCM, measurements on agrobiodiversity indicators have been collected at the investigated farms, to compare the variation on perception and management of ES among the different farmers with the agrobiodiversity per farm.

There is a large variation among farmers on the reliance of ES, as well as the provision of ES. Small-scale diverse farmers in developing countries are more reliant on ES than large scale intensive agriculture with high external inputs. Small-scale farms tend to be more diversified and therefore provide more ES than large-scale monocultures of intensified agriculture (Vandermeer et al. 1998, Swift et al. 2004). Peasant farmers are smallholder farmers, who are characterised by: the pursuit of an agricultural livelihood which combines commodity production with subsistence production; the internal social organisation of their farm is based on family labour; and an everyday form of resistance is omnipresent to the superordinates in harsh economic and socio-political conditions (Oostindië 2015, Bryceson 2015). Peasant farmers, in contrast to entrepreneurially minded farmers, build upon and internalise nature (Van der Ploeg 2008). Peasants have a co-producing and co-evolution strategy with nature, which explains the mutualistic relationship with the reliance on and provision of ES. In order to get a better understanding of the interactions between biodiversity and ES, Jackson et al. (2007) urge for more research on how agrobiodiversity contributes to ecosystem goods and services that serve society as a whole (non-excludable services). ES have to be considered in a social context, both for understanding the highly subjective valuation (Chan et al. 2012) and the role of human agency in determining ES provision (Spangenberg et al. 2014).

The research objectives of this research are (i) to understand farmers' perceptions on multiple ecosystem services and their management using the fuzzy cognitive map tool, (ii) to compare perceptions between agroecological family farmers, conventional family farmers and large scale farmers and (iii) analyse correlations among perceptions, agrobiodiversity and farm size indicators between the farm categories.

METHODS

Study area

Zona da Mata is a mesoregion in the South-Eastern part of Minas Gerais, Brazil. It is located in the Atlantic rainforest biome, which is considered the fifth biodiversity hotspot in the world, hosting many unique endemic and threatened species (Myers et al. 2000). The landscape is commonly described as a 'sea of hills' and consists of a mosaic of different land uses due to its continuously changing topography as well as conflicting interests over the land. The main land uses are pasture, commonly degraded through pastoral use or by previous land uses and occupying larger areas; coffee, the most important cash crop in the region, often intercropped with maize, beans, cassava and other crops; and forest fragments, often located in protected or less accessible areas. Although homegardens usually only occupy small areas in the farm, they are important for the food sovereignty of the families and host a high biodiversity of plant and animal species (Oliveira 2015).

Figure 1. Map of studied municipalties in Zona da Mata

The Zona da Mata has a unique history of participatory partnerships between a university, a socio-environmental NGO and farmers' organisations, which along with social and political movements, have resulted in a strong presence of agroecological awareness and practices among farmers (Cardoso et al. 2001, Cardoso and Mendes 2015). Agroecological farmers in the region, are characterised by a low use of chemical inputs, a high degree of plant diversity, complex agroecosystem management, engagement in social movements, labour relying predominantly on family members and a strong reliance on natural processes such as nutrient cycling and natural pest control (Altieri 2002). The research was conducted in Araponga, Divino and Espera Feliz (Fig. 1). These three municipalities of Zona da Mata have their own farmers' union with strong levels of involvement in the agroecological movement. The three municipalities together connect the Caparoá National Park with the State Park Serra do Brigadeiro. What is unique about the history of the Brigadeiro state park is the involvement of farmers, through their union, especially in the neighbouring municipality of Araponga, to create a natural buffer of land sharing practices surrounding the state park boundaries. For instance, farmers were actively involved to reduce fire practices and to experiment with agroforestry systems as an alternative to monocultures of coffee production (Souza et al. 2010, Mendes et al. 2015). All these activities have strongly contributed to the agroecological movement and the implementation of agroecological practices by farmers in this region (Botelho et al. 2015).

Subject definition and selection

The categories of farmer groups were defined during participatory workshops in October 2016, one in each of the three municipalities, when the local farmers and community representatives appointed the different categories of famers in the municipality. A regional categorization was constructed later based on the farmers input and survey data (Teixeira et al. 2017 – unpublished). The main categories that have been selected are agroecological family farmers conventional family farmers, including sharecroppers (locally called meieros); and large scale farmers. The distinction between agroecological and conventional farmers in reality follows a gradient and is comprised of many different ecological, social and political aspects. Yet, for the purpose of this research a hard line was drawn based on pesticide use and participation in the farmers' union or another social organisation, since these were the main characteristics defined by farmer representatives, which are easy to verify. Agroecological farmers do not use pesticides and participate in a social organisation in contrast to conventional farmers. The selection criteria for separating family farmers from large farmers are based on four requirements defined under the Brazilian law nº 11.326: labour is predominantly provided by family members; the maximum farm area is 96 hectares in Zona da Mata; a minimal family income is based on rural activities; and the property management is family based (LEI Nº 11.326). All farmers considered from the municipalities Araponga, Divino and Espera Feliz produce coffee as the main cash crop.

The farmers to be interviewed were selected using snowball sampling (Lamarque et al. 2011, Klingen et al. 2012). The first contacts with farmers willing to collaborate were provided by the farmer unions. Once we had a starting point in a municipality, we continued asking farmers to connect us with nearby people in the community representing our farmer categories. To avoid remaining stuck in a single social network, we also randomly visited farmers without prior connections. A total of 29 farmers were contacted and 24 accepted to be interviewed. The rejection was due to a lack of time or fear for their landlord in the case of sharecroppers. We conducted individual interviews with farmer families to capture within group variation in perception and management and combine the data a posteriori in aggregated results, or so called social maps (Özesmi and Özesmi 2004). Participants in the interview would include the husband and/or the wife and often some of the children as well. Farmers take decisions within the family when managing their farm, therefore a family based assessment is more representative than a group assessment. Sample sizes are satisfied when the new number of factors mentioned per interview across the farm type level off (Özesmi and Özesmi 2004). This was the case for the group of agroecological (n=10) and conventional (n=9) family farmers, however not for large farmers (n=5) (see Appendix Fig. 6). The low number of large farmers included in the study is explained by the reality that they represent only 18.4% of farmers in the Zona da Mata and thus were harder to find (IBGE 2006).

The agrobiodiversity measurements are based on indicators that are directly determined by the management of the farmer. The indicators that were measured are: (1) the number of crop types in fields and homegarden used for self-consumption and the market, where vegetable gardens are counted as a single unit; (2) the number of different products sold; and (3) the number of livestock types. To illustrate the differences between farmer categories in terms of size, the number of coffee plants, land size (ha) and the tropical livestock units (TLU) were recorded per farm. We also recorded the number of participants and the duration of the interviews as potential compounding variables that could have an influence on the outcomes of the FCM.

Constructing fuzzy cognitive maps

FCM help to map an individual's belief system, consisting of key factors that drive a system and arrows that represent perceived causal relationships, which are weighted with a score (ranging from -1 to 1). The weights represent the strength of associations often linguistically assessed by stakeholders (Papageorgiou and Salmeron 2013). The interviews were centred around the question: "what benefits do you obtain from nature?". The International Platform on Biodiverisity and Ecosystem Services (IPBES) Conceptual Framework adopted the terminology of 'nature's benefit' to be intelligible and relevant to all stakeholders while embracing the scientific concept of ES (Díaz et al. 2015). Nature's benefits to people include both beneficial and detrimental effects.

The interview consisted of five steps to guarantee that all relevant factors (nodes of the network) are included and addressed both direct and indirect benefits, and both beneficial and detrimental effects. First, an A0 sheet of paper was presented to the farmers with a post-it placed in the centre stating 'Nature's benefits'. Then the second step was to ask farmers what direct benefits they get from their land. The keywords were identified by the facilitator, written on an additional post-it and placed around the post-it stating 'Nature's benefits' (Fig. 2). This included direct services such as production for consumption and the market, water, autonomy, etc. The third step was to ask what is needed to provide these benefits. While the second round of post-its were placed on the map, also the connections were drawn to indicate the associations with other factors already present on the map. The facilitator placed the post-its on the map in such a way that it would make drawing the connections (arrows) easier. The fourth step was to ask specifically about negative influences from nature or on the provision of the direct benefits, if these had not already been mentioned by default during step 1 and 2. The fifth step was to quantify the strength of the indicated connections (arrows). Farmers could choose from a positive or negative value ranging from 1 to 5, where 1 is a very weak influence and 5 is a very strong influence (Fig. 2). The scoring of the values is arbitrary and was transcribed after the data collection into a range from 0.1 to 0.9 (positive connections) and -0.1 to -0.9 (negative connections) to fit the FCM model. Values of 1.0 were avoided, since in this case no connections exist in which one factor explains 100% of the connected factor (Kok 2009). The fifth and last step was to ask farmers what they thought about the mental map and whether it represented their personal vision. If this was not yet the case, additional amendments were made until the farmer felt satisfied. The interviews were recorded with prior consent of the farmer, in order to revise and check the quality of the map produced, as well as for future usage by colleagues of the FOREFRONT research group for further in-depth analysis.

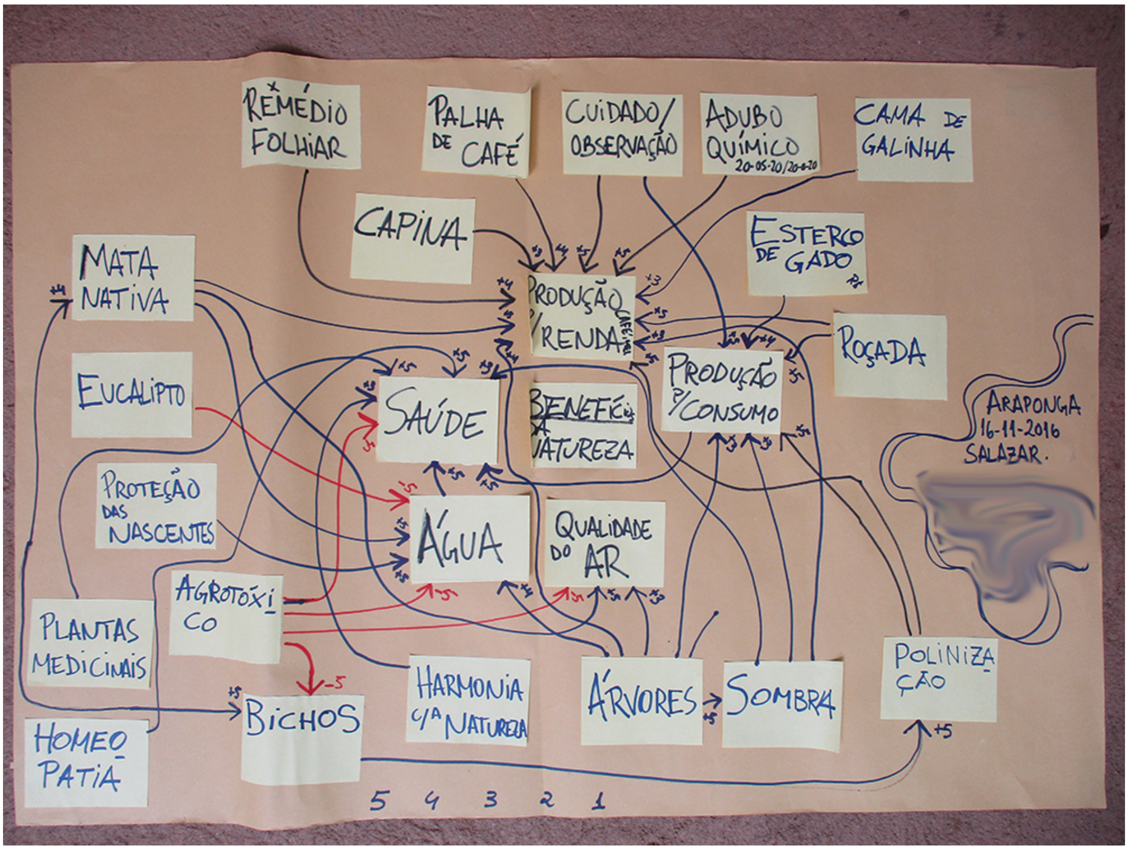

Figure 2. Example of a fuzzy cognitive map constructed together with an agroecological farmer in Araponga on 16-11-2016.

Data analysis

Various indices can be extracted from FCM data, based on the number of factors (nodes), connections (arrows) and the type of factors, distinguishing between transmitter, receiver and ordinary variables. Transmitter variables only have outgoing arrows, indicating a forcing factor, which cannot be influenced by other factors in the perceived system. Receiver variables only have ingoing arrows, indicating variables that can be controlled by other factors in the system as perceived by the stakeholder. Ordinary variables have both in- and outgoing arrows, indicating factors that can both be influenced by and have an influence on other factors in the system (Özesmi and Özesmi 2004). The FCM indices can be calculated using graph theory (Özesmi and Özesmi 2004). The suggested methodology is to code cognitive map data into adjacency matrices in the form A(D) = [a_{ij}], where the elements a_{ij} represent the strength of a connection from vertex *i* to vertex *j*, and a value of zero means no connection (see Appendix Fig. 7 and Table 3 for an example). The identified factors (variables *v*) are both listed on the vertical axis (v_i) and on the horizontal axis (v_j). Connections are indicated with the weight of the arrows, between -1 and 1. The centrality of a factor in the bigger system is determined by the sum of absolute weights of in- and outgoing arrows. In addition, the factors were categorised after the data collection as direct ES, intermediate ES, ecosystem component, external input, management practice or socioeconomic aspect. The categorisation of factors was used to understand the differences in perception among the farm categories, based on what type of factors were mentioned more frequently, which also correlates with the categories used in the referenced conceptual framework (Lescourret et al. 2015). Resulting from the lack of agreement on ES classification, we opted for an operationally useful classification separating ES in direct (final) and intermediate ES, instead of the MAE (2005) classification of provisioning, regulating, supporting and cultural ES (Fisher et al. 2009). Direct ES are final services from which humans can directly benefit, which includes provisioning and cultural ES. Intermediate ES include both regulating and supporting ES, which have a mediating functioning to generate direct ES. Cultural ES are recognised as a unique subcategory among direct ES, for analytical purposes in this study.

The individual maps were combined into social maps per farm type to represent the perceptions of a group of farmers together (Fig. 4), as well as into a community map to represent the perception of all stakeholders together. The social maps were constructed by merging the factors per group and summing the connections between the same factors of all stakeholders in the group. The weight for the connections were divided by the number of stakeholders per group, to provide comparable centrality scores between the different social groups. Positive and negative connections between the same factors cancelled each other out. For a comprehensible visual representation of the social maps (Fig. 4), a selection was made of factors that are mentioned by at least two farmers, or have a weighted centrality score higher than or equal to 0.50 to compensate for the smaller group size of large farmers. Statistical analyses were based on all factors and connections of the social maps, not necessarily visible in Fig. 4.

The FCM indices, agrobiodiversity and farm size indicators were analysed by ANOVA for normally distributed data with equal variances, and otherwise by Kruskal-Wallis when normality criteria were not met. Normality was assessed using a Shapiro-Wilk test with 0.05 significant levels and a Q-Q plot; equal variances were assessed using Levene's test. Pairwise comparisons followed by a significant ANOVA test, were conducted using a Games-Howell post-hoc test, recommended for unequal variances and group sizes (Field 2013). Pairwise comparisons followed by a significant Kruskal-Wallis test, were conducted using a Dunn test with a Benjamini & Hochberg (BH) adjustment for false discovery rate control (Benjamini and Hochberg 1995). For binomially distributed variables logistic regression analysis was used, followed by a post-hoc test with a Bonferroni adjustment. The (marginally) significant results have been analysed using a rotated Principal Components Analysis (PCA), to assess the correlations between the different variables, in combination with agrobiodiversity indicators and farm size. A Pearson's correlation matrix was computed to exclude any cases of multicollinearity ($R > 0.8$) or singularity (majority of $R < 0.3$) (see Appendix Table 5). The number of extract components were based on the scree plot (see Appendix Fig. 8) and a minimum of three communalities with a 'strong' score > .700 (see Appendix Table 4) (Field 2013).

RESULTS

In 24 interviews farmers identified a total of 104 different factors, categorised afterwards as direct ES (18; green), intermediate ES (16; blue), ecosystem properties (13; yellow), external inputs (10; red), management practices (31; turquoise) and socioeconomic aspects (16; bluegreen). Across all farmers a total of 363 unique connections were identified between the 104 different factors. The results of the FCM indices and additional indicators are presented in Table 1.

*Table 1. Overview results FCM indices, number of factors per category and additional indicators between farm types. · Marginally significant at p < .1; * Significant at p < .05; ** Significant at p < .005;*

		Statistical test	P Value	Agroecological 1 (n=10)	Conventional 2 (n=9)	Large farmer 3 (n=5)
				$\bar{x}$ ± SE	$\bar{x}$ ± SE	$\bar{x}$ ± SE
FCM indicators	Interview time (minutes)	Kruskal-Wallis	0.282	64 ± 4.4	60 ± 4.7	47 ± 4.0
	Factors (nr.), N	ANOVA	0.099·	22.7 ± 1.6	19.8 ± 1.8	21.2 ± 1.2
	Connections (nr.), C	Kruskal-Wallis	0.004**	37.0 ± 2.1^{a}	29.3 ± 2.3^{b}	26.2 ± 2.2^{b}
	Transmitter variables (nr.), T	Kruskal-Wallis	0.093·	11.5 ±1.7	12.0 ± 1.7	14.4 ± 0.9
	Receiver variables (nr.), R	Kruskal-Wallis	0.976	2.7 ± 1.3	2.8 ± 1.2	2.4 ± 0.9
	No. of ordinary variables, O	Kruskal-Wallis	0.002**	8.5 ± 1.6^{a}	5.0 ± 1.0^{b}	3.3 ± 1.3^{b}
	Density, $D = C / N(N\text{-}1)$	Kruskal-Wallis	0.038*	.077 ± 0.004^{ab}	.083 ± 0.007^{a}	.060 ± 0.002^{b}
FCM categories	Direct ES (nr.)	Kruskal-Wallis	0.005**	6.20 ± 0.42^{a}	5.67 ± 0.26^{a}	3.40 ± 0.51^{b}
	Intermediate ES (nr.)	Kruskal-Wallis	0.058·	3.40 ± 0.69	1.33 ± 0.37	2.40 ± 0.68
	Ecosystem component (nr.)	Kruskal-Wallis	0.337	2.70 ± 0.40	2.11 ± 0.26	2.60 ± 0.25
	Management (nr.)	Kruskal-Wallis	0.385	6.80 ± 0.76	6.22 ± 0.74	7.80 ± 0.20
	Socioeconomic (nr.)	Kruskal-Wallis	0.944	1.20 ± 0.51	1.00 ± 0.37	1.00 ± 0.32
	External input (nr.)	Kruskal-Wallis	0.010*	2.40 ± 0.27^{a}	3.44 ± 0.34^{b}	4.00 ± 0.32^{b}
Agro-biodive	Crop diversity (nr.)	ANOVA	0.008*	19.9 ± 3.3^{a}	9.1 ± 1.5^{b}	8.2 ± 2.4^{b}
	Types of products sold	Kruskal-Wallis	0.013*	11.7 ± 4.5^{a}	1.44 ± 0.9^{b}	1.8 ± 0.6^{ab}
	Animal types (nr.)	ANOVA	0.552	2.7 ± 0.5	2.11 ± 0.5	3 ± 0.8
Farm size	Coffee plants	Kruskal-Wallis	0.004**	11,560 ± 99.9^{a}	9,056 ± 67.0^{a}	100,000 ± 265.2^{b}
	Farm size (ha)	Kruskal-Wallis	0.003**	9.0 ± 2.9^{a}	5.2 ± 1.8^{a}	107.6 ± 9.3^{b}
	Tropical Livestock Unit, *TLU*	Kruskal-Wallis	0.003**	3 ± 1.3^{a}	4.6 ± 2.0^{a}	131.6 ± 66.1^{b}

The FCM highlighted contrasting perceptions of agroecosystems by agroecological, conventional and large farmers. Agroecological farmers identified significantly more connections per map than conventional and large farmers (p=0.013, p=0.011 respectively; Dunn's post-hoc test) and more ordinary variables (p=0.006, p=0.006 respectively), indicating that the perceived system is more complex. There was a marginally significant difference for the number of factors (p = 0.099) and the number of transmitter variables (p = 0.093) identified, but pairwise differences were not significant (p<0.05; Games-Howell post-hoc test and Dunn's post-hoc test respectively). There was a significant difference between conventional and large farmers for density (p = 0.0049; Dunn's post-hoc test), indicating a higher number of causal relationships relative to the number of factors. Agroecological farmers recognised significantly fewer external inputs on which they rely than conventional (p=0.047; Dunn's post-hoc test) and large farmers (p=0.014). Both agroecological and conventional farmers recognised significantly more direct ES than large farmers (p=0.004, p=0.0135 respectively; Dunn's post-hoc test), while only agroecological farmers recognised marginally significantly more intermediate ES than conventional farmers (p=0.055; Dunn's post-hoc test). No significant differences were found for number of ecosystem components, management and socioeconomic factors between farm types.

Agroecological farmers had a significantly higher number of crops than large farmers (p=0.029; ANOVA with Games-Howell post-hoc) and conventional farmers (p=0.042). The crop diversity count is based on all different crops found both in croplands and homegardens, which mostly consisted of perennial crops, since vegetable gardens were considered as a single unit. Agroecological farmers sold significantly more products (11.7 products) than conventional farmers (1.44 products; p=0.010; Dunn's post-hoc test). No significant differences were found with big famers (1.8 products). No significant differences were found in the number of animal types among the different farm groups (p=0.552; Kruskal-Wallis).

*Table 2. Summary test results of the content interpretation of social maps per farm type. Centrality is the sum of absolute weights of in- and outgoing connections (see Fig. 4). ˙ Marginally significant at p < .1; * Significant at p < .05; ** Significant at p < .005;*

FCM interpretation	Statistical test	p-value	Agro (1)	Conv (2)	Large (3)
			$\bar{x}$ ± SE	$\bar{x}$ ± SE	$\bar{x}$ ± SE
Water (centrality)	ANOVA	0.976	6.56 ± 0.52	6.33 ± 0.52	4.90 ±0.85
Water considered as an ordinary variable (yes/no)	Logistic regression	0.015*	95% (1 and 2 together)		40%
Trees (centrality)	Kruskal-Wallis	0.030*	3.17 ± 0.60	1.18 ± 0.48	0.64 ± 0.40
Benefits from trees (nr.)	Kruskal-Wallis	0.017*	4.10 ± 0.77[a]	1.22 ± 0.49[b]	0.80 ± 0.49[b]
Pesticides (negative outdegree)	Kruskal-Wallis	0.047*	-2.59 ± 0.24[a]	-2.61 ± 0.23[a]	-1.18 ± 0.49[b]
Pesticides (positive outdegree)	Kruskal-Wallis	0.018*	0.07 ± 0.05[a]	0.17 ± 0.18[ab]	0.38 ± 0.27[b]
Production consumption (centrality)	Kruskal-Wallis	0.052˙	5.14 ± 0.73[a]	4.56 ± 0.40[ab]	1.78 ± 1.16[b]
Cultural ES (nr.)	Kruskal-Wallis	0.043*	1.60 ± 0.22[a]	1.00 ± 0.29[ab]	0.40 ± 0.25[b]
Wildlife (centrality)	Kruskal-Wallis	0.323	2.00 ± 0.52	1.22 ± 0.48	0.84 ± 0.38

Interpretation of social maps per farm type

The FCM revealed seven major themes, which will be discussed below (Fig. 4):

1. Importance of water

Water is the most central factor for agroecological and conventional farmers and the second most central factor for large farmers and was mentioned by all farmers. There has been an ongoing drought since 2012 until 2016, resulting in springs drying up and reduced yields as reported by farmers themselves. It shows the importance and the dependence on water as a primary ecosystems service. There is a significant difference between family (agroecological

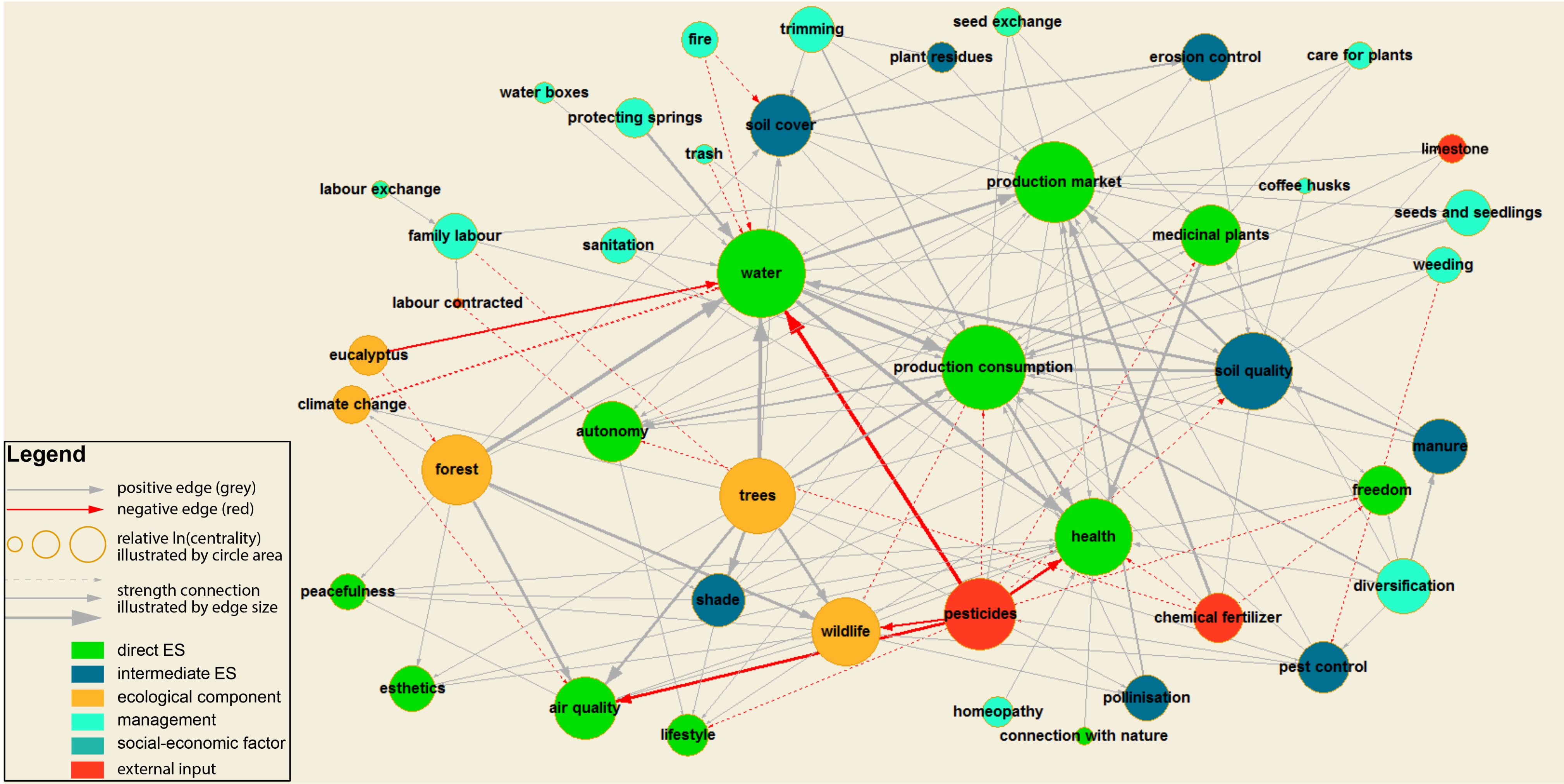

Figure 3a. Social map of agroecological family farmers (n = 10). Centrality is the sum of absolute weights of in- and outgoing connections. Displaying factors mentioned by a minimum of two farmers and with a centrality score ≥ 0.50.

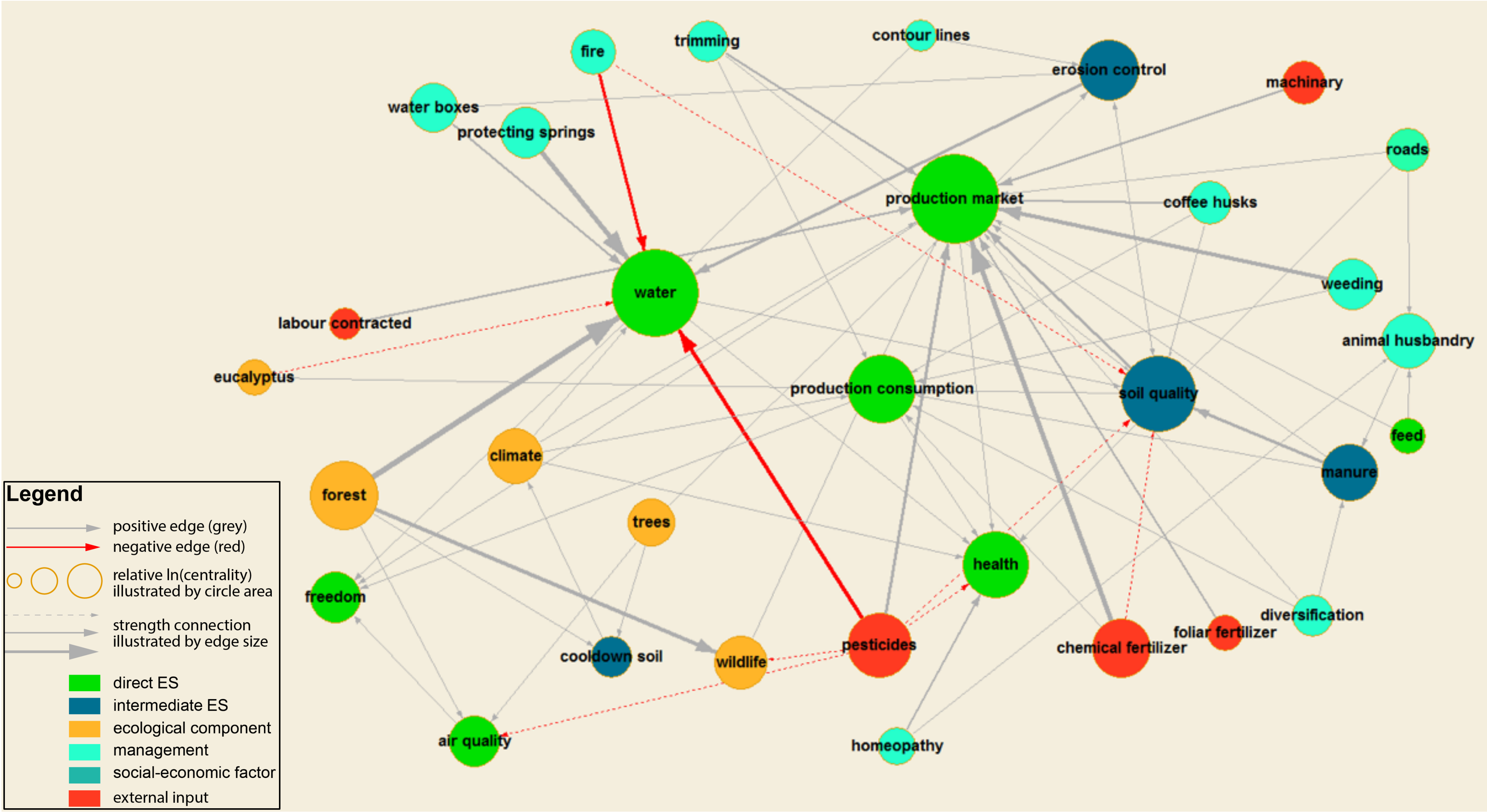

Figure 3b. Social map of conventional family farmers (n=9). Centrality is the sum of absolute weights of in- and outgoing connections. Displaying factors mentioned by a minimum of two farmers and with a centrality score ≥ 0.50)

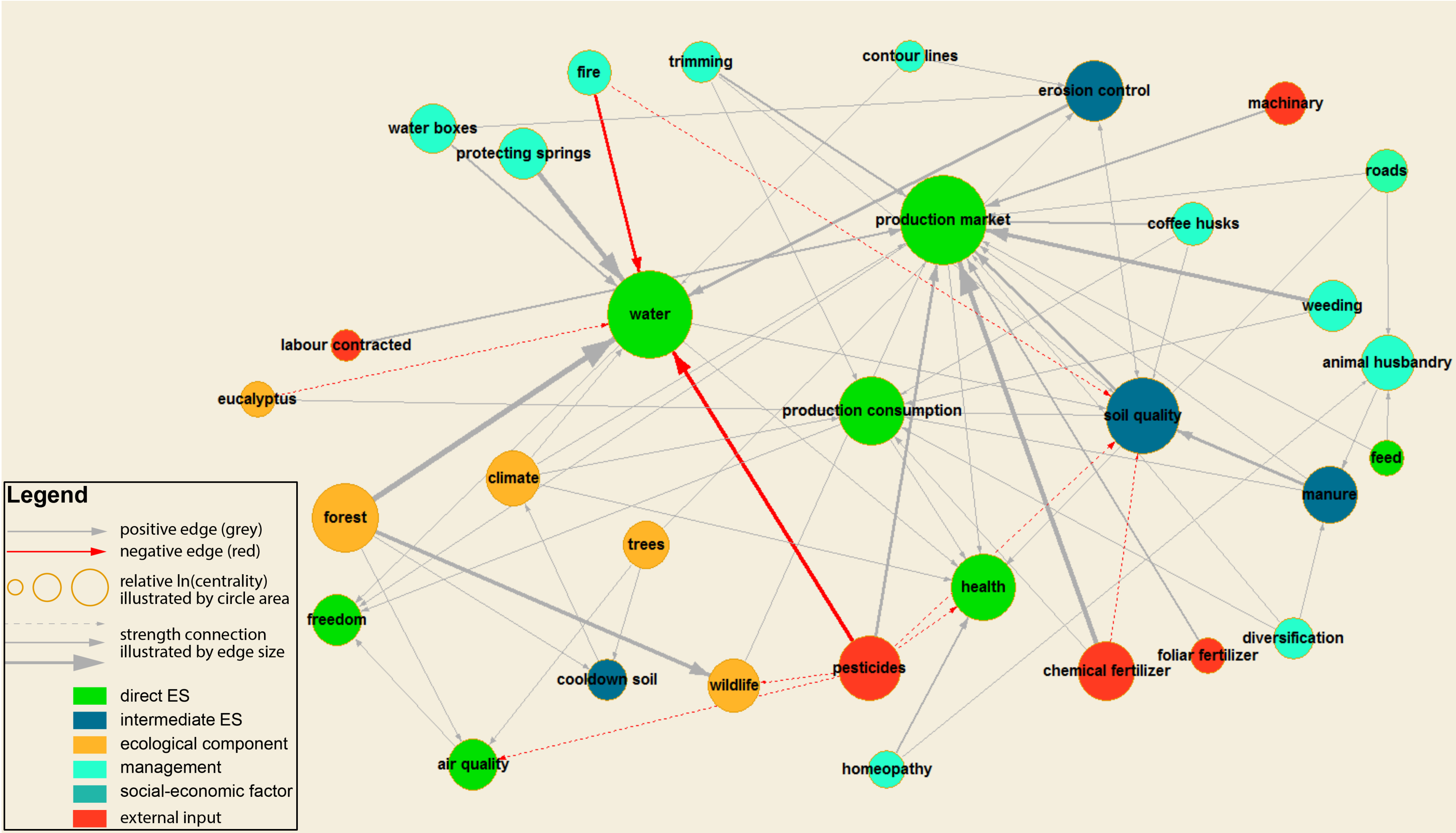

Figure 3c. Social map of large farmers (n=5). Centrality is the sum of absolute weights of in- and outgoing connections. Displaying factors mentioned by a minimum of two farmers and with a centrality score ≥ 0.50.

and conventional) farmers and large farmers in how water is perceived to affect other factors in the system (p=0.015; logistic regression). Ninety-five percent (18/19) of family farmers considered water to be an ordinary variable (having both in- and outgoing arrows), compared to 40% (2/5) of large farmers. The remaining large farmers consider water as a receiver variable, not having a direct influence on other factors in the system. Based on the community representation of all farmers together, the five most important factors positively influencing water are the forest (a relative weight of 0.65), protecting springs (0.64), trees (0.35), soil quality (0.21) and water boxes (0.21) and represent 74% of the total positive indegree of water. The three strongest negative factors influencing the availability and/or quality of water are pesticides (-0.67), presence of eucalyptus trees (-0.28) and fire (-0.22) and represent 72% of the total negative indegree of water. Water is considered most important for health (relative weight 0.52), production for consumption (0.43) and production for the market (0.40), representing 80% of all outdegree of water.

2. Role of trees

The factor "trees" include all trees outside the forest, inside and surrounding croplands and homegardens. Trees were mentioned by 15 out of the 24 farmers. There was a marginally significant difference in centrality of trees between agroecological farmers and conventional farmers (p=0.054; Dunn's post-hoc test) and large farmers (p=0.054). Agroecological farmers recognise significantly more factors (4.10 factors) than conventional (1.22; p=0.025; Dunn's post-hoc test) and large farmers (0.80; p=0.025) on which trees have an influence. The strong difference is an indication for the multiple important functions trees fulfil in the agroecosystems as recognised by agroecological farmers. Only agroecological farmers recognise the benefit of shade by trees and only family farmers (agroecological and conventional) recognise the benefit of trees on water, production for consumption and wildlife. All farm groups recognised the positive effect of trees on air quality and on some means of soil improvement, through soil cover, plants residues and erosion control. Based on the community representation of all farmers together, trees contribute most to air quality (a relative weight of 0.35), water (0.35), production for consumption (0.20), wildlife (0.19) and shade (0.18), representing 70% of all outdegree of trees.

3. Pesticides

Pesticides were mentioned by all 24 farmers. There is a significantly stronger negative influence of pesticides perceived by agroecological and conventional farmers on ecosystem properties and the delivery of ES compared to large farmers (p=0.39, p=0.39 respectively; Dunn's post-hoc test). Conventional family farmers are the only farm group in this study who use pesticides and apply these themselves in the field, in contrast to large farmers who contract employees to spray pesticides. Large farmers recognised significantly more positive benefits of pesticides than agroecological farmers (p=0.013; Dunn's post-hoc test). For the community of farmer groups, the main identified negative impacts of pesticides other than health (a relative weight of -0.70) are on water (-0.67), air quality (-0.37), wildlife (-0.23) and soil quality (-0.19), representing 89% of all negative outdegree of pesticides.

4. Peasant farming: labour and food sovereignty

Family farmers (both agroecological and conventional) have a significantly smaller land size (p=0.007, p=0.003 respectively; Dunn's post-hoc test), number of coffee plants (p=0.006, p=0.005 respectively) and Tropical Livestock Unity (p=0.004, p=0.006 respectively) than large farmers (Table 1). The dynamics of a family farmer are in many ways different from a large farmer. Peasant farmers make use of their social network as a resource of labour, mentioning labour exchange, family and the community as ways to generate production, whereas large farmers only refer to contracted labour for production. The centrality of production for consumption (food sovereignty) is significantly more central for agroecological farmers than large farmers (p=0.45; Dunn's post-hoc test). Large farmers do not tend to produce their own food, whereas all family farmers in this study have at least a small home garden.

5. Cultural ES

Agroecological farmers identified significantly more cultural ES (1.6 factors), compared to large farmers (0.4 factors; p=0.029; Dunn's post-hoc test). There was no significant difference with conventional farmers (1.0 factors). The most important cultural ES for the community of farmers as a whole are autonomy (centrality score of 0.72), freedom (0.57), lifestyle (0.42), peacefulness (0.40) and aesthetics (0.38), representing 93% of the total cultural ES. For agroecological farmers, autonomy (centrality score of 1.32) is by far the most central factor out of all cultural ES, for conventional farmers it is the third highest cultural ES (0.54) and large farmers do not mention autonomy at all, showing that this is not an item of concern for them.

6. Ecosystem components

For the community of farmers, the three most central ecosystem components are the forest (centrality score of 1.97), trees (1.87) and wildlife (1.47), representing 79% of the centrality of all ecosystem components combined. Agroecological, conventional and large farmers attach about the same importance to the forest based on the centrality score (2.30, 1.77 and 1.86 respectively). No significant differences were found for the centrality of wildlife between agroecological farmers (centrality score of 2.01) compared to conventional (1.22) and large farmers (0.84), (p=0.32; Kruskal-Wallis). On farm trees have been discussed seperately above.

7. Intermediate ES

Intermediate services were recognised as ordinary variables 81% of the cases (38/47), indicating that farmers recognised both (i) how intermediate ES can be influenced (managed) by other factors in the system and (ii) exert an influence on other factors (mostly direct ES) in the perceived system. Soil quality has the highest centrality score out of the intermediate ES among all farmer groups. Agroecological farmers recognised 20 different factors influencing soil quality, conventional farmers 9, and large farmers 11 factors in total. Based on the community map, soil quality is most strongly influenced by manure (score of 8.6), pesticides (-4.5), limestone (3.5), plant residues (2.7) and water (2.7), representing 50% of all indegree of soil quality. Soil quality influences production (both for the market and self-consumption; score of 9.9) and water (5.0), representing 73% of all indegree of soil quality. Only agroecological farmers recognised soil cover (5/10) and pollination (3/10) as an intermediate ES, with a centrality score of 0.64 and 0.27 respectively. Four agroecological farmers (n=10) and one conventional farmer (n=9) recognised natural pest control as an intermediate ES.

Principal Components Analysis

The factors that were excluded based on multicollinearity are; the number of coffee plants and Tropical Livestock Unit, which strongly correlated (R=.967 and R=.880 respectively; Pearson's correlation; Appendix Table 5) with coffee plants; and the number of ordinary variables, which strongly correlated (R=.837) with the number of connections. The factor that was excluded based on singularity is density with 14/15 correlations with a value of $R < .3$. Two components were selected based on the components with at least three meaningful commonalties (Appendix Table 4) and illustrated on a two-dimensional diagram (Fig. 4). Loadings have been rotated using a Varimax rotation.

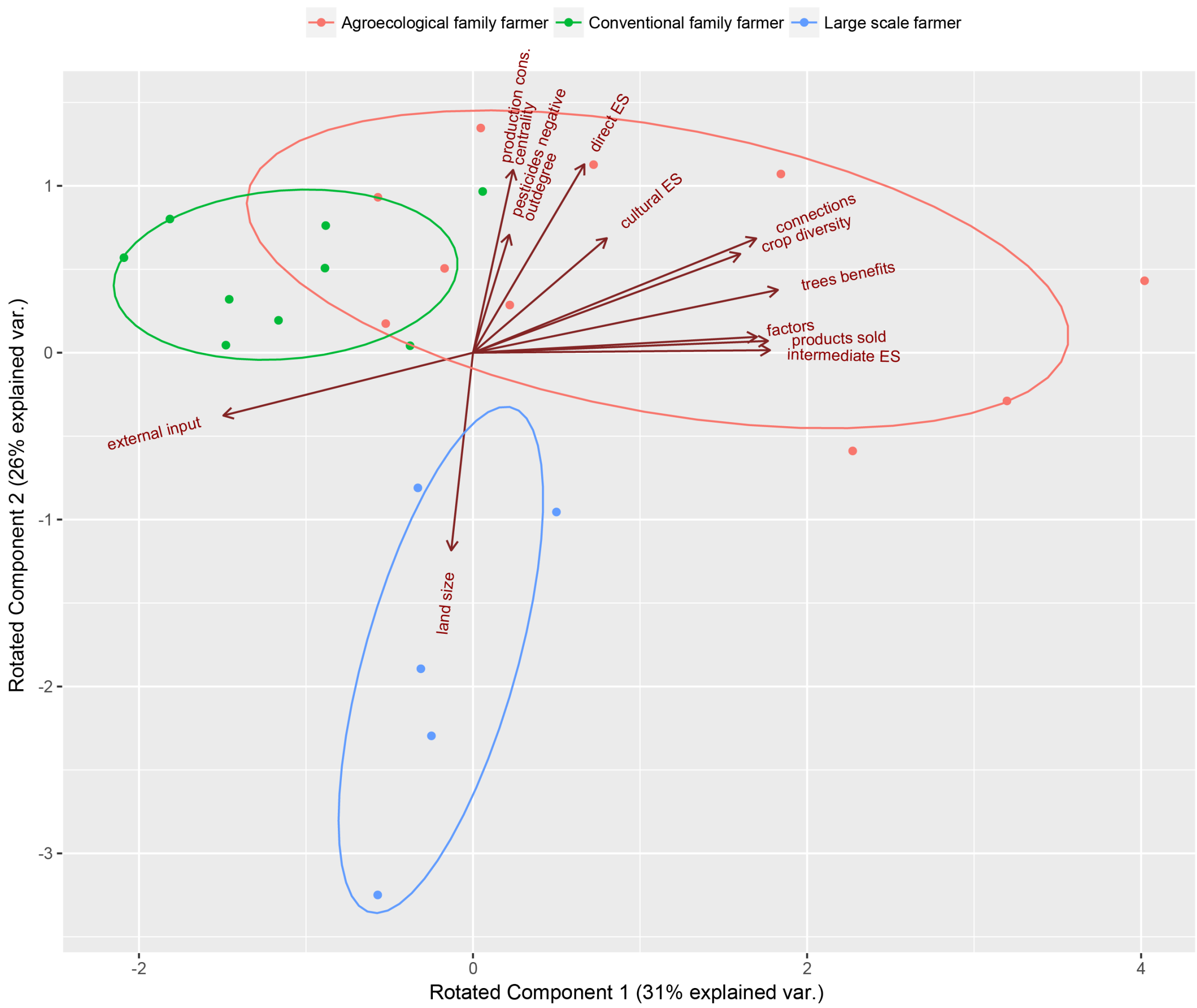

Figure 4. Rotated PCA of all (marginally) significant results from the fuzzy cognitive maps indicators, agrobiodiversity indicators and farm size. Factors with multicollinearity (R>0.8) or singularity (majority of R<.3) were excluded.

The first rotated principal component along the horizontal axis explains 31% of the total variation among all 12 variables combined and can best be interpreted as an axis of complexity of perception and farming systems. The FCM indices which correlate most with the first rotated principal component are intermediate ES, the number of factors and to some extent the number of connections. These are each indicators of complexity, describing more components and interactions in a system, typical for agroecological farming systems. These indices correlate with the agrobiodiversity indicators of the number of products sold and the crop diversity. A negative correlation along the horizontal axis are the number of external inputs identified, which indicates a more conventional farming system with high inputs and low complexity. The second rotated principal component along the vertical axis explains 26% of the total variation and can best be interpreted as an axis of farming size with family farming along the upper end and large scale farming along the lower end of the spectrum. The highest positive correlations along this axis are the centrality of the production for consumption, the perceived negative impact of pesticides and direct ES. Each of these are typical for smallholder farming. Land size correlates equally strongly in a negative direction, as a direct indication of farm size. The number of recognised cultural ES positively correlates with both components.

DISCUSSION

Our results show in general that the perception of farmers on ES and their management is highly complex and interconnected (Table 1), which has previously been suggested, but not been demonstrated in practice with an integrated model (Bennett et al. 2009, Lescourret et al. 2015). The FCM reveal farmers' understanding of the relationships between ES and different components of the agroecosystem (Fig. 4), such as management, ecosystem components and external inputs. The perception of agroecological family farmers, conventional family farmers and large scale farmers differed in many ways, representing the different farming practices. Two main trends were found among the (marginally) significant variables: a gradient of complexity and diversity along one axis and the farm size along the other axis (Fig. 4). Agroecological farmers perceived more complex farming systems and score higher on the agrobiodiversity indicators than conventional and large farmers (Table 1). Agroecological and conventional family farmers were found to have a strong peasant identity in contrast to large scale farmers (Table 2). Asking farmers about their perceived benefits of nature without an a priori defined list of options, brought forward a multiplicity of services farmers value from their agroecosystems. Farmers did not refer specifically to biodiversity as an ES, but would identify ecosystem properties such as the forest and wildlife to provide intermediate services dependent on biodiversity such as pest control, pollination and seed dispersal. The results of the study demonstrate that farmers identify direct and intermediate services that benefit themselves (excludable), such as production for consumption, health and autonomy, but also services that serve society as a whole (non-excludable), such as water, production for the market, air quality, aesthetics and peacefulness (Fisher et al. 2009). Most direct cultural ES identified are intrinsic to being a farmer, such as autonomy, lifestyle and teachings from nature (Chan et al. 2012).

The first main trend along the horizontal axis identified in the rotated principal component analysis (Fig. 4), shows a gradient among family farmers ranging from mostly conventional farmers at the lower end to agroecological farmers at the upper end. There is no clear separation between conventional and agroecological farmers, which has been identified during participatory typologies in collaboration with farmer unions in this region (Teixeira 2017 – unpublished). The horizontal gradient shows the contrast between a strong reliance on external inputs on one hand of the spectrum and an increased complexity of the farming system towards the higher end of the spectrum based on a higher number of factors, connections, intermediate ES and the number of recognised benefits from trees. Agroecological farmers also have a higher crop diversity and number of products sold (Table 1 and 2). This gradient is in accordance with the literature on characteristics that distinguish an agroecological farmer from a conventional farmer (Altieri et al. 2011, Wezel et al. 2014). In reality it is hard to draw a line between what is considered a conventional or agroecological farmer, which the data reflects. Yet, there is a clear trend showing what the agroecological transition entails. Agroecology is a movement to embody the peasant way of farming as a means to resist the influences of the Green Revolution (Hilmi 2012).

The differences among agroecological, conventional and large farmers in this study can be partly explained by the distinction between peasant farming and entrepreneurial farming (Van der Ploeg 2008). The peasant way of farming is characterised by a co-production with nature, building upon a resource base in which a diversification strategy increases ES delivery for more resilience, less reliance on external inputs, a variety of income streams from multiple crops and increased food sovereignty. The peasant condition is shaped by a continuous struggle for autonomy in the context of an omnipresent influence of the market, politics and society, to force farmers into an entrepreneurial way of farming based on the principles of the Green Revolution (Altieri et al. 2011). The second main trend in the rotated principal component analysis (Fig. 4) illustrates a clear separation along the vertical axis between family farmers on one end and large farmers on the other hand. Agroecological and conventional family farmers maintain a peasant identity by continuing to produce for consumption and value direct cultural ES more than large farmers. Large scale farmers at the other hand of the farm size spectrum follow the entrepreneurial way of farming, relying on contracted labour instead of family labour and have a larger land size, TLU and number of coffee plants (Table 1, Table 2 and Fig. 4). Family farmers also recognised a stronger negative impact of pesticides in contrast to large farmers, which can be explained by their direct usage (conventional farmers) or previous usage (agroecological farmers) in the field. In the case of the conventional family farmers it shows a paradoxical situation in which the negative consequences of pesticides are strongly recognised, however farmers continue using chemical products, since they do not see an alternative or are pressured by their landlords to use pesticides who do not tend to recognise the negative impact on health.

The differences observed between the agroecological farmers and the conventional and large farmers may reflect the results of a long-term participatory process of transition in the Zona da Mata region (Cardoso et al. 2001, Souza et al. 2010, Botelho et al. 2015). An important example of the participatory learning and knowledge exchange that have contributed to shaping the perception of agroecological farmers, is a technocratic methodology called *intercambios* (‘exchanges’ in Portuguese), initiated in collaboration with the University, the local NGO CTA-ZM and farmer unions. These gatherings are based on peasant-to-peasant learning, in which agroecological knowledge is constructed and exchanged, challenging traditional agronomic knowledge. The learning environment is strongly embedded in a cultural empowerment and redefinition of what it entails to be a peasant farmer (Zanelli et al. 2016), in which cultural ES are highly valued (Table 1). In addition the Grassroots Ecclesial Communities (CEBs), which originated during the end of the dictatorship in Brazil, have had a profound influence in the Zona da Mata in making agroecological views meaningful to farmers within a religious context through the organisation of reflection groups (Cardoso and Mendes 2015). The majority of family farmers in this study participate in a reflection group.

The significant differences between agroecological, conventional and large farmers in this study are not only about management and perception on ES, but have a cultural and spiritual basis that is strongly connected to the peasant identity (Botelho et al. 2015), to which the work of the CEBs have strongly contributed (Cardoso and Mendes 2015). Many farmers would mention God as the most important factor underlying and being connected to all factors identified, while constructing the FCMs. Due to practical constraints it was not possible to include the perceived interconnectedness of God with all that is in the FCM framework. Conventional family farmers in this region of Brazil still embody many traditional aspects that make up a peasant farmer, such as home gardens for food self-sufficiency, a strong reliance on the community for labour and a close connection to nature, yet their farming practices are evolving towards that of an entrepreneurial way of farming with high external inputs and a loss of autonomy. The remaining peasant identify of conventional family farmers is an important basis for enhancing the transition towards agroecological farming practices.

Contribution of agroecosystems

Nature conservation areas are under increasing threat by the increasing pressure on land availability for food production (Foley et al. 2005). As a result, it becomes more pertinent to increase the ES delivery of agroecosystems in a land sharing scenario (Jackson et al. 2010). Agroecosystems have already proven to be a key element for conservation of biodiversity in developed and developing countries (Baudron and Giller 2014), but still have much to improve to reach a sustainable balance between food production and environmental services (Foley et al. 2011). The benefits of ES for society as a whole are innumerable and can be further enhanced by understanding how farmers perceive and manage ES in different ways. This study demonstrates the strong potential of agroecological farmers for increasing the complexity of farming systems by building upon ecological principles and increasing biodiversity for greater ES delivery of agroecosystems. The research findings may function as a starting point for designing more sustainable farming systems, considering local perceptions. In addition, this study will facilitate providing more custom-made extension services based on the specific profiles and understanding of farmers about ES. It will also help to effectively reach out to new farmers by targeting the most relevant factors in farmers' mental constructs on ES, based on the farm categories. FCM can also be used by social organisations themselves as a participatory tool in the field to reflect upon farming practices and increase awareness about the agroecosystem.

Reflection on methodology

The Fuzzy Cognitive Maps proofed to be a useful tool for mapping a complex social-ecological system (Özesmi and Özesmi 2004, Papageorgiou and Salmeron 2013, Vasslides and Jensen 2016). The number of interviews conducted and the average number of factors and connections obtained with the FCM in this study are in line with previous studies in social environmental research (Özesmi and Özesmi 2004). The tool meets the research need identified by Lescourret et al. (2015). It is a tool that allows understanding the interactions between social and ecological systems in terms of management and ES provision. FCM remains inherently subjective, as it is based on the interpretation of the interviewer like in any other sociological research. This is not a limitation per se, only a point of attention in regards to valuing and interpreting the results. Farmers did not specify any feedback loops between components in the system such as trees that contribute to water availability, but also use up water themselves. In these cases, farmers would weigh the opposite connections against each other and specify the main trend. In one example on-farm trees were thought to contribute with a maximum weight of 0.9 to water availability, but also consume some water themselves, resulting in a final positive arrow with a weight of 0.7. During future assessments it would be better to separate these influences, so that the FCM results can also be used for scenario planning (Kok 2009). Many trends in differences among perception that appeared between the three different farmer categories, did not result in significant differences, likely due to the limited sample size. Most variables did not follow a normal distribution, which also resulted in a loss of statistical power with the usage of nonparametric tests (Field 2013). Marginally significant results were included, taking in consideration the low sample sizes and lower statistical power of the Kruskal-Wallis test. The Poisson distribution was explored as an alternative statistical model to provide a better fit to the data. Most FCM data did not meet the exact requirements of count data however, as scores are based on arbitrary numbers ranging from 1 to 5. Other statistical methods, which take in consideration spread and bounded data, may have to be explored in the future to improve the statistical testing of content related results derived from a FCM. Future research will have to explore the differences between farm types, which were not significant, but followed a trend, focusing on particular topics in detail or using larger sample sizes. FCM provides an insight into the farmers' way of thinking which can guide as a roadmap for further research. More sociological research is needed on underlying drivers to better understand how the differences between farm types came about, as well as analysing the construction of knowledge in connection to culture, including spirituality. More ecological research is needed on the mechanistic interactions between identified ES and properties, functional biodiversity and management to enhance the ES delivery of agroecosystems.

CONCLUSION

Farmers perceive ES and their management as a complex interaction of interconnected social and ecological factors. Fuzzy cognitive maps were found to be an effective tool to capture this perception. Two main trends were found among the significant results between the farmer categories: a gradient ranging from high input based systems to more complex and diverse farming systems; and a more clear separation between large scale farmers and family farmers, characterised by a peasant identity. Agroecological family farmers have a stronger mutualistic relationship with nature than conventional family and large farmers. They recognise more connections within the agroecosystem with a higher number of intermediate services, adding to the complexity of the farming system, while maintaining a higher agrobiodiversity and relying less on external inputs. On farm trees play a bigger role in the farming system, fulfilling a greater number of functions as recognised by farmers themselves. Both agroecological and conventional family farmers have a strong peasant identity, recognising more direct ES than large farmers and relying more on production for consumption. Conventional farmers, however, rely more strongly on external inputs than agroecological farmers and have a less complex perception of the agroecosystem. Large farmers in this study follow a more entrepreneurial way of farming, relying more on external inputs than agroecological farmers and acknowledging less the negative impacts of pesticides on health and the environment than family farmers. Finally, the results show the pivotal role of the farmer in creating the potential of increased ES delivery from agroecosystems. In a land sharing scenario, incentivising or rewarding agroecological farming practices shows the greatest potential for increasing ES delivery, benefiting society as a whole.

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APPENDIX

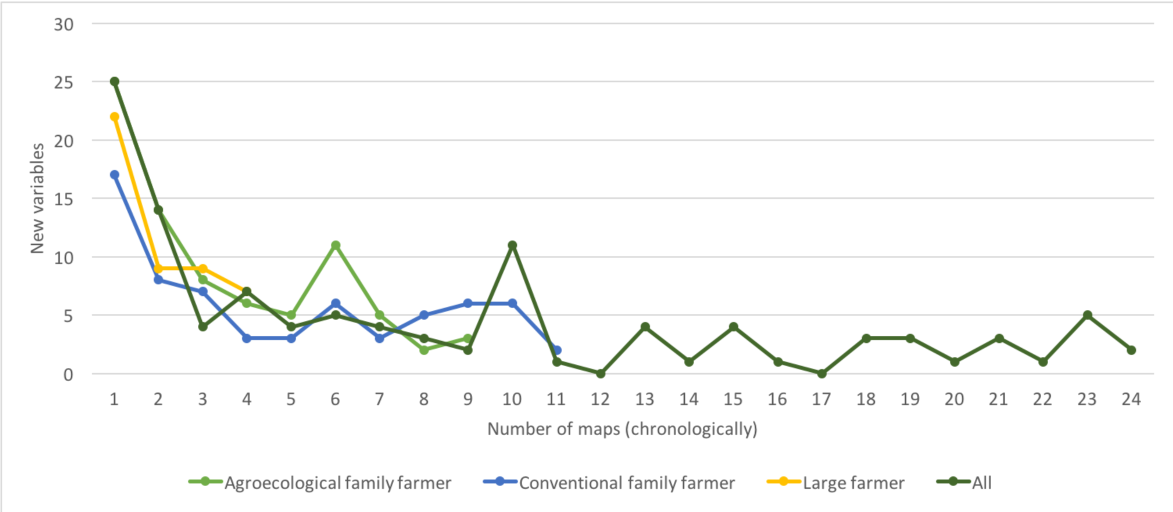

Figure 5. Accumulation curve of the number of new variables per interview on a chronological basis.

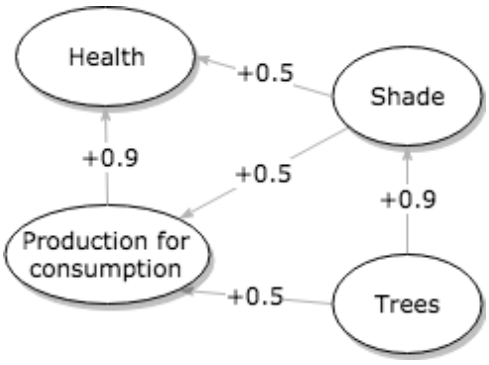

Figure 6. Example fuzzy cognitive map, based on selection from Fig. 2.

Table 3. Adjacency matrix coded from the fuzzy cognitive map in Fig. 7.

	Health	Production for consumption	Shade	Trees
Health	0	0	0	0
Production for consumption	0.9	0	0	0
Shade	0.5	0.5	0	0
Trees	0	0.5	0.9	0

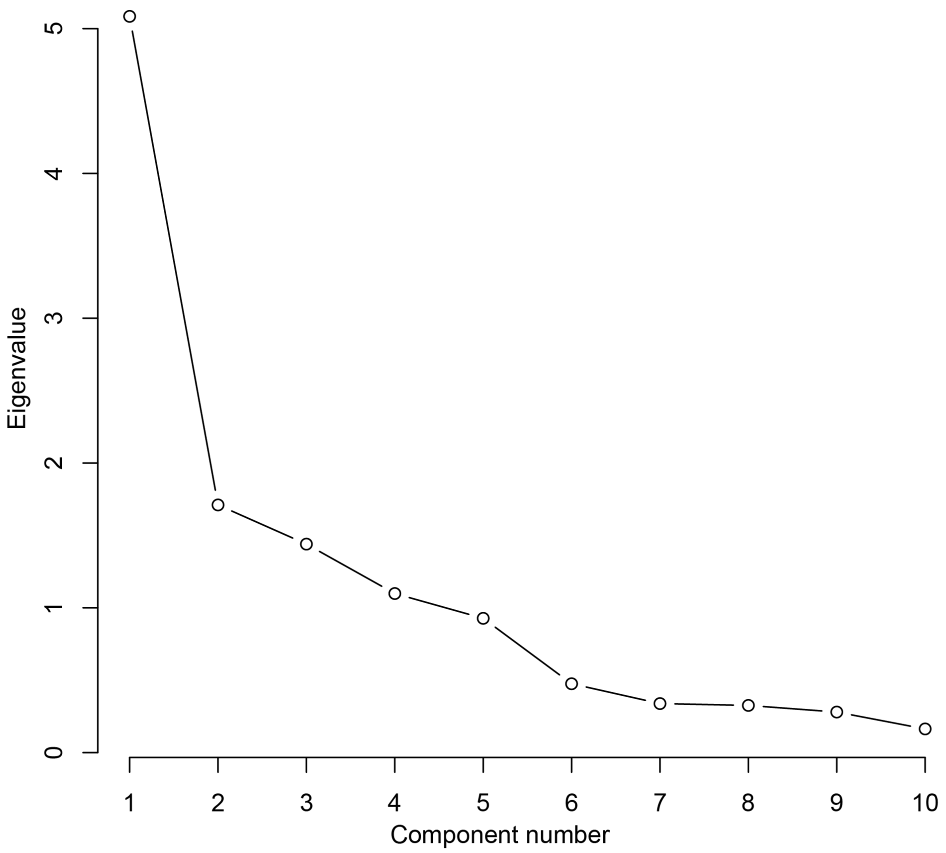

Figure 7. Scree plot for selecting the number of components as shown in PCA Fig. 4.

Table 4. Rotated component matrix showing selected factors and fit with components as shown in PCA Fig. 4.

	Rotated components	
	1	2
Factors	0.706	0.069
Crop diversity	0.665	0.427
Products sold	0.733	0.051
Trees benefits	0.758	0.272
Production consumption centrality	0.100	0.791
Direct ES	0.277	0.815
Intermediate ES	0.738	0.011
External input	-0.621	-0.272
Cultural ES	0.333	0.495
Pesticides negative outdegree	0.090	0.510
Connections	0.704	0.494
Land size	-0.054	-0.855

*Table 5. Pearson's correlation matrix for all (marginally) significant results in Table 1 and 2. * Significant at p < .05; ** Significant at p < .005;*

		density	factors	crop.diversity	products.sold	trees.benefits	production.consumption.centrality	direct.ES	intermediate.ES	external.input	cultural.ES	pesticides.negative.outdegree	connections	ordinary.variables	land.size	coffee.plants	TLU
density	Pearson Correlation	1	.118	-.065	-.100	-.084	-.035	.274	-.209	.324	.240	.079	-.182	-.228	-.175	-.157	-.155
	Sig. (2-tailed)		.584	.763	.642	.696	.871	.195	.328	.123	.259	.713	.394	.284	.414	.464	.470
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
factors	Pearson Correlation	.118	1	.473*	.465*	.360	.235	.302	.518**	-.080	.311	-.015	.618**	.403	-.097	-.146	-.137
	Sig. (2-tailed)	.584		.019	.022	.084	.269	.152	.010	.712	.140	.944	.001	.051	.650	.495	.523
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
crop.diversity	Pearson Correlation	-.065	.473*	1	.672**	.581**	.529**	.500*	.318	-.475*	.310	.180	.523**	.495*	-.372	-.407*	-.311
	Sig. (2-tailed)	.763	.019		.000	.003	.008	.013	.130	.019	.141	.399	.009	.014	.073	.048	.139
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
products.sold	Pearson Correlation	-.100	.465*	.672**	1	.461*	.275	.195	.261	-.571**	.211	.004	.322	.378	-.096	-.154	-.099
	Sig. (2-tailed)	.642	.022	.000		.023	.194	.361	.219	.004	.323	.986	.124	.069	.654	.472	.645
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
trees.benefits	Pearson Correlation	-.084	.360	.581**	.461*	1	.137	.399	.522**	-.545**	.323	.306	.723**	.757**	-.322	-.338	-.342
	Sig. (2-tailed)	.696	.084	.003	.023		.525	.053	.009	.006	.123	.146	.000	.000	.125	.106	.102
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
production.consumption.centrality	Pearson Correlation	-.035	.235	.529**	.275	.137	1	.584**	-.001	-.196	.333	.259	.443*	.289	-.579**	-.619**	-.575**
	Sig. (2-tailed)	.871	.269	.008	.194	.525		.003	.996	.358	.112	.222	.030	.171	.003	.001	.003
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
direct.ES	Pearson Correlation	.274	.302	.500*	.195	.399	.584**	1	.197	-.330	.775**	.197	.557**	.544**	-.601**	-.619**	-.541**
	Sig. (2-tailed)	.195	.152	.013	.361	.053	.003		.356	.116	.000	.357	.005	.006	.002	.001	.006
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
intermediate.ES	Pearson Correlation	-.209	.518**	.318	.261	.522**	-.001	.197	1	-.434*	.183	.267	.600**	.647**	-.144	-.125	-.188
	Sig. (2-tailed)	.328	.010	.130	.219	.009	.996	.356		.034	.392	.208	.002	.001	.502	.562	.378
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
external.input	Pearson Correlation	.324	-.080	-.475*	-.571**	-.545**	-.196	-.330	-.434*	1	-.303	-.351	-.480*	-.599**	.262	.265	.273
	Sig. (2-tailed)	.123	.712	.019	.004	.006	.358	.116	.034		.150	.093	.018	.002	.216	.211	.196
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
cultural.ES	Pearson Correlation	.240	.311	.310	.211	.323	.333	.775**	.183	-.303	1	-.089	.451*	.588**	-.220	-.253	-.212
	Sig. (2-tailed)	.259	.140	.141	.323	.123	.112	.000	.392	.150		.678	.027	.003	.301	.232	.320
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
pesticides.negative.outdegree	Pearson Correlation	.079	-.015	.180	.004	.306	.259	.197	.267	-.351	-.089	1	.357	.215	-.551**	-.483*	-.521**
	Sig. (2-tailed)	.713	.944	.399	.986	.146	.222	.357	.208	.093	.678		.087	.314	.005	.017	.009
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
connections	Pearson Correlation	-.182	.618**	.523**	.322	.723**	.443*	.557**	.600**	-.480*	.451*	.357	1	.837**	-.453*	-.481*	-.497*
	Sig. (2-tailed)	.394	.001	.009	.124	.000	.030	.005	.002	.018	.027	.087		.000	.026	.017	.014
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
ordinary.variables	Pearson Correlation	-.228	.403	.495*	.378	.757**	.289	.544**	.647**	-.599**	.588**	.215	.837**	1	-.372	-.372	-.417*
	Sig. (2-tailed)	.284	.051	.014	.069	.000	.171	.006	.001	.002	.003	.314	.000		.073	.073	.043
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
land.size	Pearson Correlation	-.175	-.097	-.372	-.096	-.322	-.579**	-.601**	-.144	.262	-.220	-.551**	-.453*	-.372	1	.967**	.880**
	Sig. (2-tailed)	.414	.650	.073	.654	.125	.003	.002	.502	.216	.301	.005	.026	.073		.000	.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
coffee.plants	Pearson Correlation	-.157	-.146	-.407*	-.154	-.338	-.619**	-.619**	-.125	.265	-.253	-.483*	-.481*	-.372	.967**	1	.775**
	Sig. (2-tailed)	.464	.495	.048	.472	.106	.001	.001	.562	.211	.232	.017	.017	.073	.000		.000
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24
TLU	Pearson Correlation	-.155	-.137	-.311	-.099	-.342	-.575**	-.541**	-.188	.273	-.212	-.521**	-.497*	-.417*	.880**	.775**	1
	Sig. (2-tailed)	.470	.523	.139	.645	.102	.003	.006	.378	.196	.320	.009	.014	.043	.000	.000	
	N	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24	24