A mixed method approach to characterize and explain the pursuit of agroecological principles at Flemish beef farms

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Abstract: *Several authors propose agroecology as a more sustainable development path for livestock systems in temperate regions, yet the relevance of agroecology to the Flemish beef sector remains largely unexplored. In order to identify what actions are taken to pursue agroecological principles by what kind of farmers and on what kind of farms and to explain why this is so, we have developed a mixed methods research approach. We collect mental models of farm functioning through direct elicitation of cognitive maps with individual farmers. We seek to complement these with quantitative measures based on an accompanying structured farm questionnaire and characterize how and to what extent agroecological principles are pursued at the farm level in semi-structured interviews. From the more complete but still empirical account of reality generated by this triple approach, we identify patterns to corroborate a grounded theory on what sustains or limits the implementation of agroecological principles at Flemish beef farms. We extensively discuss the advantages and limits of this method of data gathering, processing and analysis from a critical realist perspective.*

Keywords: *Agroecology, Livestock Systems, Mixed Methods Research, Cognitive Mapping, Critical Realism*

1. Introduction

The Flemish beef sector faces multiple sources of growing uncertainty and societal pressure (Brouwers *et al.*, 2017; Vrints & Deuninck, 2015). Several authors propose agroecology as a more sustainable development path for livestock systems in temperate regions (Bonaudo *et al.*, 2014; B. Dumont *et al.*, 2013; Wezel & Peeters, 2014), yet the relevance of agroecology to the Flemish beef sector remains largely unexplored. The environmental and political economic conditions are very different from those in tropical regions, where agroecology as a practice found its roots (e. g. Gliessman *et al.*, 1981). Biology-inspired systems based on careful integration of plants and animals in time and space, have been receding for well over a century in these regions (Mazoyer & Roudart, 2006; Peeters, 2010). It is therefore generally assumed that in Flanders cattle occur on highly specialized, capital and input intensive firms, nonetheless, more integrated and diversified systems do exist also. Since the implementation of agroecological principles requires contextualized solutions, agroecological practices will most likely take a particular form in this region. In this study, we seek to identify what actions are taken to pursue agroecological principles by what kind of farmers and on what kind of farms. The objective is to uncover the mechanisms and conditions that sustain or limit the implementation of agroecological principles at the farm level in Flanders.

In contrast to widespread assumption, both quantitative and qualitative approaches are regularly used within the natural and social sciences, be it often for different purposes and to a different extent (Mcevoy & Richards, 2006; Nuijten, 2011). Still, due to persistent disciplinary boundaries social and technical issues in agricultural research have predominantly been dealt with separately (Darnhofer *et al.*, 2016; Lacoste *et al.*, 2017; Vanwindekens *et al.*, 2013). Agroecology encompasses the holistic technical and social reconfiguration of farming systems. Studying the absence or presence of agroecology on livestock farms would as a result necessarily involve capturing both the social and the technical aspects of farming in their interconnectedness. For such an interdisciplinary endeavor, we have chosen to mix and combine quantitative and qualitative research techniques, methods, concepts and language into a single study (Creswell & Clark, 2007).

The aim of this paper is to develop and discuss a mixed methods approach for comparative and exploratory analysis. First, we propose a mental modelling approach to capture differences in farmers' perceptions of their system (section 2.1). To grasp the 'agroecologicalness'[1] of a farmer's practice, we argue that a qualitative approach is most appropriate and develop an interpretative method (see section 2.2). But still we are aware that a quantitative approach can not only facilitate the characterization of farms, but also serve to situate our case study farms within the broader cattle farm population. We also collect farm indicator scores through a farm-survey method (section 2.3). Based on a thorough literature review of possible qualitative and quantitative methods, we present in the result section a mixed method design consisting of a smart combination of these three methods. In the discussion section, we look at the potential advantages and limitations of this approach to answer our research questions.

Mixed-methods research can be justified within any research paradigm (Venkatesh *et al.*, 2016), but our approach is informed by a critical realist philosophy. Critical realism retains an ontological realism while accepting a form of epistemological relativism or constructivism (Maxwell & Mittapalli, 2010). It recognizes that our access to this world is limited and always mediated by our perceptual and theoretical lenses. It accepts epistemic relativity (that knowledge is always local and historical), but not judgmental relativity (that all viewpoints must be equally valid). It accepts the existence of different types of objects of knowledge—physical, social, and conceptual—which have different ontological and epistemological characteristics. It therefore requires a range of different research methods and methodologies to access them. For research objects characterized by an important degree of complexity, such as beef farms, a mixed-methods research strategy is probably the right approach, and critical realism supports this (Mingers *et al.*, 2013). The purpose of using multiple methods lies not so much in 'proving' the empirical findings from one method with the empirical findings of another, but rather to learn what these lenses let us see and not see, by comparing the views that different lenses convey. The idea is to set up a dialogue between diverse perspectives on the phenomena being studied, so that both a deeper and a broader understanding is gained (Maxwell & Mittapalli, 2010).

2. Selected methods.

[1] We use this term to signal that we are appreciative of the different interpretations that the concept of agroecology has come to evoke (Norder, Lamine, Bellon, & Brandenburg, 2016). It is not our intent to appropriate the term but rather to discover what it may mean in the Flemish bovine sector by engaging with farmers.

We argue that the following three methods presented in this section can be complementary, they generate different views on the same objects of analysis and can thus help us uncover alternative characteristics of the same layered reality.

2.1. Characterizing farmers' perceptions: a cognitive mapping approach

Farmers' perceptions are supposed to play an important role in management decisions (Darnhofer *et al.*, 2016; Ploeg, 2010). Therefore we analyze actors' local knowledge and beliefs. Mental modelling approaches are particularly suited for that end. Cognitive mapping is a family of semi-qualitative methods to obtain and condense qualitative knowledge of farm functioning into association matrices, which properties can be studied in a quantitative way. Cognitive mapping has been used in numerous recent publications for both analytic and transdisciplinary purposes to integrate farmers' knowledge into systemic representations that visualize the interconnectedness of both technical and social aspects of farm functioning (Akimowicz *et al.*, 2016; Bijttebier *et al.*, 2016; Christen *et al.*, 2015; Fairweather & Hunt, 2011; Garini *et al.*, 2017; Isaac *et al.*, 2009; Papageorgiou *et al.*, 2013; Popper *et al.*, 1996; Rajaram & Das, 2010; Salliou & Barnaud, 2017; Van Winsen *et al.*, 2013; Vanwindekens *et al.*, 2014). Theoretically embedded in graph theory, it is flexible enough to allow cross-model comparisons of actors' mental representations (Akimowicz *et al.*, 2016). Cognitive maps are directed graphs consisting of defined variables (nodes) and causal relationships between these variables (edges). The person making the cognitive map decides what the important variables are which affect the system under study and the relationships among these variables indicating the relative strength of the relationships with a number between −1 and 1. The map may consist of variables that refer to measurable physical quantities, but also to more complex aggregate and abstract ideas (Özesmi & Özesmi, 2004).

There are numerous ways to construct cognitive maps, and in fact, despite the widespread popularity of these techniques, there is currently no consensus within the literature concerning the most appropriate way to elicit actors' causal belief systems[2] (Hodgkinson *et al.*, 2004). Our goal is to obtain cognitive maps suitable for comparison across cases which are fair and detailed representations of how farmers think different aspects of their farm are related, specifically those aspects addressed by agroecological principles. This led us to prefer a direct structured elicitation with the free-hand method, as exemplified in the farm studies of Akimowicz *et al.* (2016) and Fairweather (2010). In section 3.2 we elaborate how these maps are practically collected and analyzed in this study.

2.2. Characterizing the pursuit of agroecological principles: an interpretative method

To disclose what supports or limits the application of agroecological insights on our case study farms, a method needs to be developed to estimate the current and actual implementation of these insights. Simply browsing a checklist or a specific set of practices will not do as agroecology involves the combinations of strategies specifically adapted to the local context. In the Flemish context these are not at hand in advance. Agroecological principles can serve as a more flexible footing for our inquiries into the presence of agroecological practices on the farm, yet a less structured and more interpretative approach is then appropriate. We share the view of Brym & Reeve (2016) that the appropriate use of agroecology as a practice must include the allowance for a developmental process towards sustainability, otherwise practicing agroecology would necessarily lead to desirable outcomes. It would not only take large efforts to create and apply an on-farm agroecological assessment tool (e. g. Botreau *et al.*, 2014), but it would also be unnecessary for our inquiry:

[2] For a wider discussion on the distinction and appropriateness of the various elicitation methods see for example Hodgkinson & Clarkson, (2005) and Laukkanen (2012).

our interest lies in identifying the means of agroecology, not whether these are effective in reaching the ends.

We thus consider any action taken at the farm level that is perceived to further agroecological principles as an agroecological practice, irrespective of whether this action is successful in attaining an improved state of affairs. Once actions are identified for each principle at each farm, we can group farms by looking at the coherence of farmers actions. We acknowledge that there is a qualitative difference between actions that are rather modest alterations to the production system, and actions which include a complete reconfiguration of food systems. This difference is commonly referred to in the literature with the concepts of Efficiency, Substitution and Redesign (Hill & MacRae, 1996). This framework may be of use as a descriptive tool to place and compare farms along a continuous gradient towards agroecological transition based on the actions identified in semi-structured interviews. This presupposes however that there is such a set of agroecological principles, yet the formulation of principles is an on-going process in the community (Altieri, 1995; Bonaudo *et al.*, 2014; Debruyne *et al.*, 2017; B. Dumont *et al.*, 2013; FAO, 2014; Stassart *et al.*, 2012; Third World Network & SOCLA, 2015; Wezel & Peeters, 2014). In part 3.2 we have proposed a set of 13 principles to meet the requirements of our study and use them in a semi-structured interview.

2.3 Characterizing farms: a traditional quantitative questionnaire.

Quantitative methods using indicators are still the mainstream approach to grasp what is owned, done or thought, by whom, where and when in a systematic way (Lacoste *et al.*, 2017). While qualitative approaches may be pertinent to identify farmers' perceptions and agroecological practices on our case study farms, we have no such information at the cattle farm population level. As we can rely on a very large dataset containing quantitative information on a sizable and representative sample of cattle farms by NIS-ADSEI (N=24.459), a structured survey, that obtains similar information of our case study farms will be of use. This will allow to situate the case study farms within the larger population and it provides an additional account of what is happening on the farm with measures deemed independent from the farmer's and researchers understanding.

3. Results

In this section we present an approach which combines the three above-mentioned methods in one design. Figure 1 shows the research process in diagrammatic form.

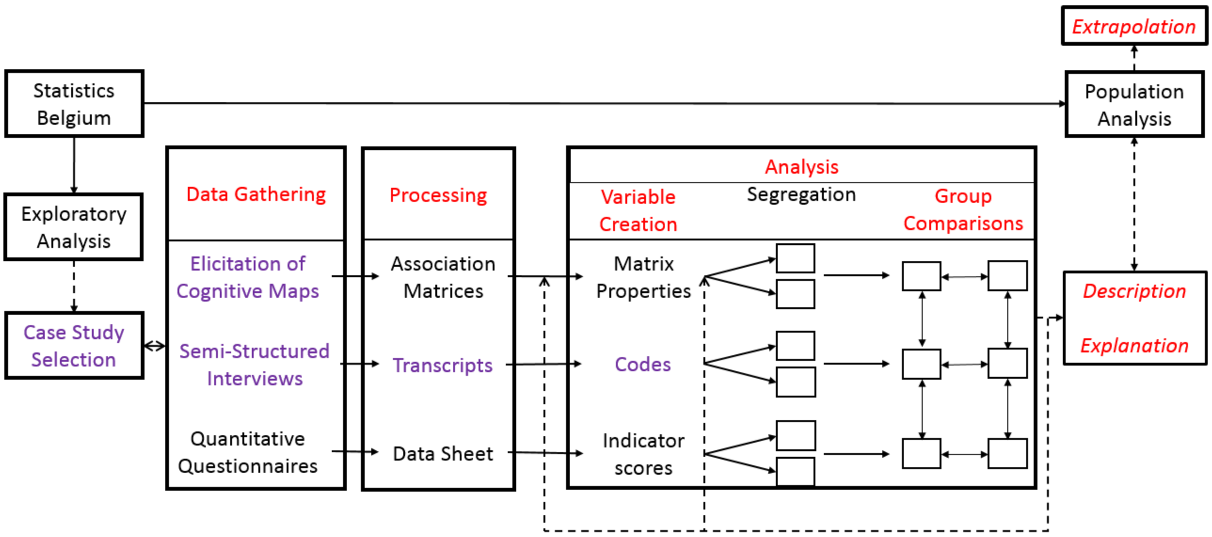

Figure 1 Diagrammatic representation of the research process. Steps in black are mainly of quantitative nature, in purple mainly of qualitative nature, and in red of mixed nature. In contrast to the full lines that represent steps where data flow, are juxtaposed or transformed, the dashed lines represent inferences that influence these data transformations: based on previous observations new hypotheses are made, which in turn will inform data gathering and analyses.

Overall the method consists of four interacting steps: case study selection, data gathering, data processing and data analysis. Informed by prior analyses of quantitative data on a large number of cattle farms in Belgium made available by Statistics Belgium, we established a stratified purposive sampling strategy to select 35 farmers for interview. Each interview consists of five distinct steps: (i) after a series of introductory open-ended questions, (ii) we assist the farmer in drawing a cognitive map of his/her farm, (iii) then the farmer is confronted with agroecological principles in semi-structured interview format, (iv) then the farmer is asked to fill out a structured survey form, (v) after which we ask the farm for referrals of other beef farmers. We thus collect information on our case study farms in three distinct formats. These data are then processed and analyzed sequentially to describe the whole sample of farms and then group farms based on indicators, practices mentioned and elicited relations separately. After this initial description the data are triangulated in order to identify correspondences and discrepancies between the views that these different methods grant us on the studied phenomena. Based on these insights new codes, indicators and grouping criteria are established, in order to identify new patterns within the data in an iterative loop. These analyses are supposed to lead to both a more complete description of the farms, the farmers and their practices, and to an explanation on what sustains or limits the implementation of agroecological principles at these beef farms. A cross-reference of the survey data (structured questionnaire) and the Belgian Statistics dataset allows us to situate the identified sample groups of farms within the wider farm population, and to extrapolate our findings. We will now explain each phase in depth.

3.1 Case study selection

A preliminary analysis of Belgian survey data from the year 2011 provided by Belgium Statistics revealed large diversity of cattle farms along multiple dimensions such as for instance scale, land use, degree of specialization, marketing strategies. Such a diversity is hard to represent in a small sample, and if one was to sample randomly organic cattle farms, on which purportedly agroecological principles are pursued to a significant extent, it would in all likelihood not turn up in the sample as they are extremely rare in Flanders (Samborski & Van Bellegem, 2016). To identify the relations that sustain or limit the implementation of agroecological principles, we want to compare instances of differing ‘agroecologicalness’.

This is done with a stratified purposive sampling design, by selecting 35 farms along the range of three axes *a priori* established: organic/non-organic, short-chain-marketing/conventional marketing, specialized beef production/mixed activities. To get into contact with farmers, we rely on existing farmer networks and on Snowball sampling[3]. Halfway through the interviews a moment of evaluation with ILVO experts familiar with the beef sector is scheduled to examine which strata of farms need further investigation.

3.2 Data gathering

To familiarize ourselves with each situation we ask a series of open-ended questions on the farm's history, current agricultural activities, perceived strengths and weaknesses of the farm, and perspectives on the future development of the farm. After this social introduction, we proceed to the elicitation of the cognitive map. For structured methods, the researcher first has to devise a concept list or pool of typically 45 to 55 concepts, The respondents are then instructed to pick, from the shared pool, their personal subsets of concepts, perceived subjectively most important or relevant (Laukkanen, 2012). Taking the advice of Markóczy & Goldberg (1995), we created a preliminary concept pool and tested this list in four pilot interviews. The preliminary concept pool contained 63 variables and was derived from completed interviews with seven Flemish organic beef farmers, conducted for the ADLO-project "*Bio in Beeld*" (Bijttebier *et al.*, 2016) which identified relevant factors influencing farmer's decision making, supplemented with factors used in the study of John Fairweather (2010). Based on the elicitation process itself and the cognitive maps these farmers drew, we reflected upon the validity of the concepts and concept pool as a whole. The concepts had to be variable, unambiguously understood, unduplicated, preferably related to agroecological principles, and cover multiple aspects of farming rather than merely economic, merely technical, or merely psycho-social aspects of farming. Through merging, reformulating and scrapping of concepts, we established a list of 48 concepts (Table 1).

Table 1 Translated list of concepts used for cognitive mapping.

Technical Results	Soil cultivation	Regulatory requirements
Other livestock	Soil organic matter	Accounting/administration
Meat quality	Crop Diversity in time and space	Hygiene and food security
Animal handling and welfare	Available land	Technical innovation
Animal Resilience	Buying fodder	Hired labor
Animal diseases, plagues and deaths	Share of concentrates in ration	Knowledge network
Medical interventions	Cash crops	Co-operation with other farmers
Total yearly meat production	Renewable Energy	Activities outside agriculture
Stable Infrastructure	Direct Sale	Continuity enterprise/succession
Nutrient emissions and losses	Product and sale channel diversity	Work pressure
Stocking rate	Investment	Time spent on the Farm
Use of manure	Subsidies	Contact with consumers
Artificial fertilizers	Pricing	Personal satisfaction
Pesticides	Income	Firm image
Biodiversity	Debt	Regional Embeddedness
Roughage Quality	Business expansion	Autonomy

Cognitive maps are then obtained as follows: first, the interviewee is explained how to draw their map by using an unrelated map. Once the interviewees understand the process of constructing a cognitive map, they are asked to sort all the concepts into three piles: one for

[3] I*. e.* by asking interviewees to give referrals to other beef farmers who may be interested to participated with very similar or very different practices (Goodman, 1961)

the factors important to their farming system, one for the factors unimportant in their farming system and the remainder for the factors that were of some importance in their farming system. The farmers then make their own causal maps. They are asked to choose any cards from the important pile and put them on a piece of A2 paper. When each farmer has about four factors on the paper he or she is given a pen and asked to draw the signed (+/-) causal connections between those factors in order to show how they are related. In the case of a farm couple, each farmer is given a pen. Other factors are then added to the emerging map. Farmers build up their causal map by adding in factors from the sorted piles. They are asked to incorporate not more than twenty important factors, large maps tend to return too many omission errors (Markóczy & Goldberg, 1995). It is important that each new factor is considered for what it causes and, in turn, what causes it. Each farmer is told that there are no right or wrong answers with this process, and that causal mapping is a process designed to allow the farmers as experts to tell us about their farming system. Comments or explanations made by the farmers are recorded. During the course of the study, we will ask subjects whether anything is missing as a way of confirming the completeness of the list.

Second, we characterize the pursuit of agroecological principles at the farm level simply by confronting the farmer in semi-structured interview format with agroecological principles, and asking the farmer what actions he or she takes to practice this. We invite the farmer to use their own cognitive map as a tool to tell us how a specific action impacts their farming system. This will allow us to analyze these interviews through the concepts used for the mapping exercise. We listed principles mentioned in the literature and considered each principle in the light of the requirements of our approach This meant asking if the principle was covering a theme commonly discussed in agroecological literature (A. M. Dumont *et al.*, 2016), if a diversity of actions could be undertaken at the level of the livestock farm and if the principle can be put in language comprehensible to the respondent. This led us to establish a set of thirteen principles, derived from the literature and tested for comprehensibility in four pilot interviews with beef farmers (Table 2). The list is a translation of the five goals of agroecology for livestock systems proposed by the report of the International Symposium on Agroecology for Food Security and Nutrition (FAO, 2014), which was an adaptation of the principles for livestock systems proposed by B. Dumont *et al.* (2013). To these ecological principles we reformulate a couple of principles proposed by Debruyne *et al.* (2017) which is in turn an effort to make the principles proposed by Stassart *et al.* (2012) more comprehensible in the Flemish context, and add in the same fashion new principles to cover the important socio-economic themes associated with agroecology identified by A. M. Dumont *et al.* (2016).

Table 2 Translation of list of agroecological principles used in the semi-structured interviews.

1. Strengthen animal health in an integrated manner
2. Close nutrient cycles
3. Maintain a high diversity of species and genetic varieties in time and space
4. Preserve and use biodiversity
5. Reduce the use of external chemical inputs
6. Increase the resilience and adaptability of the farm-ecosystem
7. Strive for financial independence and control over economic and technical decisions
8. Strive for autonomy from powerful input suppliers and purchasers
9. Exchange knowledge from a diversity of sources to resolve problems
10. Maintain the social network on the countryside
11. Strengthen the bonds between producers and consumers
12. Create locally embedded food systems of production and consumption
13. Divide the burdens and the benefits of food production and consumption equitably

Finally, a structured questionnaire is handed over to the farmer to obtain a set of quantitative measures. This survey form registers indicators on herd composition, labor force, land use, machinery at the farm, organic production, non-agricultural activities, short-chain marketing. At the end of the interview we ask the respondents if they can give the contact details of very similar and contrasting beef farmers, to enlarge our pool of farms to sample from.

The presented method of data gathering has been tested in four pilot interviews with beef farmers, varying slightly in interview guides, concepts, principles and sequence of methods. While the interview length varied considerably, we estimate that the interviews as it is now proposed can be completed within two hours.

3.3 Processing and analysis

After each interview, the collected cognitive maps are converted into association matrices and the information gathered through the structured surveys are turned into datasheets identical to the format of the dataset provided by Belgian Statistics. The semi-structured interviews (the introductory questions and confrontation with agroecological principles) are fully transcribed. The data generated by different methods contain information on the same phenomena and the results that each method yields are now triangulated in iterative fashion. The whole analytical process is documented by writing memo's on the patterns identified, the formulated hypotheses, and the choices made in coding and variable selection. The analysis consists in three distinct and repeated steps.

STEP 1: Variable creation

From this association matrices, interview transcripts and data sheets a whole host of variables can be derived. The individual matrices have various properties which can be computed such as the centrality, outdegree, indegree of different concepts, the frequency of relations and concepts *etc.* Likewise from the datasheets a series of indicators can be calculated, some of which associated with the implementation of agroecological principles (e. g. Botreau *et al.* (2014)), or sustainable practice (e. g. Lebacq *et al.* (2013)). Preliminary analysis of the transcripts from the pilot interviews led us to conclude that the following simultaneous coding scheme was useful to analyze the discussion on agroecological principles: codes are established to mark the pursuit, non-pursuit and dis-pursuit of the thirteen principles separately (e. g. -P1,0P1,+P3); means of these kinds of pursuits are then also identified and inductively coded (e. g. “direct sale”, “one breed”, “grass clover”, “planting hedges”, “do-it-yourself”); comparing these different means identified across cases will then serve to categorize each coded practice by their extent of pursuit by the ESR framework (Intensification, Efficiency, Substitution, Redesign), and by their link with one or multiple principles. The transcripts contain however much more than just information on the extent of the individuals pursuits, but also on farmer's motivations, goals, history, values, idiosyncratic beliefs, *etc.* For these, new codes and categories can certainly be developed for further analysis..

STEP 2: Segregation

Based on the variables produced, farms are first characterized as a group by creating a social cognitive map and calculating summary statistics and code frequencies. Variables are then selected to create smaller groups of farms through categorization (grouping based on one variable) and clustering (based on multiple variables), based on elicited causal relations, based on indicator scores, and based on codes, as these data were quantized in the first step (Vanwindekens *et al.*, 2014).

STEP 3: Group comparisons

Summary statistics are used to describe the differences between the identified groups in terms of perceived relations, codes and indicators (Vanwindekens *et al.*, 2014) and by creating contingency tables, we can explore whether groups established by different methods, coincide or not (Lebacq, 2015). These contrasts allow us to identify correspondences and discrepancies between the views these methods have granted us, as well as to identify recurring patterns.

REPEAT STEPS 1 to 3:

New codes, indicators and grouping criteria are generated indefinitely from the data to describe and group farms: any variable creation, selection or algorithm choice in multivariate analysis is an abstraction resting on *a priori* knowledge. The new group comparisons will expose new patterns emerge from which new insights can be gained in iterative fashion. It is the process itself that generates meta-inferences.

3.4 Making meta-inferences

To explain why certain actions are taken by certain farmers on certain farms, a theory is created through the process of data gathering, processing and analysis. We will examine critically and reflexively the observed patterns within the gathered data and hypotheses that led to these observations, captured in the written memos, contemplate different existing theories and frameworks on the observed phenomena, to formulate the best explanation of what we observed and hypothesize on the mechanisms that lie at the root or the absence or presence of agroecological practices at our case study farms.

From the analysis of the gathered data we may find that an indicator, or more likely a set of indicators, is correlated with the pursuit of agroecological principles. One may assume that farms with similar scores for these indicators as the farms of high 'agroecologicalness' in our study, are also pursuing agroecological principles to similar extent. By comparing the selected indicator scores of the case study farms with the indicators scores of farms within the large dataset made available by Statistics Belgium, we will make a qualified, inductive inference on the state of agroecological practice on Flemish beef farms today.

4. Discussion

Venkatesh *et al.* (2016) proposed a set of properties to compare mixed methods research designs. Following their scheme the proposed method can be characterized as an exploratory investigation as the study intends to develop a theory rather than to test one. It is a mono-strand mixed method, as it contains only one strand that consists of a conceptualization, experiential and inferential phase; it is a fully mixed methods design, as qualitative and quantitative research methods are combined across all stages; it is a design in which quantitative and qualitative data are gathered concurrently; while both qualitative and quantitative techniques for analysis are applied, it is qualitative-dominant study, as the qualitative data plays a pivotal role in generating an explanation to the observed patterns, which to some extent are quantified in indicators.

This method was developed for a descriptive and an explanatory purpose: first, to identify what actions Flemish beef farmers take to pursue agroecological principles and on what kind of farms these are taken; and second, to explain why this is so. A good understanding of what it is that one has observed or experienced is paramount if one wants to hypothesize about the possible mechanisms or structures capable of generating observed phenomena. It becomes clear then that using different methods for the purposes confirmation and completeness is tight into formulating a good explanation (Mcevoy & Richards, 2006).

In a comparative study such as ours, meaningful comparisons between cases are only possible of the objects of analysis are systematically traced. This the reason for the choice for the two structured methods of data gathering (a structured elicitation method and a structured questionnaire). The cognitive mapping and the farm survey allow us to compare farmers' perceptions and a selection of farm indicators respectively across the cases in an abstract and systematic way. This comes at a cost, however, as the concepts and variables registered are *a priori* established. Social phenomena are concept-dependent and thus are not independent from the agent's notion of them nor from the apparatus through which they became observable. Hence, the importance of more intensive methods (such as interviews, ethnography, historical narratives) to describe a phenomenon, and construct novel propositions on the mechanisms at work (Zachariadis *et al.*, 2013). By confronting the farmers with agroecological principles, we will generate a rich account on the interpretations of these principles, the actions the farmer may or may not take and how farmers justify these (in-) actions. This qualitative data thus allows to contextualize the data gathered through the more structured methods.

Yet the identification of agroecological practices through a semi-structured interview does not guarantee that all practices undertaken by the farmer and which may be seen as a pursuit of agroecological principles, are registered, nor does it guarantee that these said practices will correspond with actual practices, or that practices coded similarly, don't differ substantially both quantitatively and qualitatively. So while this qualitative account is pivotal to making sense of the elicited relations and surveyed indicators, by its own, the method may lack descriptive validity for its primary goal, i. e. the identification of agroecological practices. Still, statements made by farmer inconsistent with other data generated by the other methods or even by on-site observation, can be discarded.

Methodologically speaking, our method of data gathering closely resembles Akimowicz *et al.*'s (2016) study, which combined a similar elicitation method of cognitive maps with interview transcripts and a structured questionnaire. In that study the mental models were taken as "*graphical representation of the causal relationships that structure farmers' investment decision-making*", the survey results and the narratives identified in the interviews were used to contextualize these models. The status of the cognitive maps, however, is somewhat different in our study. We see these models as 'hermeneutic enablers' to structure debate about particular issues, rather than representations of the real-world (Jackson, 2001). In this sense the maps have a similar status as in transdisciplinary studies e. g. (Christen *et al.*, 2015; Özesmi & Özesmi, 2004) where they are used to clarify different views of actors on a phenomenon. The cognitive maps are neither complete nor accurate models of the farm, as the participants' misconceptions and biases about the system in question are built into the maps, nor are they necessarily accurate representations of farmers' perceptions, as such a claim would rest on the assumption "*that people understand the world around them by constructing mental models of interrelated concepts, and that these constructs guide their actions towards the surrounding environment*" (Garini *et al.*, 2017). They are however useful to describe and compare in a systematic way differences in perceptions between farmers of the importance of and causalities between a set of concepts addressed by agroecological principles. Similarly, merely by assessing farm management indicators one can compare farms in a systematic way and highlight linkages between different indicators, which can possibly be linked to sustainable practices.

At the end of the result section, we suggested that we might extrapolate correlations between farmer's views, practices, and indicators observed at our case study farms to the Flemish cattle farm population. Such a generalization from the empirical domain is problematic from a critical realist perspective, nonetheless given data availability, induction is the only way to answer our first research question, namely on what kind of farms, by what kind of farmers, and in what form agroecology is present on beef farms in Flanders. However, by identifying more generalizable mechanisms from the more complete account of our case study farms, it may be possible to specify under which conditions particular pursuits of agroecological principles may indeed be empirically traced in certain indicator scores in different contexts.

The second research question is explanatory in nature: we seek in our study to identify the underlying mechanisms that can explain why some agroecological practices are or are not applied by some farmers on certain farms. So how does one go about to explain the observed phenomena within a critical realist paradigm? On the one hand, the explanatory potential of so-called objective measures gathered through the questionnaire in and of themselves, is limited as observed regularities do not prove causation, whatever advanced statistical analysis modeling may suggest. Nonetheless such regularities are part of the phenomenon to be explained and may be the result of an exercised and actualized real causal mechanism across contexts and time (Zachariadis *et al.*, 2013). On the other hand, capturing actor's beliefs and motivations is not sufficient to explain an action too. Critical realism treats both individuals' perspectives and their situations as real phenomena that causally interact with one another. In this, critical realism supports the emphasis that critical theory places on the influence that social and economic conditions have on actor's beliefs and perceptions (Maxwell & Mittapalli, 2010). Our approach is consistent with such an ontology: as the objects of perception and perceptions themselves are constitutive of reality, both need to be captured, analyzed and explained (Mingers et al., 2013). To some extent, we believe that correspondences between the cognitive maps, stated motivations and quantitative indicators are empirical manifestations of such interactions between interpretations, social and physical contexts and farmers' actions.

But to effectively explain phenomena one needs to move from descriptions of empirical events or regularities to potential causal mechanisms, of a variety of kinds, some of which may be nonphysical and non-observable, which could potentially have generated the observed events. The notion of gravity is a good example of such a mechanism. This move from the empirical to the domain of the real, is made possible only by the logical operation of retroduction. In contrast to deduction where a rule is tested by an experiment, and to induction where a rule is established based on the frequent recurrence of similar phenomena, retroduction takes an unexplained phenomenon and proposes hypothetical mechanisms that, if they existed would generate or cause that which is to be explained (Mingers *et al.*, 2013). Due to the lack of practical application, Oliver (2012) proposes to situate the retroductive technique within a more familiar research approach, *i. e.* grounded theory. While grounded theory has been dismissed by some critical realists for its empiricism, rigidity and focus on induction, others have argued that it can be adapted to the needs of critical realist inquiry (Oliver, 2012). There has been a shift by leading authors in grounded theory methodology, from pure induction to an embrace of abductive logic, *i. e.* inference to the best explanation, to analyze data that fall outside of an initial theoretical frame or premise. This means that grounded theory can now accommodate researchers' pre-existing theoretical knowledge, hunches and hypotheses as necessary points of departure and building blocks for the development of more abstract theory (Oliver, 2012). Used in conjunction, abduction and retroduction can lead to the formation of new conceptual frameworks and theory (Meyer & Lunnay, 2013). A critical realist grounded theory approach thus emerges that is in line with its ontological and epistemological positions, by stressing the place of abduction and retroduction in theory generation, by having a dual focus on structure and agency, by conceiving of causality as mechanisms rather than as regularities, and by being informed, explicit and agnostic about already existing theories on the observed phenomena to be explained. The proposed iterative loop of coding and re-coding, somewhat inspired on a more traditional grounded theory approach, suggests that a continuous revisiting, defamiliarization, and alternative casing within existing theoretical frameworks of the gathered data (Timmermans & Tavory, 2012), a moving back and forth between *explanans* and *explanandum*, will generate new insights on the phenomena that we have observed. The proposed method is a conscious effort to put this idea into practice.

5. Conclusion and perspectives

Combining data of qualitative and quantitative nature allows to characterize on what kind of beef farms, by what kind of farmers, and in what form agroecology is present in Flanders. From the more complete but still empirical account of reality that we obtain with a mixed method approach, we identify patterns within the data, which are used to guide intensive research to hypothesize on the mechanisms and the conditions that sustain or limit the implementation of agroecological principles on Flemish beef farms. We expect that this mixed method approach will generate new insights on the relationship between agroecology and beef farming in Flanders.

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