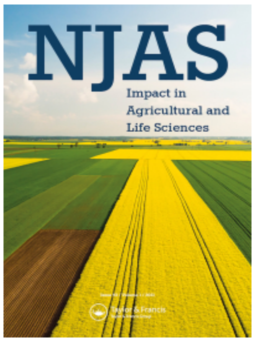

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Cultivating choices: How social context shapes farmers' considerations in crop and soil health promoter selection

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ABSTRACT

In this study, we explore how farmers decide to adopt sustainable innovations in crop and soil health management with a particular focus on the use of insect by-products, or "frass'. By employing a Means-End Chain approach, we investigate how social contexts, specifically group discussions, can shape this decision-making process. Our findings reveal that social contexts have a distinct influence on farmers' decision-making. Those engaging in group discussions considered a broader set of product attributes, incgluding price, ease of use, and environmental impact. In contrast, farmers not involved in such discussions focused predominantly on product specifics like nutrient content and organic matter. This marked distinction amplifies the importance of social interaction in expanding awareness and understanding, presenting a contrast to decisions guided solely by personal judgement and technical expertise. It highlights the nuanced and complex factors affecting adoption decisions and underscores how social dynamics can subtly guide farmers" attribute considerations, providing a deeper insight into the path towards more sustainable agricultural practices.

ARTICLE HISTORY Received 12 May 2023; Accepted 4 September 2023

KEYWORD Means-end chain; hierarchical value map; decision-making process; innovation adoption; group discussions; insect frass

1. Introduction

Soil is an invaluable component of sustainable food production in which farmers play a critical role in its management (USDA-NRCS, 2019). Farmers' decisions influence the soil's longevity, fertility and quality that in turn determine its long-term productivity and biodiversity capacity. As politicians

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and the public have become more aware of the importance of environmentally friendly and sustainable soil management, farmers are pressured to implement and use more sustainable products and practices (National Academies of Sciences Engineering and Medicine, 2017; The Nature Conservancy, 2016). Reliable innovations in crop and soil health promotion and an understanding of how farmers make decisions regarding crop and soil health promoting product selection can be a valuable step towards the long-term preservation of agricultural land.

One crop and soil health promoting innovation is the by-products of insects reared in a production setting – insects' manure, undigested feed and sheds of the insects' outer-most layer of skin which are collectively referred to as "frass" (Barragán-Fonseca et al., 2022). The crop and soil health promotion aspects are suggested to be caused by the chitin present in the shed skins. The chitin stimulates chitin-degrading microbes in the soil that in turn produce compounds which can be absorbed by the plant and stimulates induced systemic resistance. The induced systemic resistance protects the plant from various above- and below ground pests and diseases (Bai, 2015; Debode et al., 2016; Francesca et al., 2015; Gadhave & Gange, 2016; Sharma et al., 2013; Vickerson et al., 2017). Additionally, the frass is composed of organic matter, which contributes to the nutritional needs of the crops and soil (Kebli & Sinaj, 2017; Quilliam et al., 2020; Temple et al., 2013; Vickerson et al., 2017). Ongoing research continues to test the extent to which frass can promote the health of crops and soil, though more time is needed to determine its full potential and the most appropriate crop application. If deemed effective, the frass can be recycled to enrich arable farm soils, adding an element of sustainability to agricultural practices. As insects can be potentially raised on the by-products of arable farms, a circular agricultural system is created, turning what was once waste into valuable input.

Farmers' decision-making processes can be investigated using Means-End Chain (MEC) theory. MEC theory was originally based on personal construct psychology (Kelly, 1955) and was further developed by Gutman (1982) and Reynolds et al. (2001). To map a decision-making process, the theory links together means to ends with three types of constructs: attributes (product characteristics), consequences (expected outcomes from using a product), and values (personal goals). Attributes are sought to reach various consequences; consequences ultimately play a role in achieving values. The line of reasoning between constructs (from an attribute to a value) is called a ladder. Ladders are compiled from a sample population and visually presented in a map known as a hierarchical value map (HVM).

Though the MEC approach is more readily applied to consumer decision-making research, it has also been applied to farmers' decision-making. In crop farming, MEC research has been used to investigate herbicide use for grazing in Brazil (de Andréa Picolli et al., 2020), organic practices in Lebanon (Naspetti et al., 2016), biological control adoption in Iran (Abdollahzadeh et al., 2016), soil fertility management and pesticide use in Kenya (Lagerkvist et al., 2012, 2015; Okello et al., 2014) and sourcing banana planting materials in Uganda (Kilwinger et al., 2020). Applied to the context of this research, the theory assumes that farmers utilize various crop and soil health promoting measures (means) that resonate with their values (end). The resulting HVMs can therefore ultimately serve as a visualization of the reasoning farmers use when selecting crop and soil health promoting products.

Attributes and values are the means to end explored by MEC theory. Previous studies have evaluated the underlying values that motivate crop farmers' behaviour. For instance, Okello et al. (2014) found that values including wanting a comfortable life, happiness, a healthy life, independence, achievement of life goal and personal satisfaction motivated farmers' soil fertility management practices. Lagerkvist et al. (2012) identified the values of wanting independence, a comfortable life, happiness, good health and helpfulness as motivators for farmers' use of pesticides. Leduc et al. (2023) found that caring for the environment, earning a living, reputation, business sustainability, [concern for] future generations and supporting family were some of the values motivating farmers to choose certified organic or conventional production systems.

The literature, however, does not dictate what product attributes are considered when farmers make decisions particularly when regarding crop and soil protection. To our knowledge, our study is the first that elicits product attributes that drive farmers' decisions regarding crop and soil health promoter use.

To understand farmers' reasoning, it is important to consider the influence of interactions within a social context in which farmers encounter innovation-related information as it plays a role in the formation of their perceptions, attitudes and dispositions (Glover et al., 2019; Katz, 1961; Rogers, 2003; Werner et al., 2008). The role of social influences on decision making has been previously explored in agricultural research. Determining the adoption of an innovation is largely contingent on the shared experiences of others who have already used it. These personal assessments primarily circulate within interpersonal networks (Rogers, 2003). Information sharing is thus one way in which farmers can be influenced by his/her social context (Marra et al., 2003). Sharing information can feed one's formation of norms. Cialdini et al. (1990) described two different types of norms that influence a person – descriptive norms (what a person perceives that others do) and injunctive norms (what a person perceives others think they ought to do). Evidence of the influence of the descriptive norm was for instance found by Schmidtner et al. (2012) and Läpple and Kelley (2015) who used spatial data to show that neighbouring farms tend to adopt similar organic farming practices. As an example of the influence of injunctive norms on farmers, Läpple and Kelley (2013) found that organic pork producers were more aware of the opinions of family, farm advisors and the press compared to their conventional farming counterparts. For more insights into the behavioural factors that affect farmers' adoption of sustainable practices, refer to Dessart et al. (2019). Thus, to truly grasp farmers' reasoning and choices, it is vital to acknowledge the profound weight of social context and norms, as they not only shape their individual experiences but can also steer their acceptance or rejection of innovative practices.

The objective of this research was two-fold. The first objective was to explore how farmers make choices about using newer solutions like insect frass. We employed the Means-End Chain approach to understand their decision-making regarding products that benefit their crops and soil. The second objective was to examine the role of group discussions in influencing farmers' decision-making processes. We did this by comparing the hierarchical value maps of farmers who had discussions about frass in a group setting with those who had not discussed it among peers. More specifically, this research addresses the questions: what is the decision-making process farmers implement regarding the selection of crop and soil health promoting products? How does the decision-making process differ between farmers who discuss their first impressions of frass with other farmers and farmers who do not? If there is a difference, what are the potential implications for the dissemination of circular crop and soil health promoting innovations like insect frass?

Our research contributes to the current literature in three ways. First, to the best of our knowledge, our study is the first that elicits product attributes that drive farmers' decisions regarding crop and soil health promoter use. In doing so, our study provides a more nuanced and accurate understanding of what truly influences farmers' decisions. It also allows us to better understand the factors that influence the behaviours of farmers as consumers. This could lead to the development of more effective marketing and communication strategies for companies in the agricultural sector and can assist in designing products that are more closely aligned with farmers' needs and preferences. Second, our study further contributes to the understanding of the role of information sharing and presumably norms on farmers' decisions. To the best of our knowledge, we are the first to utilize the MEC analysis to investigate this. In doing so, this study provides a richer understanding of how the Means-End Chain model operates specifically in the context of agriculture. Finally, we address some of the underlying methodological concerns around MEC research analysis, as MEC research has been subject to criticism regarding its lack of standardized analysis methods. Kilwinger and van Dam (2021) revisited some of the most relevant concerns relating to MEC analysis. To address some of the concerns raised and improve the transparency and quality of MEC analysis methods, this research (1) calculates the percentage of data retained in the HVMs under varying assumptions, (2) investigates the output generated from coding on different levels of abstraction, (3) visually integrates direct and indirect relationships between constructs in the HVMs, and (4) analyses using the state-of-the-art MEC Analysis Tool (Foolen-Torgerson & Kilwinger, 2023).

2. Methods

2.1. Research design

To investigate if and how altering social contexts influences farmers' decision-making processes, farmers were split into two groups: henceforth referred to as (1) the Farmer Groups and (2) the Individual Farmers. Further insights into the demographic characteristics of the participants are shared in Section 2.4. Those in the Farmer Groups participated in group discussions with other farmers. Those in the Individual Farmers were alone when they participated in the study. Farmers in both groups were presented with a four-minute informational video about frass. Those in the Farmer Groups watched it in the company of other farmers; those in the Individual Farmers had a link sent to their email, and they watched it alone. The video was produced based on the findings of Torgerson et al. (2021) and presented (1) what insect frass is, (2) how it promotes the health of crops and soil, and (3) how farmers should apply it. The video encompassed the three types of knowledge according to Rogers' Innovation Decision Process – awareness, how-to and principles knowledge (Rogers, 2003). The informational video with English subtitles can be viewed using this link: https://youtu.be/s4Y4t7uQo0s.

After the farmers in the Farmer Groups watched the video together, they participated in discussions that facilitated sharing their first impressions of frass. To do this, farmers were asked to share (by writing down) their general impressions, opinions and concerns regarding frass and then discuss them with the group. The written notes were arranged on a chart in three categories: advantages, disadvantages and concerns. The three most frequently discussed topics included what the expected costs and associated profitability were regarding frass' use, how easy to use and applicable frass is on their farms, and because the use frass as a crop and soil health promoter is new and currently lacks evidence of its effectiveness, there can be significant consequences for those who use it. More generally speaking, the groups most often reached the conclusion that as long as frass eventually works as it is supposed to, is cost effective, and addresses their remaining concerns, they would be open to trialling it on their farms. See Appendix A for an overview of the advantages, concerns and disadvantages raised during the six group discussions. No such discussion took place for the Individual Farmers.

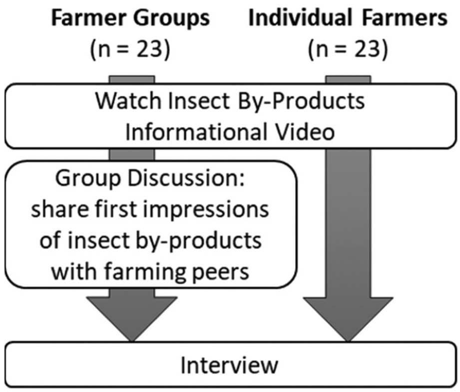

Figure 1. Research design.

After having watched the video (and for those in the Farmer Groups participating in a group discussion), all farmers (from both groups) participated in an interview. Figure 1 presents a schematic overview of the research design.

2.2. Interviews

Two research assistants underwent training prior to conducting the interviews. The training (1) explained the theoretical background of the MEC approach, (2) provided an overview of the logistical conduct of laddering interviews and advice for handling more challenging interviews, and (3) facilitated mock interviews. Most of the interviews were conducted face-to-face at the farmer's residence or farm office. However, due to the COVID-19 pandemic restrictions, the last five interviews were conducted online using Microsoft Teams. The interviews took place within sixteen days after the farmers had initially watched the informational video. The timespan varied depending on when contact details could be acquired and the farmer's availability. Farmers who participated were briefed on the research methodology, after which they confirmed their understanding and agreement by signing the consent form. The Ethics Committee of Wageningen University granted approval for this study.

During the interview, the farmers were informed of the goals of the research and were asked for permission to audio record; all agreed. The farmers were also asked if they would like to re-watch the informational video; most of whom did. Farmers in the Farmer Groups were reminded of the general conclusions (advantages, disadvantages and concerns) from the specific group discussion they had participated in.

The interview was conducted in two parts: attribute elicitation followed by soft-laddering.

2.2.1. Product characteristic elicitation

The interviews began by generating a list of the crop and soil health promoting products that the farmer had used within the last five years. A range of five years was useful in understanding farmers' motivations for using products they had recent and past experience with including those that are now banned from the marketplace (e.g. neonicotinoids). A two-step approach was used to combine salient products – ones that come most quickly to mind – with the benefits of a pre-defined list which aids in more complete recollection. To do this, the farmer was first asked, "What are the products you use to promote the health of your crops and soil?". Then a list of more general crop and soil health promoting products was presented, and the farmer was asked to mark the ones he had used within the last five years. "Insect frass" was also included in the list.

Once a list of products was developed, attributes were elicited. Some examples of attribute elicitation include free, triadic and dyadic sorting, free elicitation, and attribute selection tasks (Landfield, 1971; Reynolds et al., 2001). There are pitfalls to each approach; therefore, a combination of elicitation methods is recommended to ensure that key distinctions between products are not missed (Reynolds et al., 2001). In this research, we implemented dyadic sorting followed by free elicitation. Dyadic sorting involves presenting two products and asking the participant to make distinctions. Free elicitation elicits the most salient attributes, which are the easiest for participants to recall (Ittersum et al., 2007). It involves asking participants to indicate product characteristics that they believe are important. One disadvantage of more free elicitation methods is that consequences and values can also be elicited in addition to attributes. Therefore, to avoid confusion, we refer to them as "product characteristics" as opposed to "attributes".

For each product characteristic mentioned, the farmers were asked their preference if they had the choice between two products. For example, the farmer may state that Product A contains organic matter and Product B does not, and if given the choice, the farmer prefers a product that contains organic matter. After generating a list of preferred product characteristics, the next step was to understand how important each one was to the participant. Direct-rating was used to elicit the relevance of an attribute's importance (Ittersum et al., 2007) and was conducted by asking farmers to rate on a scale from 1 to 5 (unimportant to very important) how important each of the indicated preferred product characteristics were to him if he were to buy a new crop and soil health promoter. The rated characteristics are here forth referred to as Preferred Product Characteristic Ratings (PPCR).

2.2.2. Soft-laddering

Interviews were conducted using soft laddering as it is recommended for exploratory research with less than fifty participants (Costa et al., 2004). Preferred product characteristics rated as a 5 were used as the starting points for the laddering interviews (Reynolds et al., 2001). If time allowed, the preferred product characteristics rated as a 4 were then discussed, followed by those rated as a 3.

Farmers were asked why a particular preferred product characteristic was important to consider when looking to buy a new crop and soil health promoting product. For each response given by the participant, the follow up question, "And why is *that* important to you?" was asked until a value (e.g. quality of life) was reached or the farmer could not reason any further, at which point the next most important preferred product characteristic was discussed.

2.3. Analysis

The interviews were conducted in Dutch; therefore, Dutch native speakers transcribed and translated the interviews into English. Involving Dutch native speakers proved useful for interpreting Dutch sayings (e.g. "earning a sandwich" in Dutch refers to earning money). Their contributions arguably improved the coding accuracy.

The transcripts were coded in ATLAS.ti 9 Windows. Initially, coding was conducted by the first author and a research assistant independently. The two coded files were compared to identify inaccurate or inconsistent coding by the first author. After comparing the codes of nine interviews, the coding style (accuracy and consistency) between researchers was comparable, and the remaining interviews were coded by the first author.

Coding was performed on two levels of abstractness. For example, the code "shape" (parent code) can become more detailed by specifying "circle" and "square" (child codes). Shifting the analysis to a lower level of abstractness (from analysing parent codes to analysing child codes) results in more complex and information-rich HVMs (Reynolds et al., 2001).

Within ATLAS.ti 9, codes were linked to one another in the text. These links between the codes were then represented in the MEC analysis tool as direct or indirect links. Using an example, consider that a farmer states that A is important because of B, and B is important because of C [A to B to C]. A is therefore directly linked to B and indirectly linked to C (via B), and B is directly linked to C. Continuing with the example, consider two other farmers reasoned as follows: [A to D to C] and [A to F to C]. By only accounting for direct links, A would be in no way recognized as being associated with C, even though all three farmers have similar, though slightly differing ways of reasoning that associate A with C. Accounting for both direct and indirect links in the analysis therefore preserves more existing relations between constructs.

There are two ways to analyse MEC data: in terms of the frequency-of-responses (links are counted as many times as they are mentioned by the participant) and the number-of-respondents (a link is only counted once regardless of how often the participant mentions it) (Kilwinger & van Dam, 2021). The links in this research were counted on the basis of the number-of-respondents because of how the interviews were conducted. Using an example, consider that a farmer linked A to B and B to C. Then, the farmer indicated that D also links to B. The researcher did not ask again why B is important, as the farmer already linked it to C. Rather, the researcher asked if there were any other reasons (besides B) why D is important. Therefore, links were not elicited more than once in a given interview making the analysis on a frequency-of-responses level inappropriate.

To generate the HVMs, an analysis of the appropriate PPCR and cut-off levels was conducted. Once determined, HVMs were generated accordingly for the Farmer Groups and the Individual Farmers. The data was analysed using the MEC Analysis Tool (Foolen-Torgerson & Kilwinger, 2023). The output of the MEC Analysis Tool was used to create visual presentations of the HVM results in NodeXL.

2.3.1. Determining the level of preferred product characteristic ratings

The data can be analysed on a PPCR level 5 which includes only attributes rated as a 5 (and their subsequent ladders), or on PPCR level 4 or 5 which includes only attributes rated as 4 or 5 (and their subsequent ladders), or on PPCR level 3, 4 or 5 which includes only attributes rated as 3, 4 or 5 (and their

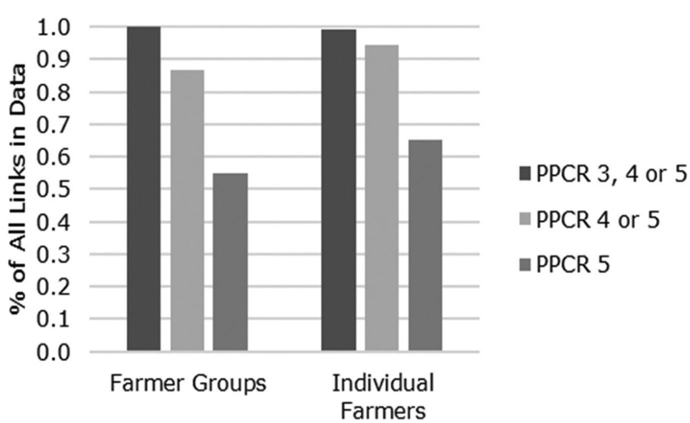

Figure 2. Percent of links retained per group and PPCR (preferred product characteristic rating) level.

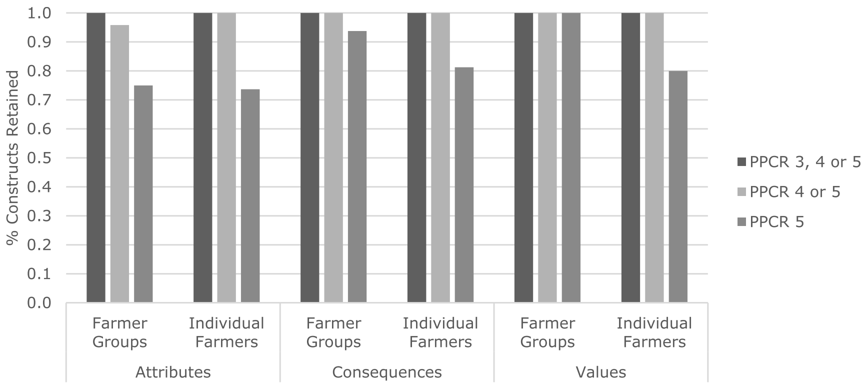

Figure 3. Percent of constructs retained per group and PPCR (preferred product characteristic rating) level.

subsequent ladders). The level of PPCR used in the analysis was determined by how many links between codes and how many constructs were retained at the various PPCR levels (see Figures 2 and 3 respectively).

Figure 2 shows that thirteen and six percent of the total links made were lost when including only PPCR 4 or 5 in the Farmer Groups and the Individual Farmers respectively. A forty-five and thirty-five percent reduction was seen when including only PPCR 5 in the Farmer Groups and the Individual Farmers respectively. When conducting a similar analysis for constructs lost, including only PPCR 4 or 5 results in 0–4% loss of constructs for the Farmer Groups and a 0% for the Individual Farmers. Including only PPCR 5 results in 0–25% loss of constructs for the Farmer Groups and 19–26% for the Individual Farmers. As we were interested in both the most important reasons and the secondary reasons that farmers have for using the products they do, it was decided to analyse and compare HVMs on PPCR level 4 or 5 to HVMs of PPCR level 5.

2.3.2. Determining a cut-off level

For a link between two constructs to appear in the final HVM (e.g. between an attribute and a consequence or between a consequence and a value), a minimum number of participants must have directly or indirectly linked the two constructs together; the minimum number of participants chosen is called a cut-off level. A high cut-off level can reduce the complexity of the HVM by retaining only the most important ladders. However, a cut-off level that is too high can also fail to retain important ladders. Therefore, a balance had to be found between data retention and readability. Cut-off level decisions are often unjustified as there is little theoretical or statistical criteria for the selection (Rogers, 2003).

In this research, the cut-off levels considered for the analysis were between two and seven participants. A cut-off level higher than seven was not considered as the percent of values retained in the HVMs of PPCR level five dropped to 0% in both groups. Selecting a cut-off level was done by calculating the Concentration Index (Pieters et al., 1994). The Concentration Index is defined as the percentage of all links that are retained at the cut-off level divided by the percent of all constructs retained at the cut-off level (Reynolds et al., 2001). Appendix B presents an overview of the Concentration Index at cut-off levels two through seven for both groups. Notably, no single cut-off level resulted in the highest Concentration Index across the groups. The decision was made to use a cut-off level of five because it had, on average, the highest Concentration Index across the groups. The percentage of constructs retained at a cut-off level of five is presented in Appendix C along with the percent of constructs retained at cut-off levels two through seven.

2.4. Sample

Forty-six Dutch arable farmers participated in this research between February 2020 and March 2021. Twenty-three participants were in Farmer Groups, and 23 participants were Individual Farmers. Those in Farmer Groups were recruited from three pre-existing study groups, resulting in six group discussions of three to six farmers. Individual Farmers were recruited from pre-existing study groups and snowball sampling.

A larger sample size was initially planned, however, due to the COVID-19 pandemic, the data collection was postponed several times. In an attempt to achieve a larger sample without extending the research timeline further, the last two group discussions and subsequent interviews were conducted online (as opposed to face-to-face). When conducting the group discussions virtually, idea sharing was limited to verbal communication.

2.4.1. Demographics

Of the 46 participating farmers, 37 identified as conventional farmers, 2 as organic farmers, and 7 as mixed (organic and conventional) farmers. Farms ranged in size (24–450 hectares) and percentage of land owned (average of 64%). Farmers were almost exclusively male and ranged in years of

Table 1. Demographics of farmers that participated in the Farmer Groups and the Individual farmers.

	Farmer Groups			Individual Farmers		
	Min	Max	Average	Min	Max	Average
Land Owned (%)	0	100	61	0	100	67
Hectares of Arable Land	18	370	116	30	488	129
Years of Arable Farming Experience	3	45	28	4	45	27
Age	26	67	52	26	70	50
Family Income Derived from Farm (%)	10	100	77	35	100	83

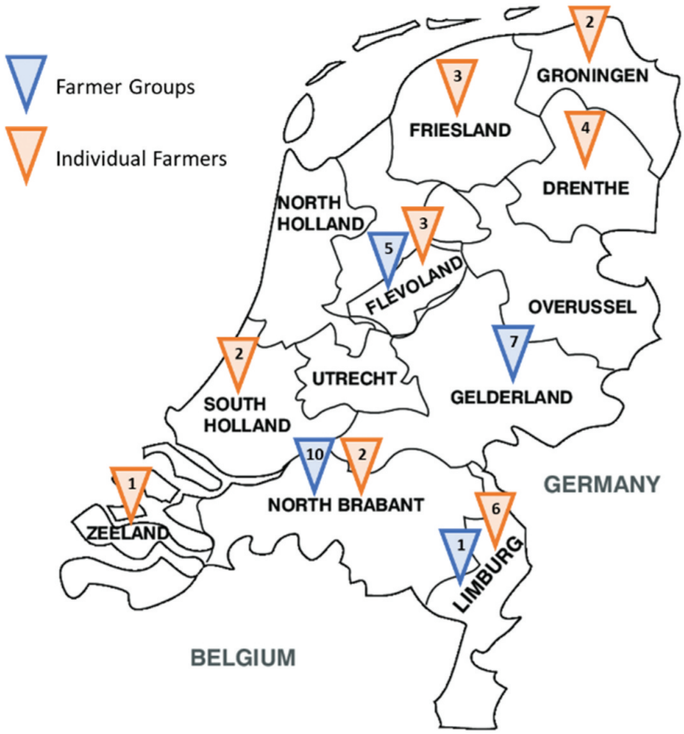

Figure 4. Distribution of participants by province.

experience (3–45 years), age (26–70 years old), and percentage of family income derived from the farm (10% − 100%) (see Table 1). Two-sample t-tests assuming equal variances were conducted, and no significant (at 5%) differences were found in the demographics of Table 1 between the two groups.

Figure 4 shows a map of the Dutch provinces where the participants' farms were located (on a province level). Noticeably, the spread of Individual Farmers is more dispersed than of those in Farmer Groups. The reason for this difference is due to how participants were acquired. Farmer Group participants originated exclusively from study groups (where participants are located relatively closer together), and Individual Farmers were acquired by study groups and snowball sampling, which resulted in more dispersion.

3. Results

The results are presented in two parts: the elicited product characteristics and the HVMs.

Table 2. Product characteristics elicited.

	Farmer Groups						Individual Farmers					
	Frequency of product characteristic mentioned (n)	Median	Count PPCR 4 or 5	HVM PPCR 4 or 5[b]	Count PPCR 5	HVM PPCR 5[b]	Frequency of product characteristic mentioned (n)	Median	Count PPCR 4 or 5	HVM PPCR 4 or 5[b]	Count PPCR 5	HVM PPCR 5[b]
PRICE												
Low Price; Good Price Quality	14	5.00	11	y	8	y	17	4.00	9	y	5	-
EXTENDED EFFECTS												
Natural or Environmentally Friendly (when deemed safe)	16	4.75 [a]	12	y	9	y	8	4.00	6	-	2	-
Long/Short Term Effects; Works Long Term	1	4.00	1	-	0	-	2	5.00	2	-	2	-
APPLICABILITY												
Easy to Apply/Use; Fits Machine	14	4.00	10	y	4	y	8	3.50	4	-	1	-
Specificity of Application	9	3.00	4	-	2	-	5	3.00	2	-	2	-
Dose	7	4.00	4	-	2	-	4	4.00	3	-	1	-
Form (Liquid or Solid)	5	4.00	3	-	1	-	1	3.00	0	-	0	-
COMPOSITION												
Organic Matter	7	4.00	4	-	3	-	15	5.00	14	y	10	y
Nutrients	5	4.00	3	-	1	-	13	4.00	8	y	3	-
Chitin	0	-	0	NA	0	NA	2	3.00	1	-	0	-
PERFORMANCE												
Familiar; Trusted; Reliable; Proven; Consistent	3	4.00	2	-	1	-	6	5.00	5	-	4	-
Effectiveness	4	4.00	3	-	1	-	6	5.00	6	-	4	-
Fast Result	1	1.00	0	-	0	-	1	4.00	1	-	0	-

(*Continued*)

Table 2. (Continued).

	Farmer Groups						Individual Farmers					
	Frequency of product characteristic mentioned (n)	Median	Count PPCR 4 or 5	HVM PPCR 4 or 5[b]	Count PPCR 5	HVM PPCR 5[b]	Frequency of product characteristic mentioned (n)	Median	Count PPCR 4 or 5	HVM PPCR 4 or 5[b]	Count PPCR 5	HVM PPCR 5[b]
Preventative	3	4.00	2	-	1	-	4	4.50	3	-	2	-
Fast Degrading; Speed of Decomposition	2	4.00	2	-	0	-	1	4.00	1	-	0	-
AVAILABILITY												
Wide Availability	1	5.00	0	-	0	-	1	4.00	1	-	0	-

[a]In some cases, the farmer mentioned characteristics that fall under the same (parent) code. For example, differentiations "natural" and "environmentally friendly" both fall under the code "Natural or Environmentally Friendly (when deemed safe)". In such cases, the average rating assigned by the farmer to these two characteristics was used so that a farmer is not represented in a code more than once. Therefore, a median of 4.75 is feasible as the median fell between 4.5 and 5.

[b]"y" means "yes"; the product characteristic appears in the specified HVM.

3.1. Product characteristic elicitation

Table 2 provides an overview of the 16 elicited product characteristics mentioned by more than one farmer during the interview, the number of farmers in each group who rated the product characteristic, the median ratings for each product characteristic, and an indication of if the product characteristic appears in the HVMs. As a note, not all of the product characteristics mentioned by farmers appear in the HVMs although the median PPCR may be five. This is either because not enough farmers initially stated it or that the farmers did not uniformly associate it with similar constructs. For example, for Individual Farmers, *Effectiveness* is associated 14 times to five consequences and three values. However, it is never associated more than five times (the determined cut-off level) to any specific consequence or value. Thus, even though *Effectiveness* has a median of five, it does not appear in the Individual Farmers' HVM. The product characteristics are organized in six categories: price, extended effects, applicability, composition, performance, and availability.

The Individual Farmers more frequently stated product characteristics relating to composition and price, whereas Farmer Groups more frequently stated and gave higher importance ratings to product characteristics relating to price, extended effects, and usability. This suggests that the group discussions ultimately made certain aspects of frass more salient which influenced the product characteristics elicited and their importance ratings. For instance, in the group discussions, the three most discussed concerns regarding frass were indeed the monetary considerations, the applicability and usability, and the potential long-term harm (e.g. toxicity) as a pure/natural product (see Appendix A for a summary of the group discussion outcomes), which related to the product characteristics identified by those in the Farmer Groups.

3.2. Hierarchical value maps

Figure (a-d) portrays the hierarchical value maps (HVMs) that are generated from the Farmer Groups and the Individual Farmers at PPCR level 5 and PPCR level 4 or 5 respectively with a cut-off level of 5. For a deeper exploration of the data, Appendix D provides an overview of the same HVMs but using child codes. The HVMs in Appendix D have a cut-off level of two so more information would be retained; granted the complexity increased. To combat the increased complexity and to make them comparable to the HVMs in Figure 5, child codes not embedded under a parent code shown in Figure 5 were removed. The results of the HVMs provide a visualization of the reasoning farmers applied when selecting the crop and soil health promoters that they have used.

Comparing the Farmer Groups (Figures 5a, c) to Individual Farmers (Figures 5b,d), it appears that Individual Farmers share a single line of reasoning; they look for a product that improves their plant and soil health. Specifically, *Organic Matter* seems to play a role for Individual Farmers in achieving this. Improving soil and crop health is beneficial for improving yields and reducing the number of inputs (and interventions), work effort and costs. In doing so, they can achieve their goals of creating a quality and safe product, earning a living and continuing to farm. When investigating PPCR level 4 or 5, *Nutrients* and *Price Quality* play a role in achieving this goal. Additionally, *Environmental Considerations* are also taken into account.

Farmers in Farmer Groups also followed this logic but with a few modifications. Already in PPCR level 5 (what farmers found most important), *Environmentally Friendly* and *Easy to Use* products are also sought to achieve goals related to *Environmental Considerations* and *Farming Continuation and Ability to Earn a Living*. Broadening to PPCR level 4 or 5, the additional value *Farming Image and Public Support* appears. Notably,

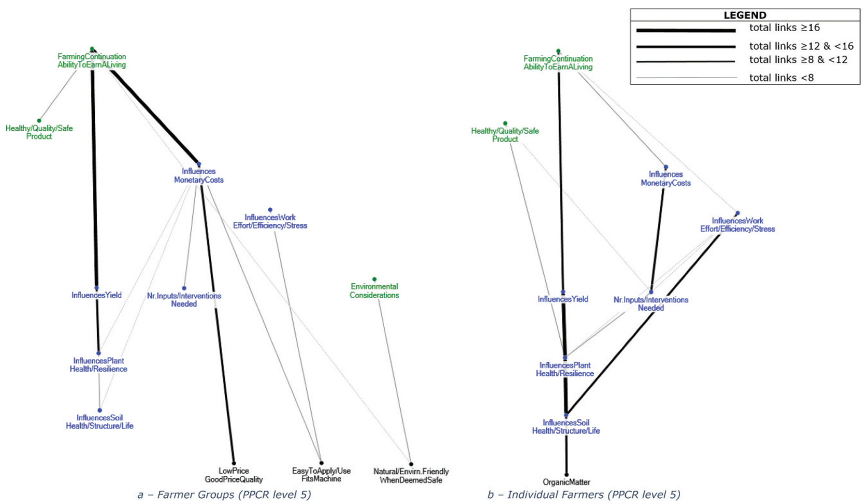

Figure 5a. (a) Farmer Groups (PPCR level 5), (b) Individual farmers (PPCR level 5). Attributes appear in black text. Consequences appear in blue text, and values appear in green text. Solid lines indicate that there are as many or more direct links between the two constructs than indirect links. Dotted lines indicate that there are more indirect than direct links. The line thickness varies for the solid lines depending on the number of total links made between the two constructs, shown in the legend. The primarily indirect links (dotted lines) all have a total number of links less than eight.Data from 23 participants are presented in each HVM at a cut-off level of 5. Farmer Groups participated in a group discussion; Individual Farmers did not.

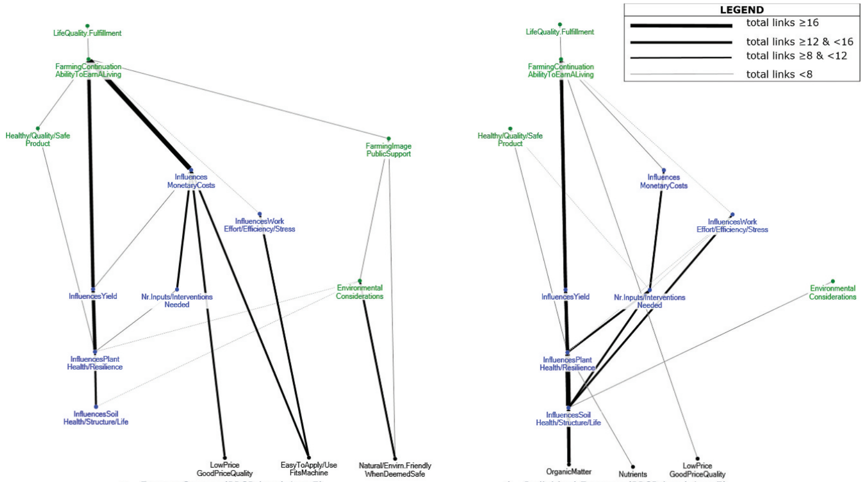

Figure 5b. (c) Farmer Groups (PPCR level 4 or 5), (d) Individual farmers (PPCR level 4 or 5). Attributes appear in black text. Consequences appear in blue text, and values appear in green text. Solid lines indicate that there are as many or more direct links between the two constructs than indirect links. Dotted lines indicate that there are more indirect than direct links. The line thickness varies for the solid lines depending on the number of total links made between the two constructs, shown in the legend. The primarily indirect links (dotted lines) all have a total number of links less than eight. Data from 23 participants are presented in each HVM at a cut-off level of 4 or 5. Farmer Groups participated in a group discussion; Individual Farmers did not.

ladders associated with attributes *Natural/Environmentally Friendly* and *Easy to Use* thicken, and *Organic Matter* and *Nutrients* are not attributes that are specifically related to achieving their goals as is the case with Individual Farmers.

When comparing the Farmer Groups and the Individual Farmers, the consequences (blue text) are the same, and the values (green text) are similar. The attributes (black text) however differ completely at PPCR level 5, and at PPCR level 4 or 5 there was only one common attribute – *Price Quality*. This suggests that all farmers share a common line of reasoning for how crop and soil health promotion impacts their farm (consequences) in terms of improved crop and soil health, improved yields, interventions needed, the influence the changes have on work effort, efficiency and stress and monetary costs. Why they strive to achieve these outcomes (values) differs slightly, but more interestingly, how they achieve these outcomes (attributes) differs greatly as also seen in the product characteristic elicitation results (see Section 3.1). The results all together suggest that discussing, in this case, the advantages, concerns and disadvantages of frass in a social context made the shared content more salient and important.

Attributes appear in black text. Consequences appear in blue text, and values appear in green text. Solid lines indicate that there are as many or more direct links between the two constructs than indirect links. Dotted lines indicate that there are more indirect than direct links. The line thickness varies for the solid lines depending on the number of total links made between the two constructs, shown in the legend. The primarily indirect links (dotted lines) all have a total number of links less than eight.

Data from 23 participants are presented in each HVM at a cut-off level of 5. Farmer Groups participated in a group discussion; Individual Farmers did not.

Data from 23 participants are presented in each HVM at a cut-off level of 4 or 5. Farmer Groups participated in a group discussion; Individual Farmers did not.

4. Discussion

The first objective of this research was to explore how farmers make choices about using newer solutions like insect frass. The results showed that farmers seek crop and soil health promoting products that they believe will improve yields and reduce work effort, costs, inputs and interventions, which ultimately aids them in creating a high-quality and safe product, earning a living and continuing to farm. Two studies, in particular, investigate topics comparable to this research. Specifically, these studies investigated Kenyan farmers' decision-making processes regarding the use of pesticides (Lagerkvist et al., 2012) and various sorts of manure and fertilizer (Okello et al., 2014) in kale production. Despite the markedly different contextual differences, the healthy/good looking plants, making money, increasing yield, and improving soil fertility are all examples of shared findings.

The second objective of this research was to examine the role of group discussions in influencing farmers' decision-making processes. The results show that those in the Farmer Groups drew upon the content that was discussed in the group discussions when explaining their decision-making processes in the interviews days to weeks after. For instance, the group discussions were useful in realizing topics related to environmental impact and ease of use. They were in a way nudged by one another to prioritize certain attributes. The desired consequences and values remained relatively uninfluenced, as would be expected. Farmers who did not participate in group discussions may have also shared the same decision-making process had they been exposed in discussions to more considerations.

Thus the results revealed an intriguing pattern. Those in the Farmer Groups took into account a broader set of product attributes, such as price, ease of use, and environmental impact. Price is an example of an attribute that can only be determined prior to a purchase (known as a search attribute). Ease of use is an example of an attribute that can only be assessed after a purchase (known as an experience attribute). Therefore, the Farmer Groups considered a mix of attributes search and experience attributes. This suggests that participation in group discussions enabled these farmers to tap into the collective wisdom of their peers, thus expanding their awareness of different attribute considerations.

In contrast, Individual Farmers (who did not participate in discussions) focused on technical specifications, indicative of search attributes (i.e. organic matter and nutrient content and price). This could suggest that farmers who rely more on their own judgement might tend to focus more on the technical specifications of products. This might be due to a greater reliance on personal experience and technical knowledge in the absence of social interactions.

This divergence may be reflective of the power of descriptive norms, wherein group discussions can shape collective perceptions of what attributes are crucial, subtly guiding farmers' attribute considerations. Hence, while consequences and values remained similar across the board, our findings highlight that the social context can indeed play a role in shaping the product attributes farmers consider to achieve them.

Using MEC approach provides crucial and more in-depth insights into the rationale farmers follow when choosing their crop and soil health promoters, and our results suggest that the product's attributes deemed relevant for achieving these goals can vary depending on the social context. This is an important finding as it suggests that group discussions may be able to influence how farmers evaluate frass. For instance, without a group discussion, evaluations may be primarily based on the perceived performance of frass as an organic matter addition. With group discussions, however, the evaluation may be based more on the perceived ease of use, price and environmental friendliness. Farmers' willingness to adopt frass could then depend on their perceptions on its ability to fulfil/contribute the attributes they deem necessary to ultimately achieve their goals.

These findings could have significant implications for how companies market their products to farmers. For instance, they might benefit from promoting the technical aspects of their products to individual farmers, while emphasizing a mix of (experience and search) attributes when interacting with farmer groups.

Because frass is still in an early phase of R&D, many of the basic concerns expressed by the farmers in the discussion groups could not be addressed (e.g. price, application details and effectiveness). Had these more basic details been available, the farmers could have had more in-depth discussions. However already, without providing such basic details, one can see that simply sharing concerns about these details was enough to integrate them into the decision-making process regarding crop and soil health promoters. Therefore, if insect frass (or other innovations in crop and soil health promotion), which are currently new and thus met with caution by farmers, eventually prove to be easier to apply, more cost effective, and better for the environment, farmers should be sincerely listened to and their concerns addressed, as these are central to their decision-making process. Granted, such innovations are only interesting when economically feasible for farmers. One should not forget, farmers' top values relating to crop and soil health promoters are to ultimately produce a healthy, high-quality and safe product that can earn them a living and stay in business; new products must therefore be financially feasible.

4.1. Research limitations

Three limitations are worthwhile discussing for this research. First, considering the relatively small sample size and the split in our sample, we refrain from making claims regarding the generalizability and external validity of the results. However, we can conclude that among the farmers interviewed in this research, the social context seems to have influenced the attributes they found necessary to achieve their goals.

Second, though the farmers were split into two groups and compared, a clearer picture of how the social context impacted the participants would be achieved if laddering interviews were conducted before and after the group discussions. In doing so, the effects of existing differences between the two groups could be mitigated. However, participants can already find one laddering interview unpleasant and time consuming; asking them to partake in two laddering interviews will likely result in dropouts, boredom and frustration. Therefore, we interpret these results acknowledging that there could be external influences of, among others, the difference in participant acquisition or regional (and often thereby cultural) differences.

Finally, as discussed in Kilwinger and van Dam (2021), "a construct that is not mentioned can still be important to a respondent". Failing to mention particular constructs may stem from, for example, a difference in product-use scenarios in mind. During the interviews, farmers were asked to what extent the preferred product characteristics they distinguished were important to them when looking to buy a new crop and soil health promoter. Some farmers considered health promotion as a means of ridding their fields of pests and diseases, while others considered health promotion as a more holistic process of building crop and soil resilience over the long-term. This led to, for instance, differences in importance assigned to *[Containing] Organic Matter*. The farmers with the product scenario of pest and disease riddance already use other products (e.g. composts or manures) for replenishing the organic matter content in their fields. For them, organic matter is not rated with high importance in a new product because it is already supplied by a product they already use. Therefore, the absence of elicited constructs from either group should not be overly interpreted.

4.2. Future research

Follow up research can proceed in several directions; we discuss three potential avenues. Further research can build on this study's investigation of the role social contexts play in farmers' decision-making processes in terms of their crop and soil health promoters. For example, a survey could be used to quantitatively investigate how social contexts influence farmers based on Theory of Planned Behaviour constructs (i.e. attitudes, subjective norms, perceived behavioural control and intentions).

As frass advances further in the R&D process, ideally it will be implemented on test farms where farmers can observe the results. At that time, it would be interesting to carry out an experiment that compares farmers' intentions to use frass under four conditions: farmers who only watch an informational video about frass (control), and farmers who watch the informational video and (1) participate in group discussions (only social context influence), (2) visit the test farm (experience), and (3) participate in group discussions and visit the test farm (interaction effect). Such research would test the impact of experience, the influence of social contexts, and the interaction effect of both to see what the most effective way is in promoting the uptake of frass.

Finally, future research could investigate farmers' preferences using a choice experiment that varies crop and soil health promoters based on the most frequently discussed attributes with the highest importance in this research. Such a study would aid in understanding which attributes are most persuasive when farmers are selecting a crop and soil health promoting product and gauge farmers' willingness to pay for such innovations.

5. Conclusion

The results of this research suggest that sharing first impressions of an innovation like the by-products of insect production in a social context can lead to the realization of less salient though important considerations regarding crop and soil health promoters. Ultimately, the social interaction that took place influenced the attributes farmers expressed as necessary to achieve their goals. If this is true, such group discussions play a vital role in broadening the perspectives and decision-making processes of farmers. Effectively communicating new findings and addressing farmers' uncertainties regarding circular innovations while encouraging (or facilitating) a dialogue amongst farmers can guide their decision-making processes that in turn, could lead to more uptake of proven and economically feasible circular innovations.

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Wageningen University's Ethics Committee Social Science (ECSS) approved the conduct of this research. Farmers who participated agreed to the research conduct by signing informed consent forms.

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Appendices

Appendix A – Conclusions from the six group discussions

To track the topics discussed in each group, one researcher served as the group moderator, a second researcher served as the note taker. Also, during the in-person discussion, the group members wrote down their thoughts on sticky notes and placed them on a large sheet of paper for further discussion. The group discussions were not audio recorded. The numbers presented in this table (n) represent how often the statement was noted in the summaries of the note takers or found on a sticky note. It is the minimum number of times that the topic was mentioned by a group. For example, (4) means that summaries from 4 group discussions included this statement, but the remaining 2 groups may have also discussed (or mentioned) the topic but it did not get documented in the group's summary by the note taker or was not found on a sticky note.

Advantages	Concerns	Disadvantages
• Frass can increase resistance and immunity of crops and the soil diversity/life. (4) • If frass is proven to be effective, is not harmful, is easily applied and is not too expensive, farmers will use it. (4) • Frass is a biological and natural product that can replace or reduce the use of other chemical products. (3) • Frass is a good alternative for banned plant protection products. (2) • Frass could increase crop yields. (2) • Frass can make the process of farming easier and less intensive. (1) • Consumers will like the circular aspects. (1)	• What are the associated costs (application and investment)? Will frass be profitable and cost effective? (6) • Is frass easy to use? Are new machines or apparatus needed to apply it? How is frass applied on farmland and in what dose? Do farmers have to change their current system to apply it? (6) • Are there negative or harmful short- or long-term side effects on the soil? Is frass pure, and does it contain any toxic substances? (5) • Is there independent scientific research carried out without any commercial interest? (4) • Does frass work effectively? (4) • Will frass be widely available to sustain all farmers' needs? (2) • Is frass legally approved? (2) • How does frass work together with other pesticides and soil improvement products and techniques? (1) • Is frass proven on the various soil types throughout the Netherlands? (1) • Does frass influence soil structure and resilience or improve crop quality? (1)	• Frass is new, unknown, and not yet well understood. A lot can go wrong. If it goes wrong, the consequences for farmers are huge. There is not enough evidence to try frass yet. (6) • Biological products are expensive and less effective compared to conventional products. Natural products can be toxic. (3) • Other products already have proven to be effective. Why should farmers change their systems? (1) • Previous experience using chitin was not positive. (1) • There could be ethical considerations towards insects with a growing vegan/vegetarian movement. (1) • Frass could create better circumstances for weeds to grow. (1) • Frass will probably not increase the value of the end-product sold and would therefore only work for high value products. (1) • Frass will probably be more difficult to use and require more intensive labour. (1) • The legislative approval needed to allow frass in practice will not happen quickly. (1)

Appendix B– Concentration index

	PPCR 4 or 5						PPCR 5					
	Farmer Groups			Individual Farmers			Farmer Groups			Individual Farmers		
Cut-off level	Nr. of Retained Linkages	Nr. of Retained Constructs	CI	Nr. of Retained Linkages	Nr. of Retained Constructs	CI	Nr. of Retained Linkages	Nr. of Retained Constructs	CI	Nr. of Retained Linkages	Nr. of Retained Constructs	CI
1	701	48	0.89	682	45	0.94	445	42	0.64	473	35	0.84
2	499	34	0.89	516	30	1.07	295	28	0.64	356	24	0.92
3	363	26	0.85	414	20	1.29	221	17	0.79	284	16	1.10
4	300	19	0.96	351	17	1.29	191	15	0.77	254	12	1.32
5	256	14	1.11	323	13	1.55	139	12	0.70	226	9	1.56
6	221	13	1.03	283	10	1.76	119	10	0.72	196	9	1.36
7	197	12	1.00	259	9	1.79	95	9	0.64	178	9	1.23

CI: Concentration Index = [Nr. of Retained Linkages/Total nr. of Linkages]/[Nr. of Retained Constructs/Total nr. of Constructs]

Farmer Groups:
Total number of Linkages = 808
Total number of Constructs = 49
Individual Farmers:
Total number of Linkages = 723
Total number of Constructs = 45

Appendix C – Percent of attributes, consequences and values retained per cut-off level

Farmer Groups; Individual Farmers

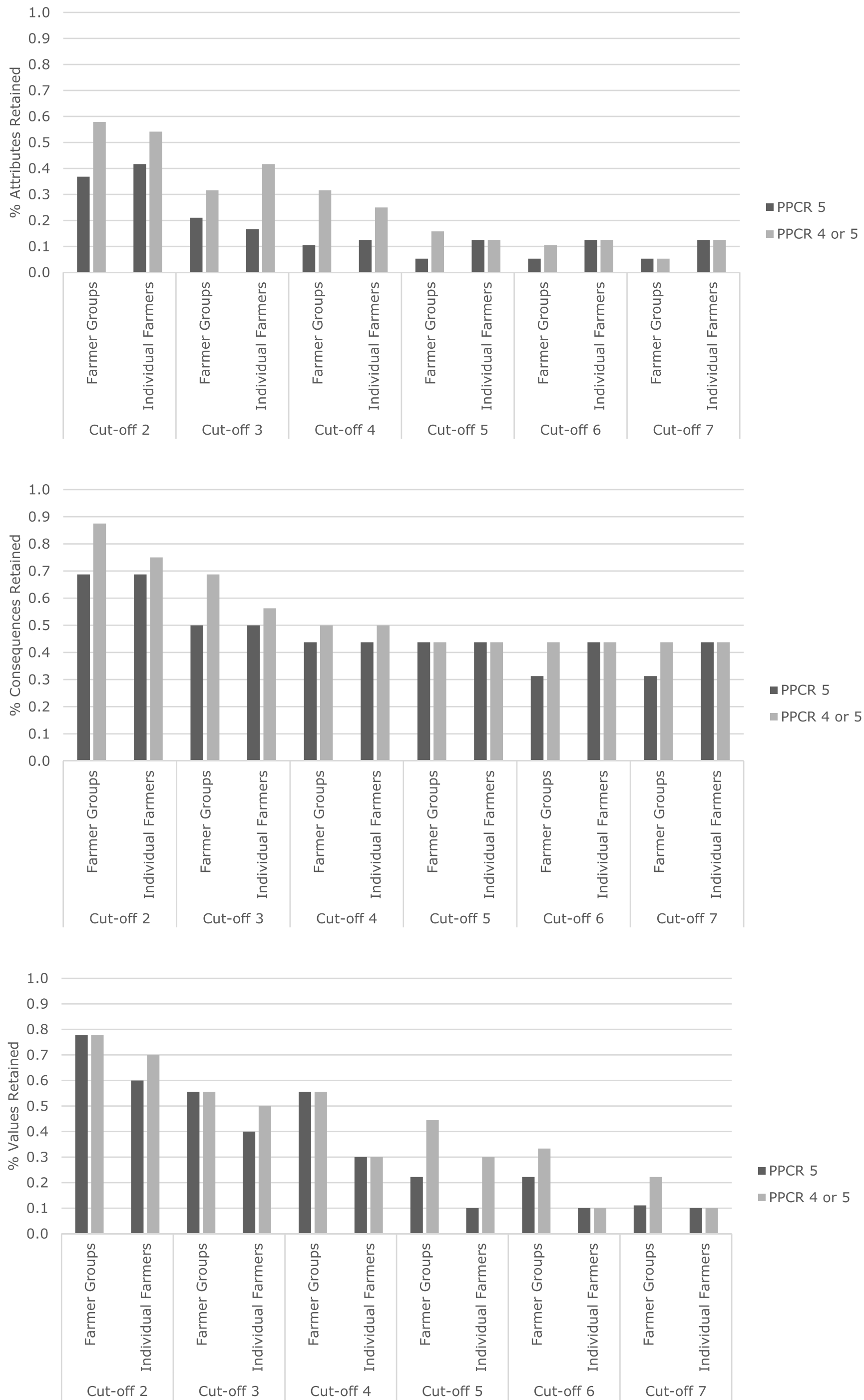

Figure C1. Percent of attributes, consequences and values retained per cut-off level.

Appendix D – Child code HVMs

Figures D1–D4 correspond respectively to Figures 5a–d and were analyzed using child codes as opposed to parent codes. Child codes were only included in Figures D1–D4 if they were embedded under a parent code presented in Figures 5a–d. This was done to reduce the complexity of HVM while gaining more information regarding the parent codes.

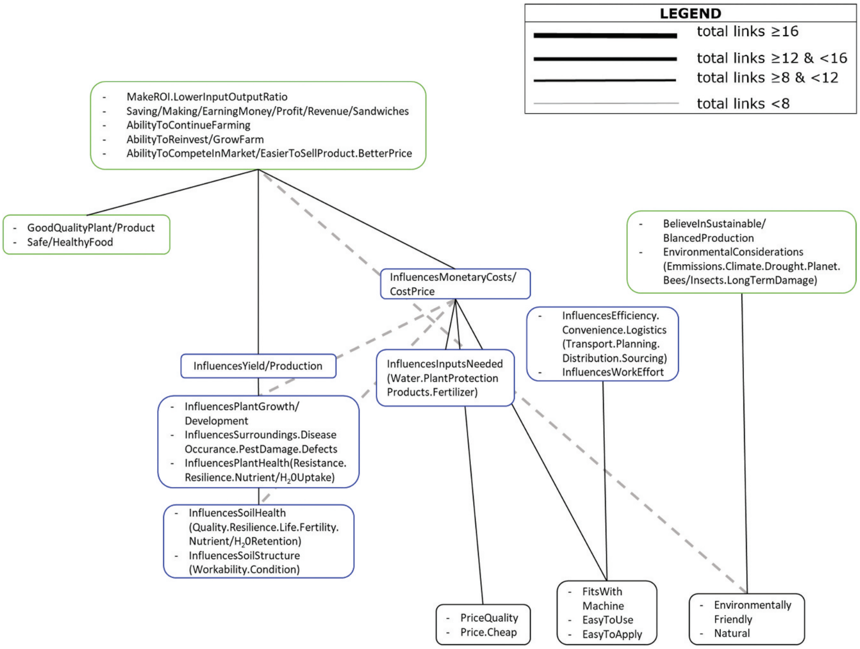

Figure D1. Farmer Groups (PPCR 5).

Attributes appear in a black text box. Consequences appear in a blue text box, and values appear in a green text box. Solid lines indicate that there are as many or more direct links between the two constructs than indirect links. Dotted lines indicate that there are more indirect than direct links. The line thickness varies for the solid lines depending on the number of total links made between the two constructs, shown in the legend. The primarily indirect links (dotted lines) all have a total number of links less than eight.

Data from 23 participants are presented in each HVM at a cut-off level of 2. This HVM corresponds to Figure 5a, which presents the HVM of Farmer Groups using parent codes at a PPCR level 5 and cut-off level 5.

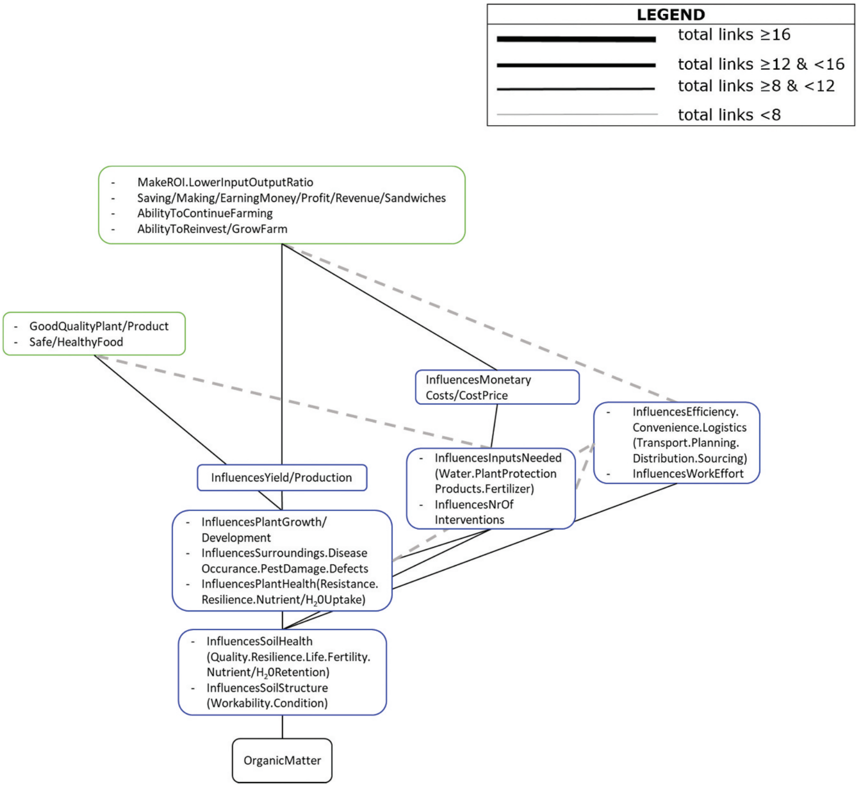

Figure D2. Individual farmers (PPCR 5).

Attributes appear in a black text box. Consequences appear in a blue text box, and values appear in a green text box. Solid lines indicate that there are as many or more direct links between the two constructs than indirect links. Dotted lines indicate that there are more indirect than direct links. The line thickness varies for the solid lines depending on the number of total links made between the two constructs, shown in the legend. The primarily indirect links (dotted lines) all have a total number of links less than eight.

Data from 23 participants are presented in each HVM at a cut-off level of 2. This HVM corresponds to Figure 5b, which presents the HVM of Individual Farmers using parent codes at a PPCR level 5 and cut-off level 5.

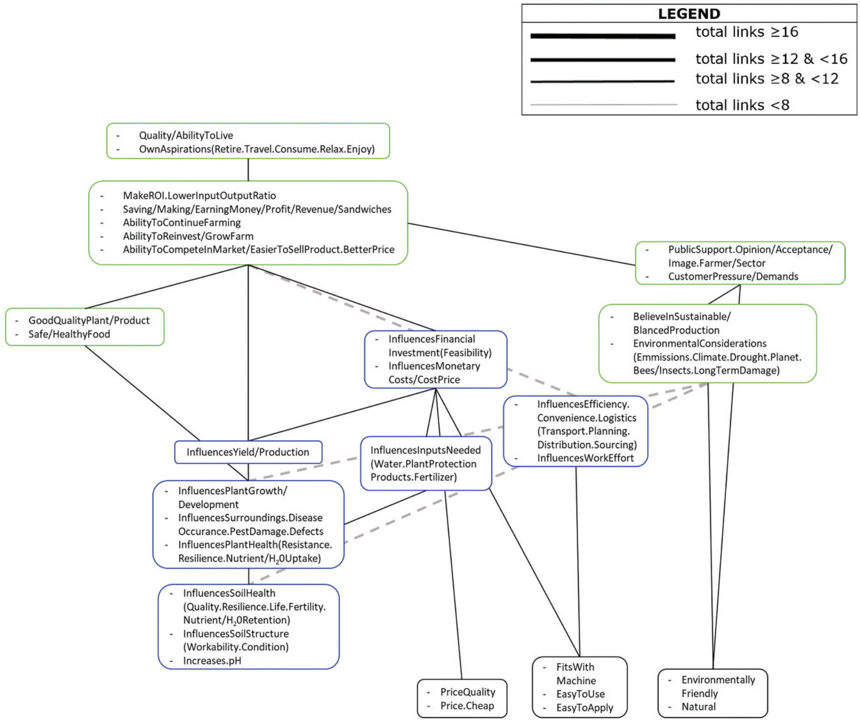

Figure D3. Farmer Groups (PPCR 4 or 5).

Attributes appear in a black text box. Consequences appear in a blue text box, and values appear in a green text box. Solid lines indicate that there are as many or more direct links between the two constructs than indirect links. Dotted lines indicate that there are more indirect than direct links. The line thickness varies for the solid lines depending on the number of total links made between the two constructs, shown in the legend. The primarily indirect links (dotted lines) all have a total number of links less than eight.

Data from 23 participants are presented in each HVM at a cut-off level of 2. This HVM corresponds to Figure 5c, which presents the HVM of Farmer Groups using parent codes at a PPCR level 4 or 5 and cut-off level 5.

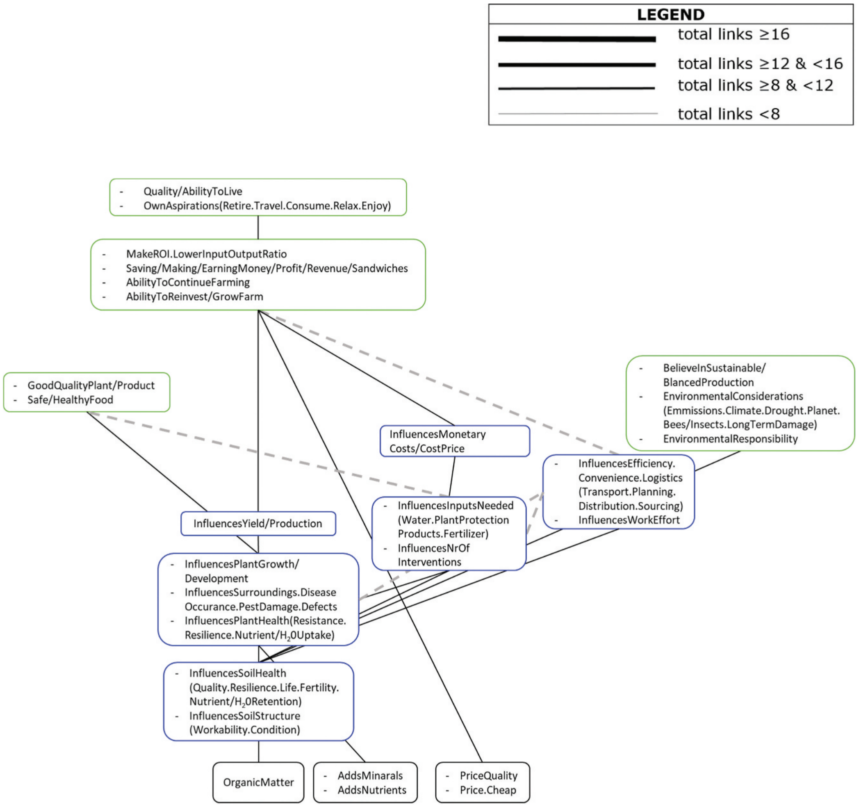

Figure D4. Individual farmers (PPCR 4 or 5).

Attributes appear in a black text box. Consequences appear in a blue text box, and values appear in a green text box. Solid lines indicate that there are as many or more direct links between the two constructs than indirect links. Dotted lines indicate that there are more indirect than direct links. The line thickness varies for the solid lines depending on the number of total links made between the two constructs, shown in the legend. The primarily indirect links (dotted lines) all have a total number of links less than eight.

Data from 23 participants are presented in each HVM at a cut-off level of 2. This HVM corresponds to Figure 5d, which presents the HVM of Individual Farmers using parent codes at a PPCR level 4 or 5 and cut-off level 5.