Fuzzy cognitive maps as a tool to assess ecosystem services considering farmers' knowledge

Mapas cognitivos fuzzy como uma ferramenta para a avaliação de serviços ecossistêmicos considerando o conhecimento dos agricultores

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Abstract

Farming systems can be understood as complex social-ecological systems, capable of providing a wide array of ecosystem services. Understanding the mechanisms and functioning behind the provision of multiple Ecosystem services is an important step for the (re-)design of more sustainable and efficient farming systems. Farmers play an important role, as they are responsible for managing multiple ecosystem services, and are direct beneficiaries. Therefore, in a research committed with the development of agroecological farming systems it is crucial to involve farmers as co-creators, considering their knowledge and needs. For that, it is necessary to use methods that make explicit farmers perceptions on multiple Ecosystem Services. The objective was to analyse if Fuzzy Cognitive Maps can be useful in involving farmers and explaining their perception. The maps were constructed with agroecological farmers in the region of Zona da Mata, and the results suggest that farmers have multiple and complex perceptions on agroecosystems and their services, and the maps were efficient in analyzing such complexity it is a and to reflect on how possible changes in the ecosystem can affect the provision of different benefits provided by nature.

Keywords: local knowledge, agroecology, social-ecological systems, farming systems

Resumo

Sistemas agrários podem ser entendidos como sistemas sócio-ecológicos complexos, capazes de prover um amplo portfólio de Serviços Ecosistêmicos. Entender os mecanismos e funcionamento por trás dos múltiplos serviços dos ecossistemas é um passo importante para o (re-)desenho de sistemas de produção agrária. Agricultores(as) são responsáveis por manejar estes múltiplos serviços e são beneficiários diretos deles. Portanto, em uma pesquisa comprometida com o desenvolvimento de sistemas agrários agroecológicos é crucial envolvêr os agricultores/as como co-criadores no processo de investigação e consider seus conhecimentos e necessidades. Para isto, deve-se utilizar métodos que permitam explicitar a percepção dos agricultores sobre múltiplos Serviços Ecosistêmicos. O objetivo foi analisar se Mapas Mentais Cognitivos seriam úteis nesta explicitação e no envolvimento com agricultores. Para isso, foram construídos mapas com agricultores agroecológicos na região da Zona da Mata. Os Resultados demonstraram que os agricultores/as possuem percepções múltiplas e complexas sobre os agroecosistemas e seus serviços e que os mapas foram eficientes para analisar tal complexidade e para a reflexão decomo possíveis mudanças nos ecosistemas podem afetar o fornecimento de diferentes benefícios providos pela natureza.

Palavras-chave: conhecimento local, agroecologia, sistemas sócio-ecológicos, sistemas de produção

Introduction

The concept of ecosystem services (ES), the benefits for people derived from nature, has been widely adopted among the scientific community since the Introduction by the Millennium Ecosystem Assessment (MEA, 2005). MEA (2005) explored the links between ecosystems and human well-being and categorized ES as provisioning, regulating, supporting and cultural services. Exploring the mechanisms and functioning behind multiple ES can be relevant for the (re-) design of more efficient and sustainable farming systems in human-modified landscapes, capable to provide food production, environmental conservation and to improve quality of life. For that, it is necessary to consider the complexity of the systems, the possible synergies and trade-offs associated with bundles of ES and the influence of multiple factors, such as natural environmental conditions, management practices and the diversity of plants and other living organisms (DURU; THEROND; FARES, 2015). The analysis of a single service can lead to bias conclusions. For instance, eucalyptus plantations have a much higher carbon storage rate than natural forests, although it can negatively affect other ecosystem functions such as hydraulic dynamics and habitat for native biodiversity. So far, the ES framework has been restrained by a mostly exclusive application from a top-down scientific perspective, tending towards investigating the dynamics of individual services (BENNETT; PETERSON; GORDON, 2009) and quantifying their value only in economic terms (SCHRÖTER et al., 2014). To actively involve farmers and their knowledge in the research is an important step to have a more holistic and complete view on the systems, as well as to increase the chances for the adoption of possible innovations on the ground (DURU; THEROND; FARES, 2015). Farmers are greatly responsible for managing multiple ES and are directly affected by changes in the level of ES provision. Our suggestion is to use Fuzzy Cognitive Maps (FCM) as a social-ecological research tool to make farmers' perception and management of multiple ES explicit (KOSKO, 1986). That way, it is possible to identify the most valued ES by farmers as well as the main factors and interactions influencing the provision of such services. The objective of this work was to analyse if FCM can be useful in involving farmers and their knowledge, explaining their perception, and helping to understand the linkages between human and nature towards the development of more sustainable farming systems.

Methodology

The use of FCM allows to map belief systems, making implicit assumptions explicit and takes in consideration nonlinear interactions and feedback loops of a system (JETTER; KOK, 2014). A FCM consists of concepts (nodes) and connections (edges), which can be quantified in terms of weights in a normalized range of [-1,+1] to represent the degree of causal influence between the concepts (KOSKO, 1986). The result is a representation of a system, including causal relationships and feedback loops. The maps are coded into adjacency matrices, in which both the rows and columns are indexed by the concepts mentioned in the map. FCM can be analyzed both in a structural manner and with a content-based interpretation. The structural indices are calculated using graph theory and give insights into how social actors perceive the system. Common indices derived from a FCM analysis are the number of concepts, number of connections, density, complexity and hierarchy index. A system can consist of many driving variables, making it hierarchical, or of more mediating variables, making the system more democratic or flat. Individual concepts appearing in a map are analyzed based on the type of variable, the in- and outdegree and the centrality score. The three variable types are transmitter variables (only outgoing edges), receiver variables (only incoming edges) and ordinary variables (both in- and outgoing variables). The variable type determines whether a concept either is a driving function, a utility variable, or a mediating function respectively, giving insight into how a social actor considers the concept to be manageable, to be influenced, or both. The in- and outdegree of a concept are the sum of the weight of incoming and outgoing edges respectively, indicating the relative influence of a concept in the system. The centrality score per concept is calculated by the absolute sum of the in- and outdegree, indicating the relative importance of a factor in the system (ÖZESMI; ÖZESMI, 2004).

Figure 1 A Fuzzy Cognitive Map constructed in the field with an agroecological farmer

FCM are easy and fast to conduct in the field, making them suitable for quick assessments of complex social-ecological systems. Non-expert social actors tend to quickly comprehend the Methodology, allowing the interaction with a facilitator constructing a FCM to be smooth and well representative of the farmer's belief system (JETTER; KOK, 2014).

We conducted 10 maps with agroecological family farmers in Zona da Mata Mineira. Agroecological farmers have a diversified production, do not use pesticides and participate in social movements. During the construction of the maps all the family, including children and youth, participated.

Results and discussion

It took on average an hour to conduct a FCM with an agroecological farmer. Young farmers tend to understand and adopt the Methodology more quickly than older farmers. The feedback of farmers participating in the construction of a FCM ranged from being positive to very positive. The most relevant added value identified by farmers in participating with the research, is that the interview gives insight into their own understanding of the management of their agroecosystem, which they have never sat down to think about themselves in detail. The participatory process helps farmers to put together many fragmented pieces of information and beliefs into a holistic overview, constructed from their own knowledge. Agroecological farmers have an integrated approach to manage the agroecosystem, however the management and perception is usually implicit and therefore not visible to outsiders. FCM make this mental representation explicit, for farmers themselves and others to reflect upon.

The results of the FCM (fig. 2), based on fig. 1, show the many connections (40) and concepts (25) that were identified by an agroecological and organic farmer in Araponga, MG. The size of the circles indicates the relative centrality and the thickness of the arrows the relative strength of the connections. The grey arrows indicate positive and red arrows negative relationships. ES were classified as direct or intermediate services, according to how they generate benefits for people. Other factors were classified as ecosystem properties, management practices, social-economic aspects and external inputs.

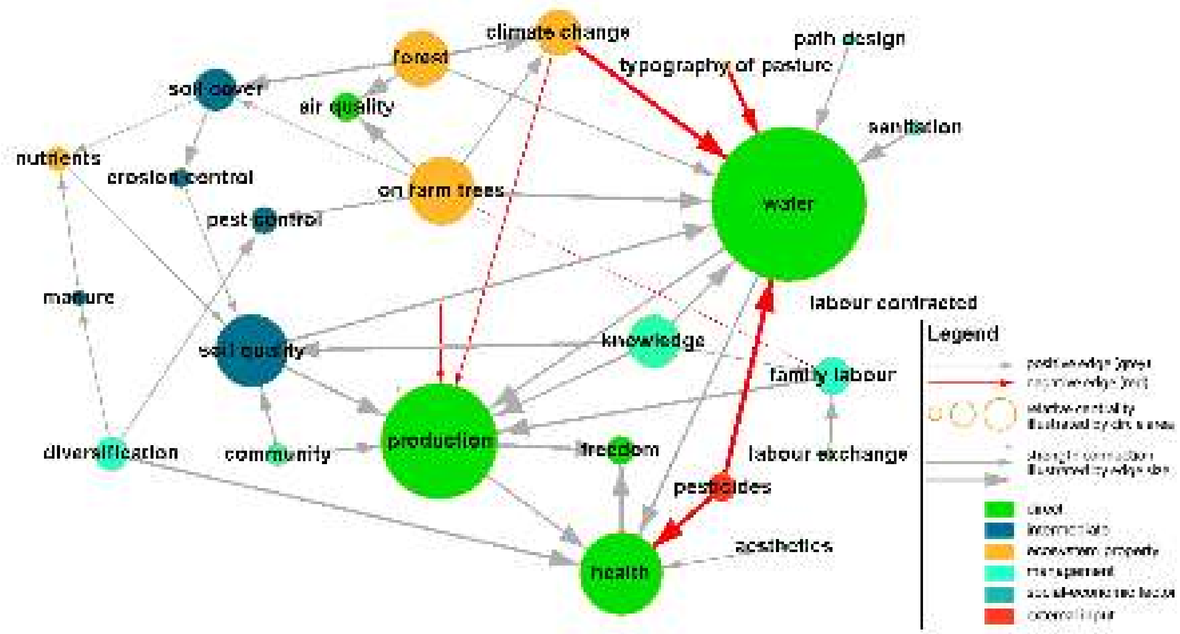

Figure 2 The analysis of a FCM based on fig. 1 using relative centrality scores and in-and outdegree per concept

Water is most central, as for most farmers in this region, where low rainfall has caused water scarcity since the last 5 years. The concepts on-farm-trees, forest and knowledge and diversification have the highest outdegree, meaning they are the strongest drivers in the system. The multiple functions recognised by on-farm-trees and the forest show the strong reliance on natural farming practices. The negative connections between on-farm-trees and production and family labour, also show the perceived downsides in agroforestry systems of some reduction in coffee (the cash crop) production and increased labour. However, the arrow is weak, indicating that some negative impact of trees are clearly outweighed by the perceived positive impacts on production mediated through water availability, improved soil quality and natural pest control. The direct and indirect ES that contribute to production are numerous and there is no reliance on external inputs such as chemical fertilizers. The farmer identified the strong negative (red thick arrows) impacts of pesticides on water and health, even though the farmer does not use these himself. Moreover, social factors as family labour availability, access to knowledge and involvement of the community (blue circles) positively influences soil quality, cash crop production and water regulation.

The results of the maps can easily be understood and shared with other social actors. The maps made with some of the farmers were presented to bachelor agronomy students during a workshop on Agroecology at the Federal University of Viçosa (November 2016). Students were surprised by the complexity and multiplicity of perceptions on agroecosystems by agroecological farmers, superseding their perceptions of farmer's knowledge and level of comprehension. The maps were also used during an interactive workshop at the Center of Alternative Technology in Zona da Mata (CTA-ZM), to make other farmers think and reflect upon the agroecosystem services and management. Using the maps as a reference, farmers would explain why they do or do not agree with certain connections, their weight and would identify missing concepts in their own understanding of an agroecosystem.

Conclusion

To sum up, FCM were an effective tool to make farmers' perception and management of multiple ES and their interconnectedness explicit. FCM allowed to identify the most relevant ES for local stakeholders (water) as well as the main driving forces in the system, as on-farm trees, forest knowledge and diversification. FCM is a promising tool to build knowledge on ES and to include farmers as co-creators in the development of sustainable farming systems. For that, it is necessary to build a more horizontal relationship between scientists and local actors, and promote interdisciplinarity by integrating different disciplines and fields of knowledge.

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