Identifying the farming models underlying Flemish beef farmers' practices from an agroecological perspective with Archetypal Analysis

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Introduction

There is increasing awareness that agriculture is multifunctional, *i. e.* that besides the production of food and fiber, agriculture provides multiple services to our societies (Caron *et al.*, 2008; HLPE, 2019). While current farming systems cannot be separated from down-stream and up-stream processes of production, and from the consumption and from the global environment, it is recognized that farmers' activities affect the various services agriculture delivers to society. This recognition has given rise to many studies seeking to determine how farming practices may shape the delivery of multiple use-values characterized as relevant in various conceptual frameworks. Endeavors to formalize actual social concerns into functions or services delivered by agricultural systems, came, however, hand in hand with the recognition that this process of abstraction is inherently normative. Indeed, there is a plurality of values underlying actors' preferences for certain farming models, as they highlight different aspects of agricultural systems (Plumecocq *et al.*, 2018). One of these emerging models in both public and academic circles is agroecology. Agroecology embraces a science, a set of practices and a social movement and has evolved over recent decades to expand in scope from a fields and farms focus to embrace complete agriculture and food systems (Wezel *et al.*, 2009). As a body of thought, agroecology sets out to analyze contemporary agricultural systems, particularly traditional and 'alternative' systems. This analysis feeds into and on a vision to transform agricultural systems. This vision articulates most concisely into a set (or rather sets) of principles for agricultural and ecological management of agri-food systems as well as wider ranging socio-economic, cultural and political principles (HLPE, 2019). Prominent agroecology advocates have opposed this model to more mainstream "bio-economy" and "sustainable intensification" agendas, supposed to be scientistic, neo-productivist, and conforming to corporate power (Altieri, Nicholls, & Montalba, 2017; Levidow, 2015). Such characterizations of the contemporary agricultural landscape as opposing models may appear a tendentious reduction of the complexity and diversity of farming systems embedded in European agricultural landscapes (Vanloqueren & Baret, 2009), and we thus spot a need to further ground these debates empirically. In this paper, we aim to differentiate between the sets of practices of a diverse group of Flemish beef farmers from an agroecological perspective, in order to discover the different farming models which underlie the practices of these farmers.

Concepts, materials and methods

At its origin, "agroecology as a practice", shows a mental model that clearly sees the linkages and interactions among all three approaches (science, movement, practice) and dimensions (ecological and techno-productive, socio-economic and cultural, and sociopolitical) of agroecology (Rivera-Ferre, 2018). Consequently, agroecology involves the combinations of practices specifically adapted to the local biophysical and social context, including interacting and changing this social context. While there is broad consensus that agroecology requires contextualized solutions (Bell & Bellon, 2018; Rosset, Altieri, & others, 2017), it is also commonly accepted that some ways of pursuing a principle may be more agroecological than others. For instance, in the literature Efficiency and Substitution measures to reduce on-farm use of external chemical inputs are often perceived as less agroecological compared to redesign measures (see Hill & MacRae, 1996). Altieri *et al.* (2017) argue that while the Efficiency and Substitution measures are good first steps, putting agroecology really into practice requires Redesign measures, as these enable holistic approaches to pursue all principles. As such, an agroecological perspective encourages in a global analysis of farmers practices to make conceptual distinctions that allow to trace how different dimensions of farming can be interconnected through practice.

We operationalized this approach in a study published earlier, by developing a conceptual framework to describe the pursuits of agroecological principles by a diverse group of Flemish beef farmers (Tessier, Bijttebier, Marchand, & Baret, 2020). We identified practices of 37 cases in semi-structured interviews with farmers, in which we confronted them with a list of 13 agroecological principles. These principles addressed not only the ecological and techno-productive dimension of agroecology (principle 1 to 6), but also covering the social dimensions regularly addressed in agroecological literature (principle 7 to 13) (Dumont, Vanloqueren, Stassart, & Baret, 2016). Based on qualitative analysis of interview transcripts, extensive literature review and expert consultation, a conceptual framework was developed. 36 Pathways of Action (POA) were described, each linked to one principle. Each of these POAs envelops several practices mentioned by these farmers (Table 1). In that study (Tessier *et al.*, 2020), we contributed to concretizing agroecology as a practice in the context of Flemish beef farming, by linking individual principles associated with agroecology to real life practices already taken by these farmers today. What that study didn't elucidate, however, was how these POAs went together in practice: namely, whether some farmers pursued all principles in multiple ways, and others didn't, or whether there a specific combinations of POAs through which farmers pursue multiple principles, but in a markedly different way.

Table 1 Short descriptions of Pathways of Actions followed by Flemish beef farmers. These were identified through an analysis published earlier of the same 37 interviews transcripts used in this study (Tessier et al., 2020)

PRINCIPLES ADRESSING THE ECOLOGICAL AND TECHNO-PRODUCTIVE DIMENSIONS	
1. Strengthen animal health in an integrated manner	
CONTROL	reduce exposure to pathogens by controlling environmental conditions
BASIC HEALTH	maintain in general the metabolic functioning of the animal
ADAPTIVE	adapt animals to a relatively uncontrolled environment
2. Close nutrient cycles	
INTERNAL CYCLING	re-use nutrient streams produced at the farm, and to satisfy nutrient needs by on-farm production.
LOSS MITIGITATION	reduce losses to the environment at different sites
EXTERNAL CYCLING	organize a partial or complete return of on-farm produced biomass through third parties
3. Maintain a high diversity of species and genetic varieties in time and space	
WITH SEPARATION	increase species and genetic diversity at farm level, with separating these in space and time
WITHOUT SEPARATION	increase species and genetic diversity at farm level, without separating these in space and time
4. Preserve and use biodiversity	
SOIL CONSERVATION	enhance biological processes to improve and maintain crop yields
NATURE CONSERVATION	conserve and even augment associated agrobiodiversity species, even if it reduces yields
5. Reduce the use of external chemical inputs	
EFFICIENCY	move towards a more efficient use of chemical inputs
SUBSTITUTION	replace synthetic inputs with alternative inputs, including solar and renewable energy inputs
REDESIGN	move towards the use of local inputs, through integrated ecosystem design and management
LOW-OUTPUT	reduce chemical inputs drastically, by accepting lower overall physical yields
TRANSFER	transfer the question of pest management, nutrient availability and energy use to other actors
6. Increase the resilience and adaptability of the farm-ecosystem against environmental shocks	
AVOID	designed the ecosystem in such a way that the chance of an environmental shock reaching the production system is reduced
MITIGATE	design the system so that physical damages are reduced when an environmental shock does hit the farm
COPE	design a business which can sustain temporary reductions in physical yields

PRINCIPLES ADRESSING THE SOCIAL DIMENSIONS	
7. Strive for autonomy from powerful input suppliers and purchasers	
DO-IT-YOURSELF	organize the mobilization of resources, the conversion of resources into end-products and the use and re-use of end-products without recourse to market mechanisms
CONTROL	improve and make use of the ability to flexibly redefine the commercial relations they have with powerful commercial player
ALTERNATIVE PARTNERS	circumvent powerful commercial players by exchanging with other partners
8. Pursue financial independence and control over economic and technical decisions	
INDEPENDENCE	minimize lending from financial institutions
LEND ON OWN TERMS	lend from banks as long as you are able to define the terms of this relationship
MANAGE FINANCES	establish and maintain the farm's own financial fund.
9. Exchange knowledge from a diversity of sources to solve problems	
BUILD KNOWLEDGE	gather information from a variety of sources.
SHARE KNOWLEDGE	share information with other farmers and/or researchers
10. Maintain the social network on the countryside	
RURUL ECONOMY	engage in activities connecting farmers with local business partners and customers
RURAL SOCIAL LIFE	engage in activities which connect farmers with regular citizens in the local community
11. Strengthen the bonds between producers and consumers	
EXCHANGE	exchange goods and services in which actors treat each other as mere possessors of commodities interested in commodity price and quality alone
RECIPROCITY	exchange goods and services between actors having an enduring give-and-take personal relationship
CO-OPERATION	share and pool goods and services in a larger organization
12. Create locally embedded food systems of production and consumption	
SELF-RELIANCE	avoid sourcing inputs from far away by self-supplying, and organize distribution to local consumers yourself
LOCAL PARTNERS	rely on local partners to supply them with inputs and commercialize their products to local consumers
13. divide the burdens and the benefits of food production and consumption equitably	
WITHIN THE REGIME	seek advantages within the mainstream institutional environment to improve social position
AROUND THE REGIME	create alternative networks of agricultural production and consumption
OUT OF AGRICULTURE	find opportunities outside of agricultural production to improve social position

To assess if and how each of these farmers sought to address these agroecological principles together we transformed this descriptive framework of these farmers' practices, as it is presented by (Tessier et al., 2020), into an analytical framework. Our approach consists of six steps involving both qualitative and quantitative methods (Figure 1). We started from the qualitative data on these farmers' practices gathered through 37 semi-structured interviews with beef farmers and the conceptual framework we put forward in our study published earlier (Tessier *et al.*, 2020), which took these same interviews as empirical entry point. These interviews contain not only references to practices related to the 13 principles we confronted them during the interviews, but also comments on their farms' history, their personal views on these principles, on the practices of other farmers, *etc.* In other words, these data are very content-rich. In unaltered form, however, they are too overwhelming for the analyst, and unpresentable to lay persons given the size of the source material. Therefore, we devised a method to transform these data into scores indicating how and to what extent each principle is pursued by each farmer relative to others, guided by the conceptual framework outlined by us in study published earlier (Tessier *et al.*, 2020). We then applied an Archetypal Analysis (AA) algorithm on these scores, to discern the different models (or ideal types) that may underlie the actual sets of practices of these beef farmers.

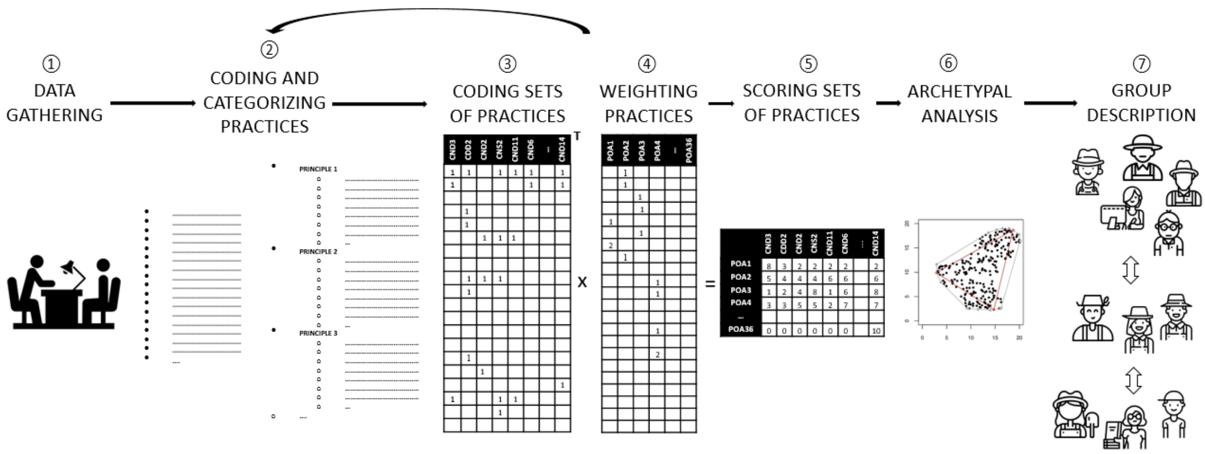

Figure 1 Diagram representing the seven steps of the method of data gathering and analysis

For the sake of clarity, we have presented the analytical process as a more or less linear, deductive process. Readers should be aware, however, that there is some interdependence between this study and our study published earlier, but conducted to an extent simultaneously (Tessier *et al.*, 2020). Both studies share the same empirical starting point, but steps 2 to 4 of the analysis process also built upon and contributed to the coding infrastructure that led to the definition of the POAs put forward by Tessier *et al.* (2020). Indeed, codes and categorizations for practices mentioned by these farmers had a double use in in our analysis of these farmers' practices from an agroecological perspective: (i) to conceptualize the different ways these farmers taken together pursued individual principles (Tessier *et al.*, 2020), and (ii) to characterize and compare the sets of practices of each farmer and group the farmers in archetypes based on these practices (this study). Because of these distinct objectives, however, the analytical steps contributing to the presented findings in this study can be isolated and presented separately, as we have done in the rest of this section. This way, we may also consider readers more interested in methods to compare different groups of farmers, rather than the analytical process laid out by Tessier et al. (2020).

STEP 1: data gathering

As stated before, this study made use of the same interview data used by a study of ours published earlier (Tessier *et al.*, 2020). To explore the full scope of agroecology as a practice in a context, we followed, initially, a stratified purposive sampling strategy, by contacting farmers along the range of three axes: organic (labeled O--)/conventional (C--), direct sale of meat (-D-) or not (-N-), specialized beef production (--S) or more mixed agricultural activities (--D). Given the composition of the actual beef farming population, as there are very few organic beef farmers, let alone specialized organic beef farmers (Timmermans & Van Bellegem, 2019)) and the exploratory nature of our research, it was deemed unnecessary to obtain a balanced or representative sample. Consequently, to further increase the diversity in management practices in our sample, we complemented the data gathering with a variational sampling approach by contacting farmers of potential interest based on previous interview experiences (Corbin & Strauss, 2014). As a result, farmers were spread unevenly along the three axes used during sampling (Table 2). Information on farmers' practices in relation to agroecological principles was gathered through semi-structured interviews with one or multiple members of the farm household. During these interviews we confronted the selected farmers with the 13 agroecological principles presented in Table 1, and asked how they saw each principle in practice on their farm. In total 37 cases were included for this study. In 24 cases, we spoke with only male-identified members of the farm household, in 5 with only female identified, and in 8 cases with both male and female-identified members of the household.

Table 2 Distribution of cases along the three axes used for purposive sampling: (transitioning to) organic or not; Direct Sale of meat or not; Diversified Agricultural Activities or not in terms rearing other livestock species than bovines for sale and/or growing cash crops (excluding wheat).

Organic?	Direct Sale of Meat?	Diversified Agricultural Activities?	N
Yes	Yes	Yes	10
		No	1
	No	Yes	1
		No	0
No	Yes	Yes	4
		No	3
	No	Yes	15
		No	3

STEP 2: coding and categorizing practices

The transcripts of these interviews were further analyzed in Nvivo 11®. A coding tree is created which contains all the practices mentioned by the interviewed individual farmers related to the 13 principles proposed by Tessier *et al.* (2020). This is done by first inductively coding all practices mentioned by the interviewed farmers which are in line or at odds with one of these principles. This first round of coding yielded 690 codes for practices mentioned by these farmers in relation to agroecological principles. In a second phase, we clustered and selected relevant codes to identify a set of practices within each principle. In total 307 of such codes were created.

STEP 3: coding sets of practices

We re-read the transcripts and applied the coding tree more systematically to make sure all practices referred to by farmers were correctly coded. To truthfully characterize the practices mentioned by each farmer, we allowed revisiting of the initial codes, by going back to the second phase of step 2. With the query tool provided by the NVivo 11 software, the result of this qualitative analysis is summarized in a binary “Sets of practice matrix” containing information on all the practices mentioned by each farmer.

STEP 4: weighting of practices

All practices linked to a principle created in the second round of coding were given a weight for their contribution to a POA of their corresponding principle. These weights are based on a qualitative assessment of the relative contribution of practices linked to a particular POA, to that POA. In this process, experts (N=8) at ILVO were also consulted to make the scoring more robust. Each expert was given three principles lying closest to their expertise, to look at the individual practices mentioned by the farmers during the discussion of the principle, the grouping of similar practices, categorization of these practices under the proposed POAs and the initial weights assigned to the practices. Importantly, these expert interviews also contributed to the refinement of preliminary POAs, and hence to the final definitions and descriptions of these POAs as found in Tessier *et al.*, (2020). This evaluation provided, moreover further input to reconsider initial codes (step 2), and hence the eventual “Sets of practice matrix” (step 3). The conclusion of this qualitative assessment is summarized in a final “Weights matrix” containing the weights of all the 307 practice codes contributing to all POAs. The weights and frequencies of these practice codes can be found in Annex 1.

STEP 5: scoring sets of practices

A score was then calculated for each farmer for each POA based on these two matrices created. The summation of the weights of all practices mentioned by each farmer is used as a measure for the extent a farmer may be pursuing a principle along each POA. In the case a POA score depended on one or two practices, we recombined POAs, to avoid paying undue attention to a single practice to characterize farmers' sets of practices. For the POA External Cycling (Principle 2 on the theme of Nutrient Cycling) and Avoid (Principle 6 on the theme of Ecological Resilience), little contributing practices were found, and we therefore combined these POAs with the POA Internal Cycling, and Mitigation into Biomass Recycling and Avoid & Mitigation respectively. Consequently, the number of dimensions is reduced from 36 to 34. The matrix product of the "Sets of practices matrix" and the "Weights matrix" results in the "Preliminary scoring matrix". We rescaled each indicator with a linear transformation so that the range for each indicator is exactly to 0 to 10.

STEP 6: Archetypal Analysis

The quantification of sets of practices into indicators scores allows us to characterize, compare and group our cases with quantitative analysis techniques. To identify the main models underlying these sets of practices, we conducted an archetypal analysis on the 34 POA indicator scores of these 37 cases. AA is a statistical method aiming at synthesizing a set of multivariate observations through a few, not necessarily observed points (archetypes), which lie on the boundary of the data scatter and represent a sort of 'pure individual types', rather than typical observations or cluster centers. Mathematically, AA as proposed by Cutler and Breiman (1994), is an unsupervised learning method that seeks extremal points in the multidimensional data – which are convex combinations of observations (convex combinations are linear combinations of points where all coefficients are positive and sum one). To conduct our analysis, we made use of the functions implemented in the R package "archetypes" (http://CRAN.R-project.org/package=archetypes) by (Eugster & Leisch, 2009). We ran the algorithm for different values of the parameter k, that is the number of archetypes, 1000 times each to avoid choosing a local minimum solution. The determination of the correct value for k is no different than the open problem of choosing the number of components in other matrix decomposition approaches (Mørup & Hansen, 2012). We plotted the relative Residual Sum of Squares (RSS) of the best solutions for increasing number of archetypes. Breaks in the resulting scree-plot were used to detect solutions with a potential favorable trade-off between complexity and model fitness. Archetype Analysis is very susceptible to outliers and may suffer from rotational ambiguity (Moliner & Epifanio, 2019; Mørup & Hansen, 2012), and we therefor compared the solutions the algorithm found by running it on different sets of scores obtained by slightly changing the weights matrix, as a way of sensitivity analysis.

STEP 7: group description

The loadings of each case for the different archetypes were used to classify cases. The membership of each case to an archetypes was determined in function of their loadings with respect to a given archetype being above a certain threshold arbitrarily set (*cfr.* Tittonell, Bruzzone, Solano-Hernández, wLópez-Ridaura, & Easdale, 2020).

To describe and compare the groupings thus obtained, we go back to a lower level of abstraction, namely the sets of practices mentioned by farmers with full membership of each archetype.

Results & Analysis

The result of the scoring is summarized in the scoring table (Figure 2), showing the 34 POA indicator scores of the 37 cases. We sorted cases by increasing sum of their scores, in order to classify farmers. A gradient is thus revealed, rather than a clear-cut separation of farmers into two extremes, with one group of farmers mentioning little or no practices for all principles and another group mentioning a great many contributing practices. Rather, the scoring table presents a mosaic of cases with strong scores for some indicators and rather low scores for others. We see some farmers pursuing a principle through all identified POA's to relatively strong degree in terms of contributing practices, while failing to mention practices contributing to any POA of another principle (e. g. CND7 has a relatively high score for both POAs for principle 6 but low POAs scores for principle 12). And we also observe some farmers failing to mention any practices in line with most principles, yet mentioning relatively many practices contributing to some particular POA's or principles (CNS5). Furthermore, we find that some farmers pursue a principle through one POA (e. g. ODS1 for Principle 3), whereas others pursue most principles through multiple POA's (ODD4). What scoring reveals then is that individual farmers appear to have different options to address each principle, and that they might neglect some principles entirely, while still pursuing other principles relatively strongly. Or they clearly choose for one POA within a principle, or address the principle through combining POA's. This confronts us with a gray area, difficult to analyze. For this we turn to the results of the AA.

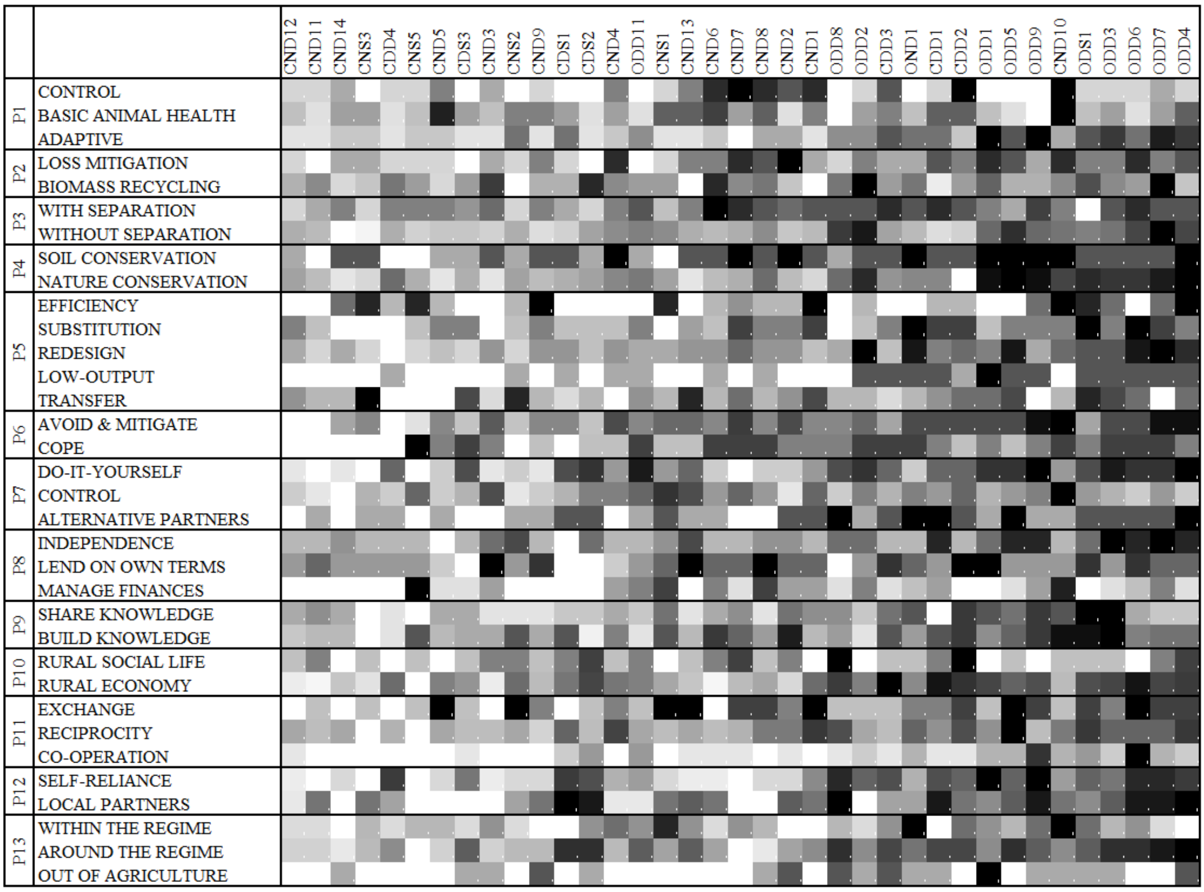

Figure 2 Individual color codes of each case for POA indicators (white 0, black 10). cases sorted by summation of all indicator scores

In order to select the appropriate value of k, we compared the model fitness (RSS) of various values of k. The strong break at the value of four in the scree plot, indicated this as an appropriate value, yet we observed that small changes to the weights assigned to practices resulted in rather different archetypes identified for this value of k (see Annex 2). The solutions for three archetypes were more robust to these slight changes in weighting, and we therefore chose this solution as the most appropriate model to differentiate between cases at the expense of slight drop in model fitness (RSS = .276 instead of .240). See Annex 2 for more details on model selection.

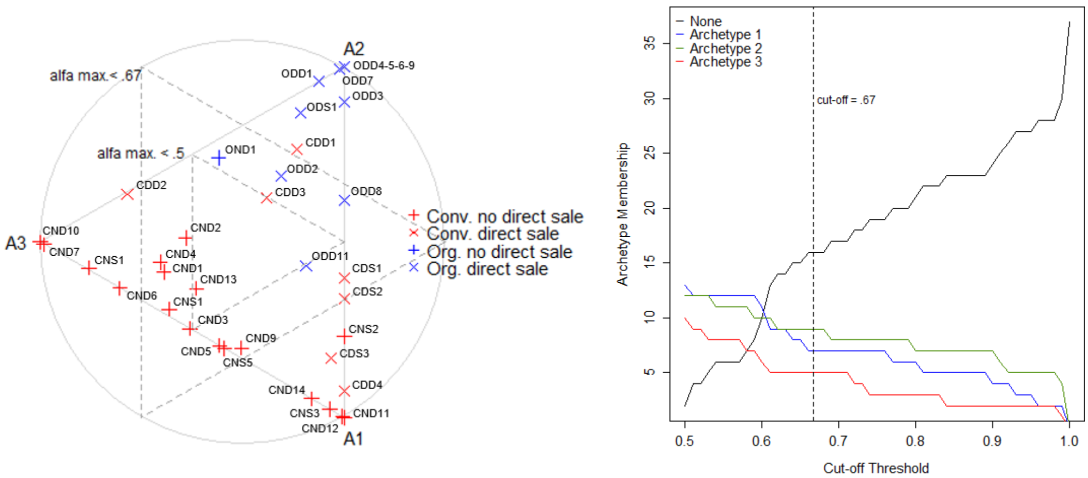

Figure 3 Left: simplex visualization of observations with respect to the archetypes identified for k = 3. Right: memberships to Archetypes in function of cut-off thresholds.

The loadings can be used as a measure for the extent each case is represented by the three archetypes identified. The simplex plot (figure 3, left) shows that a good number of cases are represented by a single archetype, as they are found near the vertices of the triangle. A number of cases are a blend of two archetypes, as they are found at the edges of the triangle, whereas a number of cases include elements of all three archetypes, though never in equal proportions. We set the cut-off threshold at two thirds, given the plateauing number of membership for the different archetypes around this number (Figure 3, right). By this threshold, a group of 16 farmers remains without distinct membership to a single archetype in the middle, but still heterogeneous in terms of the proportions in which their pursuit of agroecological principles resemble that of each of the three archetypes.

As depicted by Figure 4, there are strong differences among the three identified archetypes for most of the 34 POA indicator scores, except for “Biomass Recycling”, “Transfer” where all archetypes have somewhat similar scores, as well as “Rural Social Life” and “Out of Agriculture”, though differences are larger. Archetype 1 (A1) represents farmers who mentioned no or little practices contributing to most POAs, except for the POAs just mentioned, resulting in scores markedly below the sample average. At the 66.7% threshold level, seven farmers are represented by A1. These are all conventional farmers, five without direct selling of meat to consumers, four with diversified agricultural activities, three are specialized in beef production. Archetype 2 (A2) represents farmers that mention sets of practices that contribute to a considerably higher than average score for at least one of the POAs for every principle. The membership of A2 includes nine farmers, all but one producing organically, all but one with diversified agricultural activities, and all with direct sale of meat to consumers. Archetype 3 (A3) is similar to A2, in that it represent farmers mentioning practices related to all principles, but the theme of local food systems covered by principle 12. The membership of A3 is composed of five conventional farmers, all with diversified agricultural activities, and all but one without direct selling meat to consumers. A2 and A3 have some POAs in common, whereas other POAs are typical for just one of these archetypes. The common POAs include “Loss Mitigation”, “With Separation”, “Soil Conservation”, “Substitution”, “Redesign” (though slightly more for A2), “Avoid & Mitigate, “Cope”, “”Lend on Own Terms”, “Build Knowledge”, “Share Knowledge”, and “Exchange”. A number of POAs are characteristic for A2, namely “Adaptive”, “Without Separation”, “Nature Conservation”, “Low-Output”, “Do-It-Yourself”, “Alternative Partners”, “Independence”, “Rural Economy”, “Reciprocity”, “Co-operation”, “Self Reliance”, “Local Partners”, “Around the Regime”. The POAs characteristic for A3 are “Control Disease”, “Basic Animal Health”, “Efficiency”, “Control in Chain”, “Manage Finances”, “Within the Regime”.

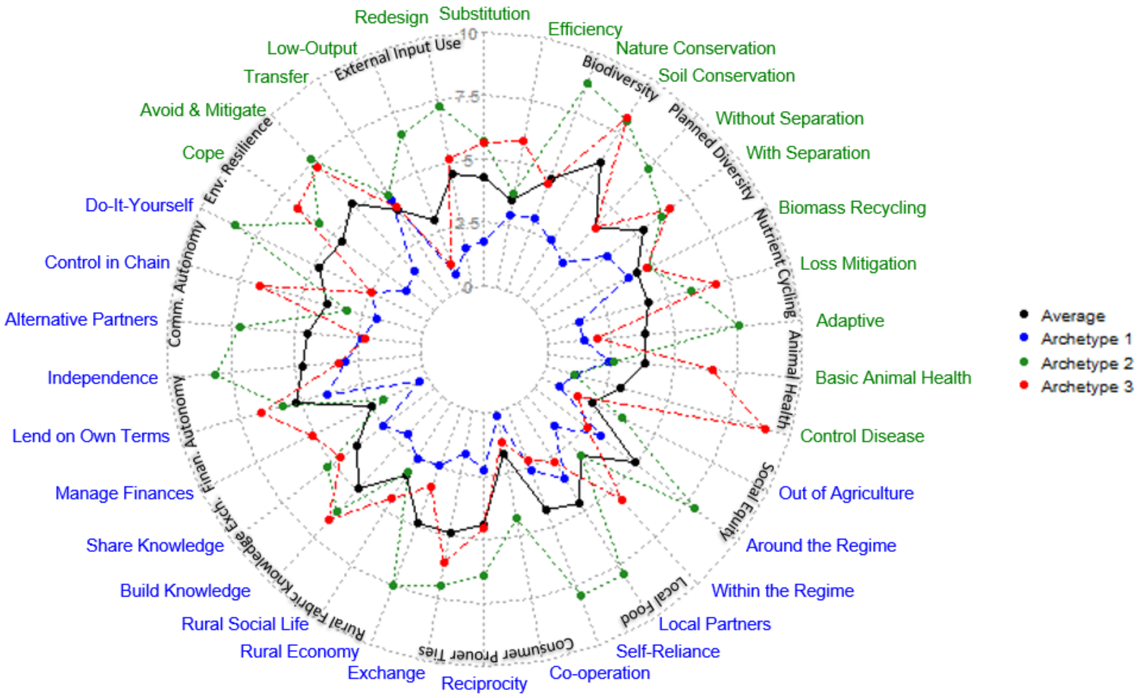

Figure 4 Radar chart depicting showing the scores of the identified Archetypes as well as the average for POA indicators related to social (blue) and ecological and techno-productive (green) dimensions of farming.

These groups of farmers have a number of particular practices in common. As these practices contributed to a number of particular POA indicator scores, they also help to explain the distinct score sets of these farmers on which basis they have been classified. In the following section we enumerate the various scored practices which two thirds or more of the farmers in at least one grouping mentioned. A1 represents farmers which mentioned, relatively speaking, few practices contributing to the implementation of agroecological principles. Still, they share a number of practices contributing to a number of POAs, setting a base level of any beef farmer in our sample is crossing: a crop rotation of minimal length, the re- use of on-farm solid manure and slurry as organic matter in the field, and in this avoiding fertilizers and slurry, which may be more harmful for soil life. They also look to reduce losses during fertilizer application. Other practices shared by two-thirds of these farmers include the import of off-farm animal genetic material (in the form of artificial insemination or breeding bull), provide adequate housing for the animals, and go to info meetings organized for farmers. A number of practices put them however, at odds with a number of POAs, such as their dependence on off-farm concentrates, selling their products through whole-sale channels, and also holding a breed (Belgian Blue) which is unable to calve naturally.

The nine farmers represented by A2, share a large set of practices related to all themes covered by the principles investigated in this study. In terms of land use strategies, these farmers engage in a variety of extensive grassland management practices, in particular grazing cattle on natural and diverse grasslands (limited stocking rate, no application of fertilizers, manure or pesticides). They tend to use cattle breeds and cross-breeds adapted to these rough grazing conditions, and requiring little concentrates for good growth. Some meadows in management may, however, be managed more intensively. Furthermore, these farmers tend to fill in at least a part of their feeding requirements for fattening cattle by producing their own concentrates in the form of grass-clover or grain-legume mixtures, and hold also different species of livestock separately. In the fields, most of these farmers use neither chemical nor organic pesticides, and rely on mechanical methods, augmentation of natural enemy populations associated with the bushes and trees installed around the fields, and crop diversification to keep pests within acceptable limits. Soil fertility is maintained by incorporating organic matter in the form of on-farm solid manure or other off-farm organic inputs, by installing green manures, legumes and temporary grasslands in the field rotation, by reduced and timely tilling resulting in lower soil disturbance. In social terms, this low-input production farming model also leads to increased commercial autonomy. For products these farmers all sell products directly to consumers on the farm, aside from local or regional sale channels via alternative third parties. Most of these farmers attested to avoid lending for farm investments, and have ties with other farmers, by rendering services to other farmers, by exchanging machinery with other farmers, by exchanging intermediary products such as fodder, feed and straw, but also by selling end-products from or to other farmers. Furthermore, they are actively involved in knowledge networks with fixed groups of (organic) farmers, but paid consultants too appear to also be a common source of knowledge for these farmers. Diversification of income sources, including subsidies, are a typical part of the sets of practices mentioned by these farmers.

The five farmers represented by A3 share a number of agricultural practices contributing to the techno-productive dimension of agroecology. In particular practices related to soil management are common, such as to monitor and limit fertilizer doses on the fields, re-use and incorporating on-farm manure and slurry in the field, maintain soil cover in winter by installing cover crops and green manures (often species mixtures). Farmers grow a variety of vegetables that are included in a crop rotation with the commonly cultivated forage crops (grass and maize for silage). The higher share of arable land to produce forage and cash crops in the farm holding also is associated with the practice of applying all on-farm produced manure and slurry produced on the farm. Compared to A2 these farmers have a rather distinct set of practices to improve animal health and reducing medical interventions, even though all of these farmers keep the Belgian Blue breed, which requires systematic C-sections and is rather sensitive for flue and scab. Typical measures mentioned are vaccination, providing adequate housing, early weaning and separating calves in the first weeks of life in small huts or boxes, while feeding colostrum, providing pathogen-free and nutritionally balanced out nutrition, and sufficient strawing in stables, and bringing in off-farm animal genetic material. For four out of these five cases, all or most cattle are sold through whole-sale channels. Even though the potatoes and vegetables grown are produced for industry and often based on a seasonal contract, in contrast to A1, farmers mention building in a financial buffer, but also to negotiate from which give them more commercial control in the “mainstream” value chain, namely. They also seek to put commercial partners in competition, to be informed about market prices, and to follow and anticipate market trends, and also seek to reduce services needed (such as spraying, transporting, planting or harvesting). These farmers mention many practices contributing to their knowledge base, be it from commercial partners, by monitoring their own activities systematically, yet they also share information with farmers both informally with colleagues and in formal learning networks with fixed groups.

Discussion

At first glance, the scoring delivers a mosaic of indicator scores, reflecting the great diversity of agroecological practices mentioned amongst the farmers interviewed. This is hardly surprising: our sampling design was specifically set up to identify the broadest spectrum of agroecological practices. Whereas our sample is far from representative of the Flemish beef farming population, the mere existence of these observed coordinates reveals the subsistence and perhaps emergence of a myriad of ways to produce beef in this context. The marked diversity in land use strategies, marketing strategies, fodder strategies, underlying these scores, rejects modernization theories which would classify farmers as those at the innovation front, and those who follow or fall behind (van der Ploeg, Laurent, Blondeau, & Bonnafous, 2009). This diversity discredits binary characterizations of existing farming systems as either conforming completely to a conventional "industrial farming" model or to an "organic farming" model. Insofar as the sum of POAs indicators can scale the agroecological nature of the systems considered, we see organic direct selling beef farmers on one end of the spectrum, and conventional whole-selling farmers on the other, yet in between these extremes there is a continuum where these *a priori* categorizations cease to be helpful. In this paper, we sought to map out this grey area with a less traditional data-driven approach, namely Archetypal Analysis. Before we implemented this algorithm, however, we also analyzed the scores with a more commonplace principal component analysis followed by cluster analysis, but found that it resulted in poorly interpretable classifications. From these earlier multivariate analyses emerged the hypothesis that the diversity of scores could be trace back to a smaller number/set of potentially overlapping farming models underlying the individual pursuits of farmers. This is the core assumption of the Archetypal Analysis (Oberlack *et al.*, 2019).

We identified three farming models: one model representing farmers mentioning a bare minimum of practices contributing to agroecology A1, and two models, A2 and A3, representing farmers that do integrate elements of agroecology. Farmers represented by A1, due to their silence on practices related to various principles, may be termed "un-agroecological", compared to the other farmers in the sample. In an absolute sense, some of their practices (e.g. production and incorporation of solid manure) do contribute to agroecology, in particular on the themes of biomass recycling and the maintenance of soil life at the local and regional level. Based on these farmers' accounts, many go beyond these basic steps, we identified two models, which overlap a number of POAs. Particularly but not exclusively these models can relate to the techno-productive dimensions of agroecology, even if they markedly diverge from most of the agroecological principles related to social dimensions.

Conceptually, A2 represents a low-input, low-capital, but knowledge intensive farming model embedded within alternative commercial and social networks, which actively seeks to become autonomous from regime institutions. It therefore bears resemblance to the "peasant farming" model (van der Ploeg, 2011). There are differences, however: this model is rather similar in terms of biomass cycling to the other models, with its dependence on off-farm produced straw, manure and/or feed. This illustrates that even for these Flemish beef farmers the involvement in markets for such external, though often locally-produced, inputs is not uncommon, and they manage their farm as a semi-open system. Furthermore, low-output practices are also associated with this model, suggesting that this model does not prioritize yields per se. This may indicate that these farmers have transitioned to a "post-productivist" form of agriculture, long overdue according to some authors (e. g. Wilson, 2008), yet also accentuates the on-going academic and public debate on how to address the issues of food security and food sovereignty in the coming decades (Bernstein, 2014; Edelman, 2014).

The third model, A3, may fall short for the principle of local food systems, it represents farmers predominately involved in whole-selling of their products. These farmers have taken significant steps to implement agroecological principles, even though they are strongly involved in national to global commodity circuits. For a number of POA scores ("Loss Mitigation", "With Separation", "Soil Conservation", "Redesign"), these farmers are even undistinguishable from farmers from A2. Some practices may be in line with some agroecological principles that seem to be compatible with a conventional circuit, as they may improve or maintain crop yield and quality, without extra costs in the long term. On the opposite, practices which come at the cost of total factor productivity, specifically those associated with 'Low-Output' and 'Nature Conservation' POA, are not adopted in of this farming model, indicating that this model of pursuing agroecological principles still fits within a productivist logic. According to Holt-Giménez and Altieri (2013), such neo-productivist farming models, generally labeled "sustainable intensification" and "bio-economy", do not challenge the current social world order. Our research results do bear out that these farmers are not uncoupling their food systems from agro-industrial companies, yet their position is not entirely submissive either. These farmers have their own way of seeking advantages within the mainstream chain, though admittedly, these strategies may well require good social position to begin with in terms of factor endowments and negotiation skills.

We noted some overlap between A2 and A3, but in terms of animal health management A3 is the opposite of A2. As such, this study presents more evidence of a lock-in of conventional beef production into what Stassart & Jamar (2008) called the "Belgian Blue référentiel". The Belgian Blue breed is famous for its unparalleled levels of production efficiency, and has been for decades now the dominant breed held for beef production in Belgium (Peeters, 2010). In order to reach these performances, however, the animals require particular intensive care and feeding practices. In Belgium, actors involved in the beef value chain are completely dedicated to and designed the processing, transporting, and selling of Belgian Blue meat. Likewise, farms are equally dedicated to produce meat compatible with these expectations. Currently, whole-selling of beef is embedded in these particular management practices. As meat from other breeds does not meet these particular standards, farmers choosing to hold other cattle breeds have to rely on other sale channels, in order to be economically viable. We would note, however, that the observation of such a lock-in doesn't make conventional beef production in Flanders an exceptional case. There is ample evidence that the terms and conditions of trade with the food manufacturing and retail industry confine the choices farmers have to produce agricultural commodities (Burch & Lawrence, 2009; Fuchs & Kalfagianni, 2010), suggesting these current management practices need to be explained in social structural terms.

In this study, information on farmers' practices related to different dimensions of agroecology and farming more generally, has been gathered from a heterogeneous group of farmers. This sets it apart from studies focusing only on the ecological and techno-productive dimensions of agroecology as a practice (Botreau, Farruggia, Martin, Pomiès, & Dumont, 2014; D'Annolfo, Gemmill-Herren, Graeub, & Garibaldi, 2017; Guthman, 2000; Merot *et al.*, 2020), and those limited to the study of "proto-agroecological" instances (Dumont *et al.*, 2016; van der Ploeg *et al.*, 2019). There is an urgent need for tools that can verify the promise of agroecological practices (HLPE, 2019). While our research interests for this study lie in establishing the presence of the means of agroecology, *i. e.* agroecological practices, on our case study farms, rather than their effectiveness in meeting certain agroecological ends, this study's methodological contribution to such an assessment does not escape us. After all, the identification of systems managed more along agroecological lines is prerequisite to studying the performance of such systems. Our research results establish the value of a scoring system that condenses qualitative information on farmers practices into carefully designed, case study specific indicators. The developed scoring system allowed to condense this complexity into indicators, so that this multidimensionality and diversity of farmer's practices could be analyzed in its totality, while remaining relatively grounded. The scoring system showed its usefulness as a cross-case analysis tool to differentiate between sets of practices in relatively large sample sizes. Furthermore, we shed light on this complexity by identifying different farming models underlying sets of practices of these farmers. For this we mobilized Archetypal Analysis as a data-driven classification method, which we believe greatly enhanced the interpretability of the observed diversity. As Moliner & Epifanio (2019) suggest, humans understand the diversity among observations better when the individual observations are shown through the extreme observations in the sample rather than as linear combinations of the variables (as is the case of Principal Component Analysis), or distance to cluster centers exhibiting close to average behavior.

We would stipulate, however, that the presented method and the presented application of the method has its limits. This study relies on a framework which was derived from the very same accounts of these farmers (Tessier *et al.*, 2020). While it demonstrates the internal validity of this grounded framework, the application of this framework in other settings is still lacking. However, it must be noted that the accounts given by farmers constituted only one of the three bases from which the framework described by Tessier *et al.* (2020) emerged. Practices mentioned by farmers were triangulated with literature review and expert opinions. Moreover, categorizations of practices was done based on an assessment of mentioned practices in the aggregate, rather than looking at sets of practices on a case-by-case basis. This process of abstraction allowed a more detached and thus objective assessment of individual cases. Still, the weighting of practices can be criticized for introducing researcher bias. Indeed, assigning weights to practices is inherently a judgment call, albeit a scientifically motivated one. We asked experts to weight the practices, but found that some rejected this as a simplification, or felt ill-positioned to do so, whereas others, particularly those with social scientific background had little objections. These abstractions were necessary simplifications given the nature of the data used for this study. The advantage of our method, however, is that the clear separation of coded practices and weights, renders the qualitative assessment of the sets of practices mentioned by farmers more transparent, flexible and easy to evaluate the robustness of the findings. This last feature proved particularly useful to choose among the solutions found by Archetypal Analysis Algorithm. The main limitation of the two studies (Tessier et al. 2020 and the present paper), is that they take farmers' accounts of their actions as empirical entry point. The method of data gathering is deeply hermeneutical, as it greatly depends on the farmers' understanding of these principles, their understanding of their own actions, and their understanding of interview situation itself. This is not without its downsides: a farmer may misinterpret the question or misrepresent his/her practices, or s/he may not be able or willing for a range of reasons to articulate what actions are taken to pursue a certain principle during the interview. Based on our analysis we found that the identification of agroecological practices through a semi-structured interview does far from guarantee that all practices taken by a farmer related to the pursuit of agroecological principles, are registered. The method therefore does not allow to separate *empirically* the less talkative but agroecological farmers in actual practice, from those who are not, as they have also little to say. Other methods of data gathering such as a structured questionnaires, could be developed to trace in a more systematic way the actions taken by farmers, which will lead to a more accurate characterization of sets of practices. However, while a more systematic assessment of the presence of means of agroecology at each studied case is still lacking, our study may well have laid the foundation for such assessment tool.

Conclusion

Our study shows that by taking an integrated agroecological perspective, different archetypes can be identified which underlie the sets of practices of this diverse group of Flemish beef farmers. This interdisciplinary investigation of actions taken by actual farmers may thus further ground empirically theorizations of farming models in this context. Concepts put forward in the literature to distinguish between different sustainable development pathways at the farm level, such as "Sustainable Intensification" and "Peasant Farming" were shown to be useful to some extent to describe the different models based on a data-driven classification of our cases. Hence, our study suggests that these concepts aren't merely academic constructions divorced from farmers' realities, but indeed have some validity in this context and indeed provides empirical grounds to make such distinctions. But still, none of the interviewed farmers represented these models in a pure state. In fact, our results indicate that many farmers don't go very far in either approach, or are situated in between these farming models, As Brédart & Stassart (2017) suggested, farmers are on their own trajectory of combining various practices fitting their situation and their judgment. The sets of practices they end up constructing therefore resist ideal-typical classification. In fact, the ability of farmers to blend practices fitting both or either one of these models, may actually explain some of the controversies surrounding the definition and delimitation of agroecologically managed farming systems. Without going into the legitimacy of the concerns surrounding the co-optation of agroecology by powerful institutions (Holt-Giménez & Altieri, 2013; Norder, Lamine, Bellon, & Brandenburg, 2016), we would suggest that disputes on the definition of agroecology may stem from the overlap in management principles and indeed actual farming practices of the different farming models being proposed.

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