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**How can the design of Decision Support Tools for different agricultural stakeholders be improved?**

Dimitrios Iakovidis*, Yiorgos Gadanakis, Julian Park, Jorge Campos Gonzalez

School of Agriculture, Policy and Development, University of Reading, Earley Gate, Whiteknights, Reading RG6 6EU, UK; d.iakovidis@pgr.reading.ac.uk (D.I.) g.gadanakis@reading.ac.uk (Y.G.); j.r.park@reading.ac.uk (J.P.); jorge.camposgonzalez@reading.ac.uk (J.C.G)

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* Corresponding Author: Dimitrios Iakovidis, d.iakovidis@pgr.reading.ac.uk, School of Agriculture, Policy and Development, University of Reading, Earley Gate, Whiteknights, Reading RG6 6EU, UK;

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## Abstract

The sustainability of Mediterranean agriculture is under threat due to factors such as climate change, the spatial distribution and size of holdings, the ageing rural population and the environmental and social pressures in rural areas. Decision Support Tools (DST) can help overcome these challenges by enhancing the decision-making of farmers and advisers, enabling evidence-based decisions which will improve the sustainability of farming systems in the area.

An essential requirement of an effective design of a DST is the early-stage engagement of stakeholders in a co-production approach to define end user needs and requirements. In this research twenty-nine stakeholders comprising farmers and advisers, extension officers, policy makers and industry representatives were selected from within the regional unit of Argolida and the Greek National Ministry of Rural Development and Food to facilitate user need analysis. A Q-methodology approach was utilised to provide an in-depth understanding of the perspectives and needs of the differing stakeholder groups.

The results illustrated that the use of the Q-methodology as a mechanism of analysing stakeholders' subjective viewpoints can offer valuable insights and can be used to study distinct perspectives existing within a group on a topic of interest. In addition, the research illustrates how the method can serve as the required first step of end user need analysis in a co-production of services approach for the design of an effective DST in agriculture.



**Keywords** [Q-methodology, DST, agricultural management, decision-making, farm sustainability]

**JEL code** (Q160 Agricultural R&D; Agricultural Technology)

# 1. Introduction

Farming systems in the Mediterranean basin are facing considerable challenges that are linked to intrinsic (small holding size, ageing rural population, low level of education) and extrinsic factors (climate change, land degradation, natural resources scarcity) that affect the sustainable future of agriculture in the area (Iakovidis et al., 2023). The use of effective DSTs within the agricultural sector provides the opportunity to improve the sustainability performance of farms (Lundström et al., 2016) and thus address the wider region challenges effectively.

Innovative and technologically advanced DST products can provide farmers and advisers a means through which they can rationalise their production processes and better adapt to the needs and requirements of their crops which in turn can lead to better financial, environmental and societal results (Lundström et al., 2016). Even though existing tools vary in terms of approach they usually aim to enhance the effectiveness of farm management (Rossi et al., 2014) by incorporating science into practice to assist farmers production and ultimately livelihood (Hochman & Carberry, 2011).

Yet despite the advantages presented a number of studies as described by Alvarez and Nuthall (2006) spanning almost three decades have come to the conclusion that the adoption rate of DSTs remains disappointingly low for various reasons. These reasons range from poor cost-benefit relationships to complexity and from failure to address the real problem to lack of integration or computer literacy. As Stewart et al., (2013) concluded the barriers to uptake are diverse, and successful DST adoption and use, is dependent on its capacity to address a range of practical requirements.

In this research users and stakeholders' understanding of DSTs is explored and their needs are identified to aid the recognition of DST requirements. This enables the framing of emerging challenges in a manner that facilitates solutions that can act as a base for future co-production of DST.

# 2. Materials and methods

## 2.1. Outline of research

This research investigates the perceptions of stakeholders in relation to the end user needs and requirements for the design of an effective DST to improve farm sustainability. Stakeholders' subjective viewpoints and beliefs about DST are presented and evaluated in a case study for the Argolida region in the Peloponnese, Greece. To encourage the engagement of stakeholders working coactively towards a sustainable future for agriculture groups of farmers, advisers, extension officers, industry representatives and policy makers were employed to take part in focus groups discussions. The Q-methodology was used to identify the needs and requirements of farmers and advisers towards the use and adoption of DST through the combination of qualitative and quantitative methods to investigate the subjective viewpoints and beliefs of those directly involved in the topic.

## 2.2. Q-methodology

Q-methodology is a research approach that integrates quantitative and qualitative methods in order to explore subjective viewpoints and beliefs about a topic. In this research, the steps followed are described in Figure 1.

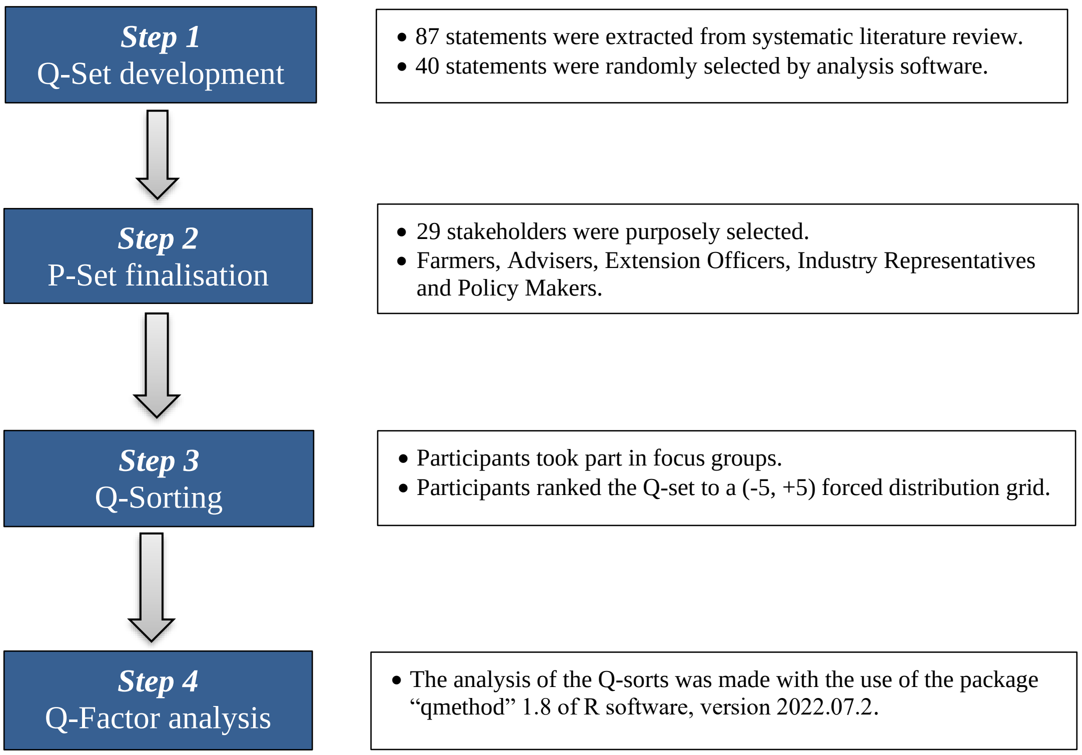


**Figure 1**: Q-Methodology process used in the research

### 2.2.1. Q-set development

The Q-set development involves the creation of statements about the topic under study. In similar studies this is referred to as concourse sampling and it involves the selection of key statements from relevant academic literature. These key statements could consider the ideas and the concepts that can be sensibly expressed about the topic in the literature or alternatively in any other publicly available resources.

For the purposes of this research a systematic literature review was conducted with the use of key words identified by the researchers involved in this project and Boolean operators (AND, OR and NOT). The search was conducted in two major multidisciplinary databases of bibliographic information Scopus and Web of Science.

In order to report the results of the systematic review a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) Statement was used and 23 articles were finally selected from key academic literature. After an extensive review of these 23 articles, 87 statements were generated by the researchers. They were all imported with the function *"import.q.concourse"* of the package *"qmethod"* 1.8 (Zabala & Held, 2020) into "R" software that was used for the analysis and with the function *"build.q.set"* 40 of them were randomly[1] selected as the Q-set., This set of statements was used as the basis for participant ranking.

### 2.2.2. P-set finalisation

This stage involved the selection of the Q participants. These participants are referred to as the 'P-set'. Q-methodology essentially uses purposive sampling. Thus, participants are selected because of their ability to articulate a viewpoint on the topic under study because of their knowledge, experience, professional expertise and ultimately because their perspective matters. Additionally, it is important to have a P-set that is large and wide-ranging enough to represent the subjective views pertaining to a topic under investigation.

[1] The function *"build.q.set"* implements a number of tests on the validity and consistency of inputs and subsets a concourse of items into a sample of selected items. Returns a dataframe with handles as row names, and languages (if applicable) as columns.

For the purposes of this research a group of 29 stakeholders were employed as the P-set and are presented in Table 1.

**Table 1:** P-sample with codification

| | Stakeholders | No | Code name |
|---|---|---|---|
| **1** | Farmer | 10 | Far1 – Far10 |
| **2** | Adviser | 5 | AD1 – AD5 |
| **3** | Extension Officer | 5 | EO1 – EO5 |
| **4** | Industry Representative | 5 | IR1 – IR5 |
| **5** | Policy Maker | 4 | PM1 – PM4 |

They were selected from within the area under study (regional unit of Argolida, Greece) except for the policy makers who were from the National Ministry of Rural Development and Food.

### 2.2.3. Data collection – Q-sorting

The data were collected based on the Q-sorts with the forced distribution (-5, -4, -3, -2, -1, 0, +1, +2, +3, +4, +5) described in Fig. 1 using (+5) for the statement *"Most like what I think"* and (-5) for *the "Least like what I think"* (with "I" being a given participant). The Q-sort was conducted in focus groups of five. Farmers (2 groups), advisers (1), extension officers (1) participated in the focus groups. For Industry representatives and policy makers it was not possible to convene in-person focus groups due to their other commitments and thus they were provided with instructions and guidance and they were given the Q-sorts (Fig. 2) and the Q-set in order to complete them in individually.

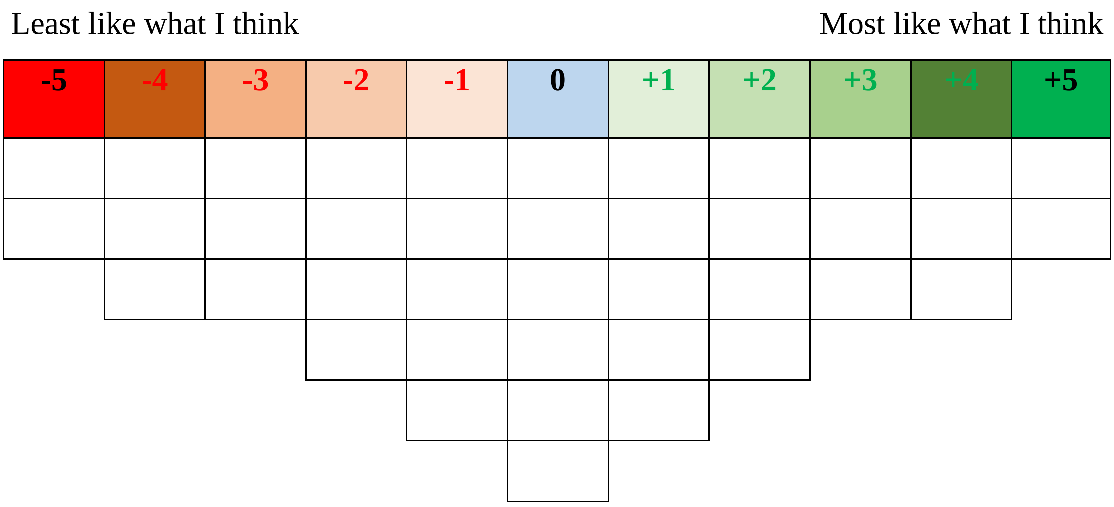


**Figure 2:** Blank Q-sort presented in the focus groups.

### 2.2.4. Quantitative Analysis – PCA

For measuring the subjectiveness on the use and adoption of DST in agriculture, in Argolida, Greece, a factor analysis known as Q-methodology was applied. The Q-method analysis performed a principal component analysis (PCA) for the extraction of factors, varimax rotation to clarify the relationship among factors and maximize the variance of the first extracted ones, automatic flagging to calculate the statement scores and the application of the Pearson correlation coefficient.

The analysis of the Q-sorts was made with the use of the package “qmethod” 1.8 (Zabala & Held, 2020) of R software, version 2022.07.2 that implemented a number of tests on the validity and consistency of inputs. The full code and the data used in R can be provided upon request.

### 2.2.5. Qualitative Interpretation of factors

Qualitative interpretation of factors is achieved by placing the Q-sorts values for each of the extracted factors. The values are calculated during the quantitative analyses of Q-methodology and represent the degree by which the participants Q-sorts loaded on the factor. The way the statements are configurated on a factor Q-sort is very important and ensures a comprehensive snapshot is provided of the major viewpoints and beliefs being expressed by the P-set.

## 3. Results

### 3.1. Q-methodology analysis

For the extraction of the factors, a separate Principal Component Analysis (PCA) was performed. The Kaiser-Guttman criterion and the Scree test (constructing the screeplot) were employed to decide on the number of principal components to retain. Thus, five factors presented in Table 2 were extracted.

**Table 2:** Five factors test results.

| 5 Factors | | | | | | |
|---|---|---|---|---|---|---|
| | **Average Reliability Coefficient** | **Number of loading Q-sorts** | **Eigenvalues** | **Explained Variance (%)** | **Composite Reliability** | **Standard Error Factor scores** |
| **F1 Cost – Efficiency** | 0.8 | 9 | 4.4 | 15 | 0.97 | 0.16 |
| **F2 Functionality - Performance** | 0.8 | 6 | 3.7 | 12.9 | 0.96 | 0.2 |
| **F3 Relevance – Ease of Use** | 0.8 | 4 | 2.9 | 10 | 0.94 | 0.24 |
| **F4 Education – Training** | 0.8 | 4 | 2.8 | 9.5 | 0.94 | 0.24 |
| **F5 Applicability - Compliance** | 0.8 | 2 | 2.2 | 7.8 | 0.89 | 0.33 |

After the extraction of the factors the analysis provided the factor loadings for each participant that demonstrates how the participants are associated with each factor extracted. For every factor there were flagged participants which were the representative participants of each factor. A higher score of loading factor indicates a high correlation of participants with their represented factors. In this way participants can be grouped and an interpretation of what these participants have in common can be highlighted along with an explanation of their viewpoints and expressed beliefs.

Furthermore, the Q-methodology analysis produced z-scores for statements and all factors. The z-score is a weighted average of the values that the Q-sorts most closely related to the factor, give to a statement. For each factor, there is a statement that "loads heavier on it" meaning it is higher correlated to that factor than any other. This result outlines the five factor arrays for the research and helps inform how to interpret the factors in terms of attitudes and/or opinions that people in that factor tended to express rather than in terms of participant's capacity. For example, in factor 1, statement 5 loads heavier than any other statement in that factor and it has been ranked higher by two farmers and one industry representative. The higher the z-score, the more correlated the statement is to the factor.

## 3.2. Factor interpretation

In order to proceed to factor interpretation two types of data were used. At first the socio-demographic data of the P-set and then the findings of the Q-methodology analysis. The interpretation has been attempted with the help of the holistic technique of "crib sheets" that have been suggested by Watts & Stenner, (2012). The crib sheets provide a list of statements for each factor classified into 4 categories. The two categories include the statements that were given the highest ranking in the factor array (the two items ranked at +5) and those that were given the lowest ranking (the two items at -5). There are two more important categories that depict and list the statements that ranked higher or lower respectively on the specific factor than on any of the other extracted factors. The value of this categorisation is that it allows identification of the statements that make the most influential and critical contributions within each factor array.

## 4. Discussion

How can the needs and requirements of end users for effective DST use and adoption to improve farm sustainability was the question of this research. The results have provided a number of findings that need to be positioned in the broader context of the literature regarding this subject.

Applying the Q-methodology has enabled the identification of typologies of stakeholders according to their sociodemographic characteristics and the information drawn regarding the similarity and/or the differentiation between the 29 participants of the study in terms of the five extracted factors. The rotation of factors highlighted which participants present similar viewpoints and who has conflicting opinions regarding the use and adoption of DST. This process enabled the identification of the needs and requirements of farmers and advisers, as end users, regarding the use and adoption of DST.

The five extracted factors represent the five viewpoints of stakeholders regarding the use and adoption of DST from end users. In fact, Q-methodology focuses on the variety and plurality within the P-sample (Hermelingmeier & Nicholas, 2017), that supports its molecular hypothesis which is the subjectiveness of viewpoints and beliefs. Highlighting similarities and differences in subjective opinions is feasible in Q-methodology because of the statistical validity of the factor analysis and the consideration that the interpretative task of catching meanings within the viewpoints expressed should not be disregarded (Iofrida et al., 2018).

The use of Q-methodology allowed a shift in emphasis away from the actual technology and thus enabled insights into potential users and their attitudes and beliefs about it (Pereira et al., 2016). In this spirit stakeholders participating in this research expressed their viewpoints contemplating not the actual DST product but its usefulness in their daily practices and habits. For example, the stakeholders in the first and fifth factor have positive opinions about the involvement of farmers in the processes of agricultural technology development (Douthwaite et al., 2001) while those in the second and fifth factor believe strongly that DST must have multiple benefits for the stakeholders involved. Farmers, advisers, extension officers, industry representatives and policy makers could all benefit from this shift as their documented behaviours, viewpoints and beliefs can be used as an early-stage step in a co-production of services approach for the design of an effective DST in agriculture.

Another very important issue that emerged from this research was the issue of Q-Methodology applications. In the field of agricultural technology and innovation adoption the method (due to its subjectivity features) can facilitate the investigation of diverse viewpoints across a range of agricultural topics, thus adding to existing research methods. There are few if any examples of a similar approach being adopted in the Mediterranean region. to explore viewpoints and beliefs about DST use and adoption in agriculture. Furthermore, the use of Q-Methodology as a potential learning tool in itself can help stakeholders understand the sector from a broader professional, cultural and social context, as already been documented by Leggette & Redwine, (2016).

Finally, Q-Methodology can be used to rethink and/or create policies for the dissemination of innovative tools (Vecchio et al., 2022) such as DST, and, in this regard, provide a better understanding of the transfer of innovation to the agricultural sector to improve the effectiveness of innovation policy. To this end, policy-making for the integration of end-user aspirations and needs within current research can address the socio-economic challenges associated with the adoption and use of technology innovations such as DSTs (Ara et al., 2021). This could ultimately lead to the build of the human and social capacity required to gain trust and confidence and increase the adoption rate of technology and innovation.

## 5. Conclusions

Our results show that Q methodology is a robust tool (Carr & Liu, 2016), and a congruent method (Cuppen et al., 2016) for incorporating  end users' perspectives into DST use and adoption.

DSTs constitute a very important tool for farm business management at regional and national level and this should drive policy makers to form the appropriate policies to support and promote the incorporation of such tools into everyday practices of farm managers and advisers.

The findings of this research should aid both farmers and advisers as well as the scientists as they enable and facilitate further research regarding a co-design model for DST tailored to the needs and requirements of end users as they have been recognised by stakeholders in the area. In this way DSTs will integrate more effectively into farmer's agricultural practices and processes while at the same time promoting social coherence by supporting the view that DST role lies in their potential to support social learning between stakeholders.

Future work should continue to investigate farmers' and advisers' needs and requirements regarding DST at all levels and use the findings in a co-production of services approach to effectively design efficient DST for the end users. This means that farmers may require modified extension services, greater understanding of the industry requirements and vice versa. Policy makers would benefit from a more detailed understanding of farmers' knowledge and knowledge practices. This would be enhanced by the further work on educational and professional development frameworks and networks, facilitating the adoption and use of DST to enhance the decision-making process and enable the change towards more sustainable farming systems.

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