Q Methodology, a useful tool to foster multi-actor innovation networks performance.

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Abstract: We address in this paper opportunities of Q Methodology for empirical agricultural innovation studies. In the systems perspective on innovation, multi-actor innovation networks are seen as a key strategy to successful innovation. Given the several types of actors involved, the scientific and policy literature points at the need for 'innovation brokers' to build capacity for collective innovation and prevent innovation network failures. This paper aims at introducing Q Methodology as a fitting and promising tool to assist these systemic facilitators to probe more deeply into the mechanisms of social learning and collective cognition. Q Methodology is a mixed method that provides quantitative structure to individuals' opinions via factor analysis, based on a clear methodological structure and process. It has gained popularity in a range of 'messy' studies to analyze and typify the diversity of worldviews on complex and socially contested issues. Increasingly considered as a well-established method to address rural research questions, its use in agricultural innovation studies is still missing.
After providing a deal of practical information about the conduct of Q methodological research, we thus offer to reflect on the usefulness of Q Methodology in fostering multi-actor innovation network performance.

Keywords: Q Methodology, mixed method, stakeholder analysis, agricultural innovation system, innovation broker, multi-actor innovation network

Introduction

Q Methodology has a rich, if little known, history. In 1935, the psychologist and physicist William Stephenson – a doctoral student of Charles Spearman – published a letter in *Nature* (Stephenson, 1935); the letter announced that he had reconceptualized correlation analysis in such a way that in place of correlating tests in relation to random variables expressing traits, he had developed a method to correlate whole aspects of persons. What Stephenson introduced as an objective study of human subjectivity would grow into the scientific method Q Methodology (hereafter referred to as Q). Considerably developed and codified by the political scientist Steven Brown (1980), Q has been used in a wide range of studies applications seeking to uncover and analyze similarities and differences in the subjective viewpoints of individuals (McKeown, 1990).
In the eight decades since it was first proposed by Stephenson, Q has spawned both an increasing community of active practitioners, and recurrent severe critiques (*eg* Burt & Stephenson, 1939; Cattell, 1951; Kampen & Tamás, 2014), which the Q community in turn considers as repeated substantial misunderstandings of its mathematical and practical aspects (Brown et al., 2015). However, the last 15 years have witnessed a further increase in published Q studies – and a decline in published criticisms –: 92 publications per year in the years 2001-2013 compared to 35 in the years up to 1991-2000 (Brown et al., 2015). According to Donner (2001), *Q* is particularly well-suited for topics where it is necessary to recognize social complexity and, consequently, has slowly gained popularity in a range of 'messy' environmental issues (*eg* Addams and Proops, 2000; Cuppen et al., 2010; Curry et al., 2013; Hermans et al., 2012; Visser et al., 2007, 2011).

Regarding farming research, Previte et al. (2007) advocate that *Q*, were it to become better known, can be successfully applied to address rural research questions, while Fairweather and Klonsky (2009) argue that Q is "the only well-established method that rests on what farmers state is their approach to managing a farm rather than on methods that rely on researcher assessments of farming styles".

Q methodology is useful when one wishes to characterize how different groups of people think about a particular issue in a systemic way. It can be used to explore perspectives on any issue area where there is subjective disagreement, making it particularly useful for studying controversy – and there is a lot of controversy with regard to food and farming. A well-delivered Q study reveals the key viewpoints extant among a group of participants and allows those viewpoints to be understood holistically yet with a high level of qualitative detail.

We had the opportunity to personally ascertain the soundness of the method through its application in four contrasting cases. Three of these cases involved unsustainable and conflicting uses of natural resources: (1) cereal fallows in arid Tunisia (Visser et al., 2011), (2) marginal farmland with high nature value (turloughs) in West Ireland (Visser et al., 2007), and (3) endemic medicinal and aromatic plants with high economic value in the High Moroccan Atlas (Louah, 2010). Our fourth Q study aimed at understanding barriers to the development of modern agroforestry in South Belgium (Louah et al., in press) – agroforestry being increasingly promoted by scientists as a sound environmentally friendly farming innovation for European productive areas (Palma et al., 2007).

The idea of using Q methodology arose as we were looking for a way of scientifically integrating the human ecology (practices, worldviews, values) of food and farming issues. In our opinion and experience, whereas in food and farming issues, the human ecology is quintessential for understanding, more often than not it is ignored or silenced. As natural scientists, we were ill equipped to explicitly take on board the human factor and societal concerns, and especially suspicious of researcher bias when it comes to studying phenomena that are hard or impossible to measure, thus quantify, or at least break down in measurable bits and bites. Compared to purely qualitative methods – with, in our sense, often unclear interpretation processes – Q is very appealing because it involves a more rigorous analytical framework minimizing researcher's bias (Brown, 1980), as well as very well defined and transparent steps – see the next point for overview of Q basic steps and assets. Therefore, Q opened doors toward transdisciplinary research, and thus to successfully understand, in various contexts, systemic barriers to sustainable management or innovation, and how to overcome these barriers. Q was also the gateway to other, complementary, methodologies for investigating human ecology.

Today we focus our research on food system redesign, and more especially on the development of agroecological innovation. Research in system redesign views innovation not just as an end-product of science and technology to be transferred to end-users but as a process of socio-technical nature. It is important to acknowledge that, *in fine*, food system redesign happens through stakeholder action, whether accompanied or not by (formal) research. Examples abound of farmers who redesigned their farms over the course of a decade or longer without any formal help by state-funded research. However, even though their output/input efficiency, productive potential, and socio-economic viability have been scientifically demonstrated, and even though some small scale experiments and initiatives hold promise for upscaling, food system redesign for stronger sustainability does not break through. Reasons can be summarized with the concepts of (systemic) lock-in and path dependency (Geels, 2002; Geels & Schot, 2007; Vanloqueren & Baret, 2009).

The recent reports of Dedeurwaerdere (2014) and of the Standing Committee on Agricultural Research (EU SCAR, 2012) are very explicit on the need to reorganize (agricultural) research following a more comprehensive perspective on the nature of innovation (in farming). Today, the involvement of innovation brokers within multi-actor innovation networks emerges as a key strategy to foster food system redesign (Klerkx et al., 2012; Louah et al., 2015). **We suggest that Q methodology holds promise to support innovation brokers in the definition of collective or concerted action, and thus to enhance innovation networks performances.**

Before making our case on Q opportunities for empirical agricultural innovation studies, we describe the basic steps of the method while highlighting its key strengths and some common methodological pitfalls. To underline the practical use of the methodology, we illustrate these steps with our case study on barriers hampering agroforestry development in Wallonia (South Belgium).

How to do Q

The Q approach is an original mixed method that provides quantitative structure to individuals' opinions via factor analysis, thus allowing an in-depth understanding of the topic at stake. Practically speaking, the research process entails six well-defined steps summarized in Figure 1 and further described below (Brown, 1980; McKeown & Thomas, 1988; Watts & Stenner, 2012).

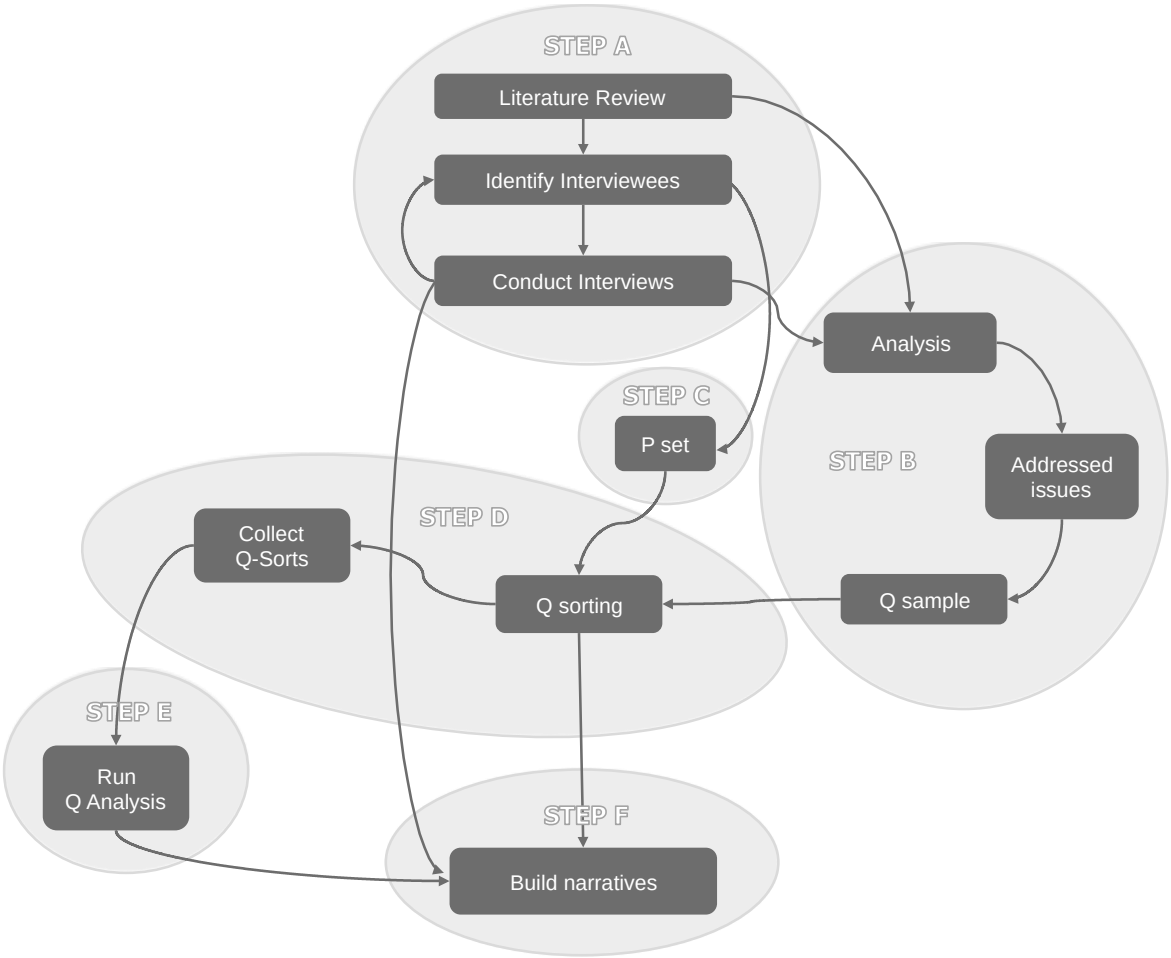

Figure 1. Flow chart of the six-steps Q methodological research process

(A) Development of the concourse

Essentially, Q requires the researcher to give attention to the discourse under investigation; that is, the views held by the stakeholders. Q study begins with the development of a collection of items, typically statements, within that discourse. This collection of items is called the 'concourse'. Not to be confused with the concept of discourse, concourse is used in *Q* for the collection of opinion statements about the topic that captures the range of issues and worldviews at stake relative to that topic (Van Exel & de Graaf, 2005). In practice, the concourse can be elicited from various sources: interviews, focus groups, participant observation, text from grey or scientific literature, websites and other media (McKeown & Thomas, 1988). Opinion statements are collected verbatim from these sources – oral ones should be audio-tape-recorded –, until it appears that 'saturation point' has been reached.

Context on agroforestry (AF) was set through 50 individual open-ended interviews with three local sources of opinion: (1) farmers; (2) researchers, and (3) decision makers from different levels of Walloon institutional and associative bodies related to agriculture and/or forestry. Each stakeholder was contacted by phone to get a first appointment, and presented the approach as being part of a European research about agricultural innovation. We never mentioned "agroforestry" or "trees" on the phone to avoid influencing the stakeholder before the interview. The few refusals to a first interview were due to a planning problem. Of the 53 stakeholders contacted, only three have not been interviewed. Table 1 shown in illustration of step C displays the number of interviews conducted per interviewee type.

(B) Q sample selection

Once the concourse is captured, it needs to be reduced down to a manageable size. It is indeed difficult and time consuming for respondents to evaluate a too large number of statements (Brown, 1980). The task becomes one of selection, organization, and analysis, so as to draw the Q sample, *ie* a subset of typically 20 to 60 opinion statements. An opinion statement is understood to be a kind of stimulus that triggers respondents search for meaning (Glynos et al., 2009). It is important to note that the selected statements come verbatim from the sources, with no influence of the researcher's own reference frame.

The Q sample is not undertaken haphazardly. As the selected statements are the essence of the subjectivity that will later emerge from their sorting by the respondents (*cf* step D) (Brown, 1986), particular care is needed to ensure that the sample is representative of both the array of expressed opinions and of as many sub-issues within the topic as possible. In other words, the Q sample has to be compiled in a way to get to the *quintessence* (Barry & Proops, 1999) of world-views and issues at hand, so that the respondents can truly express their views (Brown, 1986).

Usually, a design principle is used in order to ensure that all aspects of the topic of interest have been covered, and to ensure that the sample do not favour one aspect over another – avoiding the potential incorporation of a bias into the final Q sample. This artificial categorization of statements has to be considered as a mere way for the observer to organize in order to facilitate the selection of statements for the Q sample. In doing so, he has to ensure that the sample is balanced, *ie* that one respondent has an equal opportunity to react positively and negatively to statements in at least one of the main categories. Therefore, within one category, both statements reflecting positive and negative assertion, and thus disagreement among the concourse, have to be selected (Stephenson, 1953). Pilot-testing is also often used in order to obtain a final 'well-structured' Q sample, *ie* ensuring optimum balance, appropriateness, applicability, intelligibility and compre-hensiveness – notably one statement should consist of just one idea on which to (dis)agree.

It is important to realize that although the Q researcher may choose to identify a particular statement with a specific category, this a-priori 'labeling' and the selected statement in itself make little difference to the subsequent data processing. While it comprises the raw materials of the study, the Q sample indeed possesses no specific meaning prior to the sorting process by the respondents (Watts & Stenner, 2005). As Brown (1980) pointed out: "ultimately, this artificiality is replaced by categories that are operant, *ie*, that represent functional as opposed to merely logical distinctions". Therefore as long as a Q sample is representative of the concourse, the sampled statements may differ with no impact on Q results (Eden et al., 2005). This key feature is a gauge of researcher's bias minimization and is further discussed in step D.

A list of 228 statements faithfully quoted from the 50 interviewees have been extracted. A balanced Q sample has been build through the categorization of the concourse into three issues: (1) Agriculture status and trends, (2) AF ecology and practices, and (3) Barriers to AF. Pilot-testing allowed us to obtain a final well-structured Q sample of 42 statements. Table 2 and 3 shown in illustration of step D display a selection of the final Q sample.

(C) Q sorters selection (p set)

Once the Q sample is drawn, it is submitted to respondents or 'Q sorters' for the 'Q sorting' task (*cf* step D). The Q sorters constitute the p set – usually 12 to 40 people – and are purposely sampled as 'people that have something to say in relation to the topic' (Watts & Stenner, 2012). Besides, the p set also has to emphasize diversity (Watts & Stenner, 2012). Indeed, while the statement selection focuses on being representative of the concourse, the selection of respondents seek to represent the breadth of existing opinion around the topic rather than being somehow representative of the population as a whole. Depending on the question of interest, the p set might include for example policy makers, specialists in a particular field, people living in a certain area, or affected by a particular issue.

The p set of our Q study on AF consisted in a structured sample of 20 respondents (cf Table 1) expected to have a clear and distinct viewpoint regarding the topic. All the 20 stakeholders who were asked to carry out the Q sorting agreed to do so. Only four Q sorters hadn't been interviewed before since we argue that the interpretation step needs to rely both on interviews and Q sorting to increase in rigour.

Table 1. AF Q study: Distribution of interviews and Q sorts among interviewee types

	Farmers	*Researchers*	*Decision makers*	*Total*
Interview only	*30*	*2*	*2*	*34*
Q sort only	*2*	*1*	*1*	*4*
Interview and Q sort	*10*	*1*	*5*	*16*
Total interviews	*40*	*3*	*7*	*50*
Total Q sorts	*12*	*2*	*6*	*20*

(D) Q sort generation through Q sorting

Once generated, the Q sample is submitted to the appreciation of the p set through the 'Q sorting'. Before proceeding, the right material needs to be prepared. Q statements have to be organized by the predefined categories, given a unique numbering code and written on individual printed cards. They will be sorted with the help of a laminated A1 paper sheet on which a grid is drawn with column headings that correspond with all possible ratings. For example in each of our Q studies, we choose seven possible rankings and thus columns from left to right were respectively headed as follows: I could not disagree more (-3), I strongly disagree (-2), I disagree (-1), I don't know (0), I agree (+1), I strongly agree (+2), I could not agree more (+3). But depending on the research questions, other scales for ranking can be developed. This homemade device allows conducting the Q sorting, which consists in asking one Q sorter to physically place each card on the grid according to the extent to which he agrees or disagrees with the statement it displays. It is through this sorting that each Q sorter gives subjective meaning to the statements. As illustrated in Figure 2, the grid allows for statement ranking in relation to the ranking of the other statements, rather than evaluating them individually. This relative ranking is assumed to decrease the risk of arbitrary or biased sorting, for example under influence of the respondent's mood at the time of sorting, and thus enhance the repeatability of the sort (Raadgever et al., 2008).

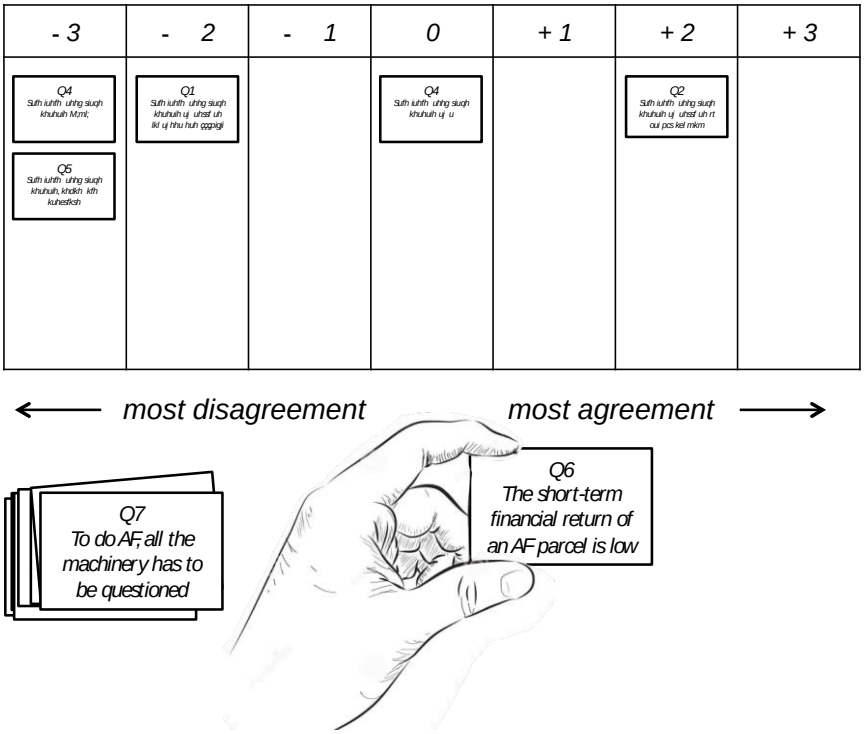

Figure 2. Illustration of a Q sorting process

The Q sorting is assisted. Thanks to the grid, the researcher can help enhance the internal coherence of the ranking. It goes without saying that caution must be employed to ensure that contradicting statements don't receive similar scores. But to illuminate the more fine-grained Q sorter worldview, researcher also needs to assist the Q sorter when it comes to nuancing between two close scores. All along the process, the researcher has to carefully collect, and record qualitative data about how the participant has interpreted the statements in their Q sort and what implications those statements have in the context of their overall viewpoint.

These comments are major data as they will later aid the interpretation of the viewpoints captured by each of the extracted factors (*cf* step F). Once all the statements are placed on the Q grid, and the participant is satisfied with it, this becomes the 'Q sort', *ie* the collection of scores of the Q sorter of all statements; it reflects the respondent's perspective on the topic at hand. The researcher can now record the array of attributed scores on a sheet of paper.

We insist on the fact that it is the holistic pattern of the Q sort that matters, not the statements themselves. In a single person's Q sort, the scores attributed to statements represent interactions that have taken place from within a common frame of reference: the perspective of the Q sorter. Each score is implicated in all the other scores, each at least implicitly having been compared with all the others, none being independent of the others. The meaning we strive to find via Q thus does not reside in the statements themselves, but rather in the pattern of their Q sort (Brown, 1993).

The 22 Q sorters were asked to place each ones of the 42 cards in the grid. No particular statistical distribution was and every comments emit during the process have been noted and recorded. Each Q sorting lasted on average about 2 hours and happened in a positive atmosphere. In general, Q sorters were reluctant initially but grew more confident and took pleasure in the exercise as Q sorting progressed. Table 2 and 3 display a selection of significant statements respectively causing dissensus and consensus among the three idealized views emerging from our Q study on AF – ie a transformative viewpoint (TV), a politically correctness viewpoint (PC) and a viewpoint maintaining the status quo (SQ) (see illustration of step F). While dissensus statements could be found in each category, almost no consensus statements were found in the categories related to AF – ie AF ecology & practices and AF.

Table 3. AF Q study: A selection of distinguishing statements, with their respective category, label and scores attributed by each of the three extracted idealized views.

Cat.	Q statements	Scores		
		TV	SQ	PC
Agric. status & trends	Q15 Our soils are not being depleted at all	-3	0	1
	Q27 Nature provides valuable assets to agriculture but these have been woefully neglected	3	1	0
	Q31 We are not fools, experiences such as AF ought to be carried out by others	-2	-1	2
	Q28 We would not be able to farm without chemical fertilizers	-2	0	2
AF ecology & practices	Q34 AF allows to regenerate soils by enriching them in carbon and in nitrogen	3	1	0
	Q41 AF would be more appropriate for land that is less productive than ours	-2	-2	2
	Q37 Intercropping several plant species results in a higher overall productivity compared to pure stands.	3	1	0
	Q35 Tree shade during haying causes delays in drying	0	1	2
Barriers to AF development	Q6 The short-term financial return of an AF parcel is low	2	1	1
	Q12 Making an income from hardwood in AF is not possible	-2	-2	0
	Q14 Increases in agricultural productivity thanks to AF must be quite obvious before throwing yourself into it.	0	0	2
	Q2 Farmers are afraid at working with trees while foresters are afraid at working in a farming environment	2	0	1

Table 4. AF Q study: A selection of consensus statements, with their respective category, label and scores attributed by each of the three extracted idealized views.

Cat.	Q statements	Scores		
		TV	SQ	PC
Agric. status & trends	Q30 It would be better to take away all the subsidies and to ensure fair pricing	2	1	2
	Q25 Farmers are bound by the subsidies	2	0	2
	Q19 In Wallonia there is not much in terms of information support for farmers	-1	-1	-1
	Q21 The major change can't be implemented only by the elected officials, all the different actors in civil society need to contribute	2	2	2
Barriers	Q11 You must be the owner of the field to do AF	2	1	2

(E) Statistical analysis of Q sorts

It is at this stage that the researcher analyzes the Q sorts thanks to a sophisticated statistical procedure and with the assistance of modern computing technology. The analyses of Q sorts involve correlation, factor analysis, and the calculation of factor scores (Brown, 1980; Stephenson, 1953). This step is a purely technical and objective procedure, and therefore sometimes referred to as the scientific base of Q (Van Exel & de Graaf, 2005). Yet, as we will see hereafter, parts of this factor analysis process are qualitative.

Prior to analysis, a data matrix is built with the Q sorts as variables (columns) and all Q statements as objects (rows). Typically for Q, the correlation of variables thus generates a correlation matrix that reflects the relationship of each Q sort configuration with every other Q sort configuration – and not the relationship of each statement with every other statement. The initial correlation matrix is then subjected to factor analysis in order to produce a set of factors onto which the respondents load effectively on the basis of the Q sorts they have created. Indeed respondents are clustered on the basis of the degree of similarity between their Q sorts, thus respondents that load onto the same factor will have created very similar Q sorts or 'sorting patterns' (Watts & Stenner, 2005).

Clustered variables (Q sorts) suggest a shared view among a group of people. Q factor analysis allows to reveal these shared views in the form of idealized sorting patterns of the Q statements, and shows which Q sorts are correlated with these few idealized views (Brown, 1980, 1993). The endpoint statistical analysis is reached when each of the significant factors is represented by its own best-estimate Q sort or idealized statement patterns that will undergo the next step of interpretation.

Today, several Q methodological packages ease these statistical analyses – *eg* PCQ (Stricklin & Almeida, 2001) and PQ Method (Schmolck & Atkinson, 2013) – by automatically generating the initial correlation matrix and making processes of factor extraction, rotation and estimation very straightforward. Rotation just consists of changing the reference points of the geometric coordinate frame in order to enhance the interpretability of the extracted factors (McKeown & Thomas, 1988). Despite the computer automation, the researcher has to make some decisions as the analysis proceeds, starting with the selection of the factor analysis and factor rotation methods. Two factor extraction methods and two factor rotation methods are most widely used by Q researchers, namely, and, respectively: Centroid and Principal components, and Hand rotation and Varimax rotation. There exists a lively and old debate within the Q community about the use and abuse of either of these methods (see Brown et al., 2015; Kramer & de Hegedus, 2003). Suffice it to summarize here that Centroid extraction is the method of choice of leading Q methodologists

based on philosophical considerations related to their preference for Hand rotation (Brown, 1980; Brown et al., 2015; Stephenson, 1953).

The final substep is to decide which factors should be selected for interpretation – usually from two to four. A standard requirement is to select only those factors with an eigenvalue in excess of 1.0, as factors going below this minimum explain less of the overall study variance than would any single Q sort. A second standard requirement is that an interpretable Q factor must ordinarily have at least two Q sorts that load significantly upon it alone (Watts & Stenner, 2012). Such significantly loading Q sorts are representative of the factor as they exemplify the shared item pattern or configuration that is characteristic of that factor. The retained idealized factors – usually from two to four – are hereafter referred to as Q Factors.

As many Q researchers, we opted for the simplicity and reliability of PCA and Varimax procedures. Q analysis outputs found to be very satisfying, since these procedures are both consonant with our aims of using Q, namely to reveal the range of viewpoints on AF that were favored by the p set. As stated by Brown (1980, 238), there is ultimately no substitute for careful consideration in the context of a particular study. Yet now that we are fully aware of the debate on statistical considerations, we are likely to use the method of Centroid extraction and Hand rotation procedures in our future Q study.

The PCA and Varimax procedures yielded four significant factors referred to as PC1, PC2, PC3 and PC4. PC1 carried the greatest proportion of the total variation (36.52%), while PC2, PC3 and PC4 carried respectively 11.20, 8.78 and 8.12%. The loadings of the original variables (Q sorts) on PC1 and PC2 (Figure 3) show that the conversation on AF broke down into three distinct idealized Q sorts. The loading of the statement scores on PC2 as a function of PC1 shows the spread of the statements on the main correlation axes (Figure 4).

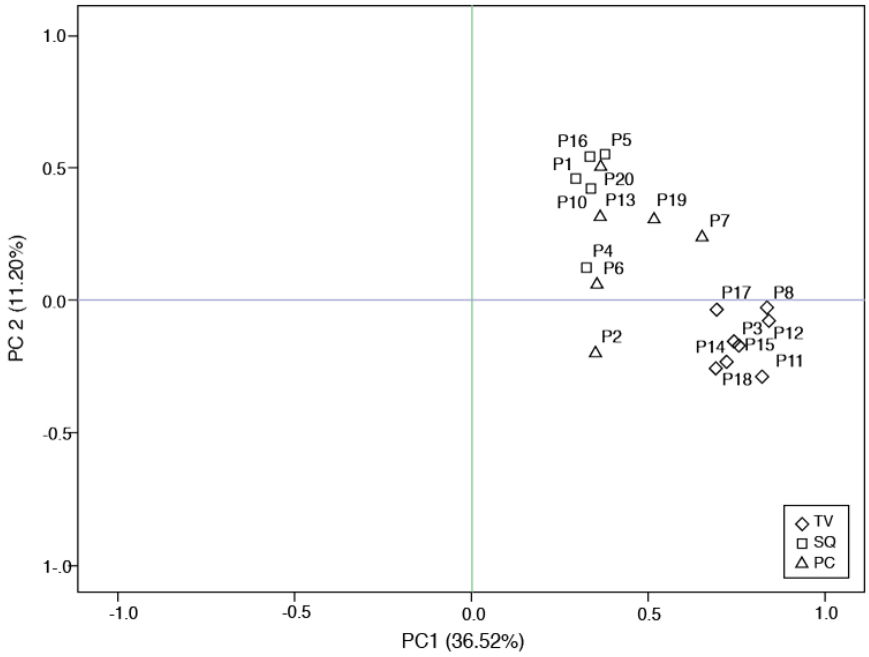

Figure 3. AF Q study: Loading plot of the PCA on all statements (PC1, PC2). Q sorts are grouped based on the discourse they belong to, ie TV, SQ or PC.

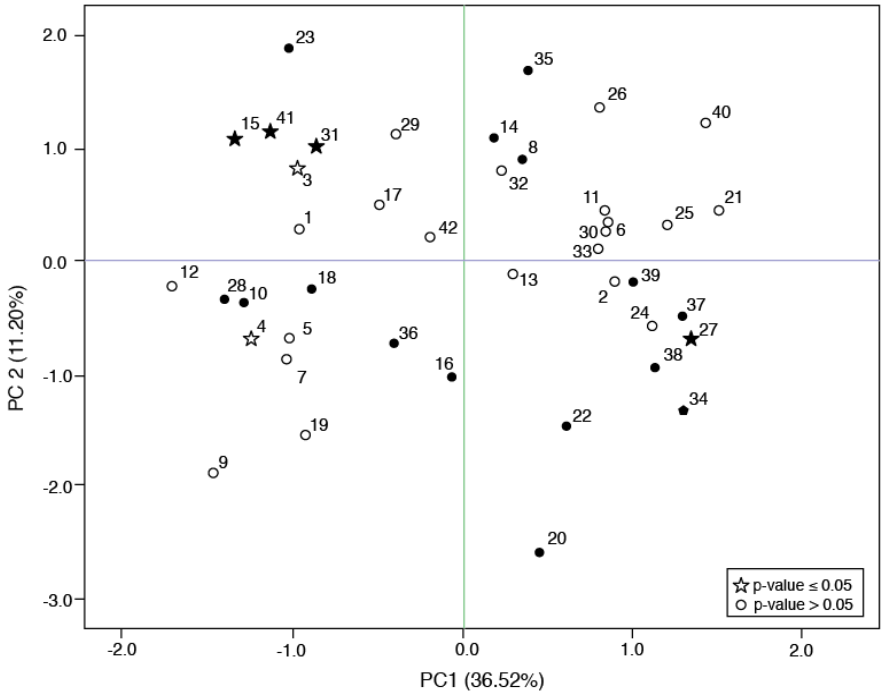

Figure 4. AF Q study: Score plot of the PCA on PC1 and PC2 for all Q statements. Statements are grouped into two categories according to the significance of difference between the discourses. Statements used for the interpretation of the discourses are shaded.

(F) Interpretation of Q outputs

The interpretative task consists of summarizing the narratives respectively depicting the idealized worldviews of the topic as being expressed by the distinctive Q Factors. The construction of each narrative demands the researcher to sequentially develop an explanation that fits the data associated with the positioning and overall configuration of the statements in the idealized Q sort, supplemented by discussions and comments recorded while constructing the concourse and during Q sorting. This 'abductive' reasoning (Watts & Stenner, 2005) is not so amenable of providing a set of substeps to follow in a simple logical order. There are no clear guidelines here. The researcher works slowly to a conclusion that is defensible (Fairweather & Rinne, 2012).

The abductive process of Q Factors' interpretation is firstly based on four basic tables, and associated graphics, generated by Q statistical analysis (for more details, see (Brown, 1993; McKeown & Thomas, 1988; Stephenson, 1953; Watts & Stenner, 2012). These four types of table respectively display:

- **Q Factor scores (or factor loadings)**

The table of 'Factor scores' is the most important output: it displays a listing of the Q Factors' scores that are used to determine which sorts are represented by which Q Factor, *ie* load significantly on it. Q Factors can therefore be seen as typologies since they group people of similar views. This table – and its associated plot (illustrated in Figure 3) – allows visualizing that all the Q sorters can be identified as reduced number types via data reduction. However, it does not explain these types. The other output tables must be examined to describe the emergent distinctive idealized Q sorts and to label these.

- **Representative sorts for each Q Factor**

The Q sorts of respondents loading significantly on a particular Q Factor are used to create one idealized Q sort, also known as 'representative sort' of that Factor. The 'z-score' represent the idealized position of each statement in one idealized sorting grid (Brown, 1980; McKeown & Thomas, 1988). This second type of table, generated for each Q Factor, display a list of the Q sample statements rank-ordered according to their z-scores in order to create the representative sort of each Q Factor. Usually relatively clear and distinctive viewpoints are already beginning to emerge from these respective statements rankings. Whilst the most extreme z-scores are the most useful for interpreting the Q Factor, it is a mistake to assume that 'everything happens' at the extreme positions of the distribution – see the remark below on interpretive failures.

- **Distinguishing Statements**

The tables of distinguishing statements, also generated for each Q Factor, display the statements that distinguish each Factor from the other Q Factors – at a significance level of 0.05 (Watts & Stenner, 2012). The more the significance level is low, the more the statement distinguishes the associated Factor from the others with a lower probability that this difference is due to chance. This additional information allows gaining insights into each idealized view on the issue at stake. It thus may also contribute to the labeling of the distinctive Q Factors or views.

- **Consensus Statements**

The table of consensus statements, generated for all the Q Factors, displays the statements that do not distinguish between any of the Q Factors (Brown, 1980). In other words it displays the existing agreement across the different views on the issue. Focusing on agreement among the concourse topic can be of particular interest to start a dialogue related to commonality, a key idea in organizational change (Ramlo, 2015) and thus, as we will discuss later, of particular interest for innovation networks. The consensus among Q Factors also reveals important insight into Q sorters' views and narratives' labeling.

Distinguishing and consensus statements can also be visualized on the 'score plot' (illustrated by Figure 4). Hence, the positions of the statements (Figure 4) can also be interpreted along with the positions of the Q sorts (Figure 3) with regard to the same axes.

The resulting plots from our Q analysis on AF showed that PC1 stands for the common agreement among stakeholders (since all Q sorts have a positive score on it). PC2 stands for disagreement opposing more strongly groups TV and SQ, PC3 for disagreement opposing more strongly groups TV and PC, and finally PC4 stands for a general disagreement between all stakeholders.

Although several substeps of the analysis include calculating statistical significance - which is highly quantitative –, it must to be highlight that the interpreting and naming of the Q Factors falls into a more typical qualitative framework.

The three extracted narratives on AF in Wallonia have been constructed on stakeholders' interviews (step A), Q statistical analysis' outputs (step F) and Q sorters' comments (step D). While it was not our initial intention, the resulting narratives were linked to distinctive expressions of 'good farming', and thus supporting different farming styles. These three views on 'how to farm' are sum up below:

- Factor TV, ie the 'transformational viewpoint' discourse, resembles stakeholders (1) in their desire to redesign agricultural practices through capitalization on ecological processes in order to improve sustainability (2) clearly supporting AF development in Wallonia considering its environmental assets and the quality of the landscape as the main advantages; and (3) arguing that innovations are and should be undertaken by farmers themselves in order to be tailored and adapted in a site-specific way to highly variable and diverse farm conditions.

- Factor SQ, ie the discourse maintaining the 'status quo', resembles stakeholders considering (1) farming practices as benign for the environment; (2) AF to be inappropriate in Wallonia and (3) farmers as end-users of innovative technological packages developed by specialized industrial and scientific institutions.

- Factor PC, ie the political correctness discourse, resembles stakeholders (1) assuming that small adaptations are needed to improve agriculture's sustainability but without challenging the validity of the current modern system model in itself; (2) considering AF as a viable option but only if its agronomic feasibility and economic profitability are scientifically proven in Walloon context; and (3) agreeing with SQ with the top down technology transfer approach.

We close this section by pointing out the risk of serious interpretative failure relative to the representative sort tables. As stated above, a concentration on too few statements in the array, typically on the ones with extreme z-scores, hinders to capture the holistic nature of the interpreted viewpoint at hand. A typical mistake is to assume that a statement ranked 'zero' displays indifference or neutrality and to consider this statement as of little importance. However the zero attributed by a particular Factor may become very informative when consideration is given to the ranking of the same statement by the other Q Factors. Statement rankings in this supposedly 'neutral' area of the configuration thus shouldn't be disregarded, otherwise one may fail to capture the subtleties of the viewpoint being expressed.

For example, Factor SQ attributed a zero score to Q28 – '*We would not be able to farm without chemical fertilizers' – while Facors TV and SQ respectively attributed -2 and +2 to the statement. Q28 has found to be one of the distinguishing statements, and qualitative data gathered from stakeholders clustering with SQ showed that the zero ranking doesn't reflect a neutral position but a nuanced one.*

Opportunities for Q methodology to foster agricultural innovation

In the systems perspective on innovation, multi-actor innovation networks (hereafter referred to as MAIN) are seen as a key strategy to foster robust transitions leading to a redesign of farming systems – see Pittaway (2004) broad review on networking and innovation. Such a multi-actor configurations show many operational differences (Klerkx et al., 2012) but they all somehow facilitate and undertake a collective process around identified agricultural innovation challenges and opportunities, at different levels in agricultural innovation systems (AIS) – *eg* village, country, sector or value chain. MAIN generally do not emerge autonomously, and their deliberative setup implies that connections between members need to be forged and their interactions need to be coordinated (Röling & Jiggins, 1998). According AIS scholars, actors positioning themselves as a systemic intermediary and systemic facilitator therefore play a significant role (Leeuwis & Aarts, 2011). A so-called 'innovation broker' is considered as a member of an actors network who is focused neither on the generation nor the implementation of innovations, but on enabling other actors to innovate (Winch & Courtney, 2007). Innovation brokers aims at enabling this co-evolution of innovation by facilitating linkages among different actors who were previously not connected for various reasons – such as cognitive distance, high transaction costs and information asymmetry (Klerkx & Aarts, 2013). Hence, while the innovation potential precisely builds on this very rich social fabric, innovation brokering means raising the challenge of improving communication between actors with different cultural and cognitive frames as well as different stakes and interests (Kilelu et al., 2013; Nooteboom, 2000).

Innovation brokers thus must develop the skills required effectively to facilitate reflexive human interaction so that it yields desirable outcomes, *ie* social learning and concerted action (Röling, 2002). According Röling (2002) this implies an understanding of collective human behaviour that goes beyond the emergent property of individuals pursuing maximum utility. It implies understanding how people make sense of the world and socially construct it. As we showed in the previous section, Q methodology is a convenient and sound tool to advancing such understanding.

Q Methodology as an appropriate research tool for innovation brokers

While, to our knowledge, Q has never been used as such, we suggest that it holds a great potential in allowing innovation brokers to probe more deeply into the mechanisms of social learning and collective cognition[1] within a particular MAIN.

More concretely, a Q study on a particular MAIN and regarding a specific topic would allow an innovation broker to get deep insight into (1) the range of actors worldviews on the topic, (2) the prevalent variations in the topic's discourse, and (3) the way these variations logically relate to each other. Thanks to Q, the innovation broker could identify patterns of discourse that characterize the narratives (Q factors) of collective actors about the topic. Such a deep understanding of stakeholders' worldviews provides relevant informative supports to foster a range of MAIN key enablers such as conflict resolution, negotiated agreement, shared learning, convergence of goals and concerted action. This means that Q findings could assist innovation brokers at effectively developing a common understanding and agreement space both in the definition of common objectives and their respective prioritization, and in the negotiation of the issues raised. Creating/increasing this common space stimulates changes among actors and finally leads to successful innovation (Klerkx et al., 2013).

[1] Cognition has to be understood has 'the process of knowing', as defined in the Santiago theory of cognition (Maturana & Varela, 1992). The theory considers cognition as a broad concept that involves perception, emotion and action (Capra, 1996).

Imagine that the 20 Q sorters of our AF study constitute all the members of a MAIN. This MAIN, involving TV, SQ and PC views, could maybe be performing when it comes to innovations seeking to emancipate farmers from subsidies – see Q30 and Q 25, ie consensus statements. Yet, the agreement area being much reduced, this kind of MAIN makes little or no sense. Regarding the development of AF – or other agroecological innovation –, the MAIN should be subdivided to bring together stakeholders – not only farmers – supporting a TV farming style. Conducting a more narrower Q study on this sub-MAIN would reveal points of contention and of agreement about the effective implementation of AF systems and likely lead to concrete actions.

The resulting plots from our Q analysis on AF showed that PC1 stands for the common agreement among stakeholders (since all Q sorts have a positive score on it). PC2 stands for disagreement opposing more strongly groups TV and SQ, PC3 for disagreement opposing more strongly groups TV and PC, and finally PC4 stands for a general disagreement between all stakeholders.

Q applications could be of four types depending on the particular objective at hand. These are:

- diagnostics, *eg to identify what the collective actors define as a valuable innovation*;
- analysis of a thematic issue, *eg modern agroforestry or market access*;
- design of action, *eg for the design of common on-farm experimental plots*;
- monitoring of action, *eg to assess the set up of these on-farm experimental plots.*

Q methodological strengths for innovation brokers

From a methodological standpoint, Q offers several strengths regarding innovation brokers' functions. These strengths are:

- the examination of subjectivity within an objective framework, based on a clear structure and process, which can bring clarity to the typical complex and socially contested topics at stake and therefore enhance communication and negotiation within the MAIN;
- the emphasize on the active and engaging role of actors along the data gathering process, which stimulate their reflection upon their beliefs, thoughts, perceptions and state of mind; this holds the potential benefit of increasing actors' awareness and understanding of the topics – *ie* action research –, enhancing change management and other sensitive organizational issues;
- the 'bottom up' or 'self-interpretative' nature of the emergent shared viewpoints, since Q Factors directly results from the 'undeconstructed' Q sample and Q sorts formulated by actors; this allows to avoid the risky bias of innovation brokers' assumptions about the way understandings are structured;
- the focus on actors' shared viewpoints whilst considering their individual viewpoints; this allows to integrate the personal and the social viewpoints in a coherent manner (Watts, 2009).
- the equal consideration of all voices and viewpoints in the Q analysis process, which is particularly useful to elicit marginalized and 'silenced' viewpoints within a MAIN.
- and, finally, the discovering of both expressible and 'hardly' expressible' (and thus hardly discoverable) aspects underlying actors' worldviews.

  Emotional dimensions are often illustrative examples hardly expressible aspects, ie that have significant influence on innovation processes (Schön, 1983; Van Dam, 2009) – eg emotional commitment, a key aspect of leadership for innovation –, but still often missing from the analysis of innovation success and failure stories – see Anderson et al. (2014) for review on innovation analysis.

  The 'unsayable' nature of these aspects can either comes from the fact that they are, at first sight, considered as having no influence on actors worlviews/behaviours regarding the topic at stake, or either because they are deeply anchored in individuals sub-consciousness. Q is a

convenient manner to bring hardly discoverable aspects to light while other methods based on open-ended interviews would struggle to do so – let's remember that Q has been developed by a psychologist!

All these valuable and original assets can, however, only be effective through the meticulous and properly sampling of the statements about the topic at stake (Paige & Morin, 2016): people can 'tell a story' only if they have the appropriate statements with which to tell it. First and foremost, the Q analysis thus has to be conducted in a study context whose objectives must be clearly defined.

Q methodological limitations for innovation brokers and recommendation

In terms of limitations, Q has been criticized for lacking generalizability (Van Exel & de Graaf, 2005). However, Q does not claim to provide findings that can be extrapolated across a population, "the results are the distinct subjectivities about a topic that are operant, not the percentage of individuals (...) that adheres to any of them" (Van Exel & de Graaf, 2005, p.3). Besides Q studies findings have been shown to be reliable and stable over time (Brown, 1980; Stephenson, 1953) but, crucially, in the shared viewpoints expressed only, rather than in the individual Q sort arrays. This leaves Q sorters free to change their minds whilst expecting the emergent manifold of shared viewpoints to show a degree of consistency over time (Fairweather & Rinne, 2012; Watts, 2005).

The real limitation of Q to assist innovation brokers rather lies in its inadequacy to address actors' relationships, and thus in lacking to capture the dynamics and the actors 'agency' within a network. Yet balancing relationships within a MAIN also constitutes a key enabler of its performance – see Klerkx & Aarts (2013) for further details. We close this paper by suggesting a more holistic methodological framework allowing to overcome this limitation: the combination of Q methodology with Social Network Analysis[2] – SNA (Kolleck, 2013). While, to our knowledge, Q has never been combined with SNA, their complementarity would enable innovation brokers to embrace together the deep understanding of actors' worldviews and relationships, and therefore to better take up challenges, dilemmas and paradoxes disabling the interactive innovation process (Klerkx & Aarts, 2013; Pittaway et al., 2004).

Conclusion

We addressed the opportunities of Q Methodology for empirical agricultural innovation system studies. This led us to consider the potential role of Q in analyzing and supporting innovation processes within multi-actor innovation networks. We argued that Q is a fitting and promising tool to assist innovation brokers into building capacity for collective innovation and preventing innovation network failures. However, Q remains limited to provide actors' worldviews without addressing the relationships between these actors. To overcome this limitation, we conclude that Q Methodology may be even more valuable when combined with Social Network Analysis. This refreshing and holistic approach holds the potential to support innovation brokers arrive at shared visions, well-established linkages and information flows amongst different actors, conducive incentives that enhance well-developed human capital, and hence innovation network performance. In our sense, this novel methodological framework is a path worth exploring in (agricultural) innovation network studies.

[2] Social network analysis allows mapping institutional linkages, visualizing relationships between actors, and assessing the position of actors within the network – in terms of centrality, number of ties, strength of ties – (Spielman et al., 2011).

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