Land Use Policy 107 (2021) 105491

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

# Actor analysis for sustainable soil management – A case study from the Netherlands

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ARTICLE INFO

*Keywords:*
Soil quality
Sustainable soil management
Actor analysis
Analytical Hierarchy Process (AHP)
Power-interest mapping

ABSTRACT

Soil quality is an important determinant of the productivity, environmental quality and resilience of agricultural ecosystems. In addition to the farmer, there are other actors who may have different interests in soil quality, hampering the implementation of sustainable soil management. To date, these actors have received surprisingly little attention. This study presents an inventory of actors involved in sustainable soil management, including farmers, but also value chain participants (e.g. input suppliers and processors), environmentally engaged actors and policy makers. We applied Analytical Hierarchy Process (AHP) to elicit actors' priorities for soil sustainability criteria. AHP is a method of multi-criteria analysis that uses pairwise comparisons to assess the relative importance of criteria. Additionally, we differentiated actors based on their involvement and perceived ability to influence decision-making. Based on the results of a survey, actors were placed in a power-interest grid. In this grid, the self-perceived power and interest of actors was differentiated from their power and interest as perceived by other actors. The main findings were that a complex and heterogenous network of actors exists around the farmer. Within this network, farmers and related value chain participants showed a priority for economic soil sustainability criteria. Environmentally engaged actors were confirmed to have a clear priority for environmental criteria. The power-interest grids underscored the prime role of farmers and the relatively high power of value chain participants. The self-assessment of power-interest compared to assessment by others revealed noticeable differences, especially for NGOs and environmentally engaged actors. This study provides an overview of which actors to involve in decision-making on sustainable soil management, which is illustrated for the EU mission "Soil Health and Food".

## 1. Introduction

A rising global population results in an increased demand for agricultural products (Alexandratos and Bruinsma, 2012). At the same time, competition for space due to e.g. urbanization and development of industrial areas has led to a decreased availability of agricultural land (Amundson et al., 2015). Soil quality is a key factor in agricultural production, as it determines the crop productivity, farm resilience and environmental quality of agricultural ecosystems (Stevens, 2018; Karlen et al., 1997). Unsustainable soil management can lead to soil degradation (Koch et al., 2013), including erosion, loss of soil organic matter and soil compaction. One-third of the worldwide available agricultural land is already moderately to highly degraded (FAO and ITPS, 2015). Moreover, the soil's capacity to deal with extreme weather conditions like droughts is getting increasingly important (Wall and Smit, 2005), and therefore, preserving or improving soil quality is an increasingly pressing issue.

Soil quality is of pivotal importance to farmers since they operate and often own the land. Farmers must make a sufficient economic return on the farm, whilst also meeting environmental and societal demands. However, beyond farmers, soil quality affects other actors as well. An actor is defined as an individual, group or organisation who takes action in the view of a problem situation (Koppenjan and Klijn, 2004). The literature provides a vast but disparate overview on definitions of stakeholders and actors. Although the terms "actor" and "stakeholder" are often used interchangeably, we prefer to use "actor". In our vision, "actor" is a more suitable term for those institutions that do not have a clear stake but still play an important role in the problem or situation, e.

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https://doi.org/10.1016/j.landusepol.2021.105491
Received 13 May 2020; Received in revised form 17 February 2021; Accepted 16 April 2021
Available online 6 May 2021

g. governments.

Farms are at the beginning of a value chain, hence a decline in soil quality (e.g. via crop yield) has an impact on the following actors in this value chain. Agricultural ecosystems are part of regional ecosystems. A decline in soil quality influences actors that depend on these ecosystems. An example is drinking water companies that face pollution of groundwater with nitrate due to an insufficient nutrient retention capacity. Because actors have different interests in soil quality, they might have different priorities on how to sustainably manage soil. Bouma and McBratney (2013) define soil quality as a "wicked" environmental problem: many actors are involved, each with different opinions and interests. Wicked problems are hard to solve, as they require a set of options in which the expectations of all actors involved need to be balanced.

Previous research underscores the need to involve actors beyond famers in sustainable soil management (Bünemann et al., 2018a; Bouma and Montanarella, 2016; Bouma, 2014). For instance, Butler et al. (2013) provide an overview of actors involved in land use and water quality management in the Great Barrier Reef in Australia. O'Sullivan et al. (2018) present a framework to bridge the gap between science, stakeholders and policy. However, surprisingly little attention has been paid to a structured inventory of actors involved in soil quality from an economic, environmental and social perspective. Although the above-mentioned studies identify a broad range of actors, they do not explicitly address their priorities in sustainable soil management. Not all actors have the same priorities and therefore involved actors do not always merit equal levels of consideration (Freeman, 2010; Cohen, 1996). Examples of studies identifying actors' priorities are Petrini et al. (2016) and Duke and Aull-Hyde (2002). Identifying an actors' priority does not inform us on the importance we should attribute to that actors' priority as not all actors have equal power to influence decisions and equal active involvement in the problem (Cohen, 1996). For example, a non-governmental organization (NGO) can have a clear priority on nature conservation and have a high degree of interest. However, the NGO lacks direct power to influence decisions. Therefore, the actors' degree of interest and power to influence decisions also have to be taken into account (Raakjær Nielsen and Mathiesen, 2006; Honert, 2001). To the best of our knowledge, an integrated actor analysis consisting of a comprehensive actor inventory, assessment of actors' priorities and the degree of power and interest of involved actors has not been applied to sustainable soil management.

The aim of this study is to provide a comprehensive analysis of the actors involved in sustainable soil management in the Netherlands. To achieve this aim, we defined the following research questions:

(1) Who are the actors in sustainable soil management in the Netherlands, what are their roles and their underlying relationships?
(2) What are the priorities of these actors regarding sustainable soil management?
(3) What is the power of actors to influence decisions and their degree of interest in sustainable soil management?
(4) How can this study contribute to implementation of sustainable soil management?

We answer research question 1 with an actor inventory based on literature and expert reflections. We use a survey spread among all defined actor groups to elicit actors' priorities for soil sustainability criteria. The survey is also used to determine the degree of power and interest of the actors involved. Actors' power and interest are assessed based on (a) their self-assessment and (b) assessment by others. The fourth research question is answered using an illustration on how the results of our study can be used for the recent EU mission "Soil Health and Food" (European Commission, 2020).

We use the Netherlands as a case study. High product demands and fierce competition for space by e.g. urbanization and recreation generate land scarcity (CBS, 2016). Agricultural ecosystems, natural ecosystems and rural livelihoods are in close interaction with each other, which leads to high societal and environmental demands on famers (Schulte et al., 2019). We focus on the actors involved in soil quality on arable and dairy farms in the Netherlands as they are the main land users (CBS, 2019).

## 2. Methods

### 2.1. Actor inventory

In this study, we conceptualize actors using network theory (Koppenjan and Klijn, 2004). A key characteristic of this theory is the presence of powerful central actors, on which the other actors in the network depend for communication (Rowley, 1997). Arable and dairy farmers are the central actors in sustainable soil management because they manage the land, often own it, and have a prime interest in preserving soil quality as the basis for their current and future income.

We used a stepwise approach adapted from Chapter 2 in de Haan and de Heer (2012) and Section 7.3 in Koppenjan and Klijn (2004) to create an initial inventory of actors. First, we made a primary selection of actors based on literature and existing projects on soil quality. As a second step, we described the role of each actor. In the third step we made groups of actors based on their role, e.g. suppliers of seeds, fertilizer and pesticides were all grouped as "input suppliers". The fourth step was to validate the selection of actors, the role of these actors and their grouping in an iterative process with eight experts chosen from our network. The experts had diverse backgrounds in the field of economics, soil science, agronomy, engineering and environment. In the final step we selected the actors based on the expert validations. We included all actors mentioned by more than one expert.

We used relationships derived from the actors' role and group to structure the actor inventory. We focussed on the direct relationships of the central actor with other actors. Farmers as central actors can have three different types of relation with other actors (adapted from Rowley, 1997). (1) A finance-based and formal relationship based on transfer of products, services or external effects of production, (2) a formal relationship based on a hierarchical position, e.g. through legislation or product requirements and (3) an informal influence e.g. via societal pressure or lobbying. In addition, we distinguish primary and secondary actors. Primary actors have financial transactions with the central actor and can have formal requirements. Such actors typically are investors, customers and suppliers, as well as public actors whose regulations must be obeyed (Jawahar and McLaughlin, 2001). Secondary actors lack these formal relationships but still have enough influence to merit consideration. If their expectations are violated, they will be able to influence primary actors (Garvare and Johansson, 2010). Typical examples of secondary actors are NGOs and knowledge institutions (Garvare and Johansson, 2010).

### 2.2. Actors' priorities

We used Analytical Hierarchy Process (AHP) developed by Saaty (1980) to elicit actors' priorities. AHP is a method of multi-criteria analysis that uses pairwise comparisons between criteria to assess the relative importance of each criterion (Saaty, 1980). AHP is a proven and frequently applied method for multi-criteria analysis and the study of actors involvement in natural resource management problems (Cegan et al., 2017; Petrini et al., 2016; Segura et al., 2014; Kukrety et al., 2013; Duke and Aull-Hyde, 2002). Moreover, AHP is a non-statistical method which makes it especially useful for this study, as our focus is on a broad inclusion of actors rather than on representativeness.

AHP requires the set-up of a hierarchical goal tree (Gallego et al., 2019). Fig. 1 presents the AHP goal tree for this study. The first level refers to the overall goal, sustainable soil management in the Netherlands. The second level represents the criteria that should be

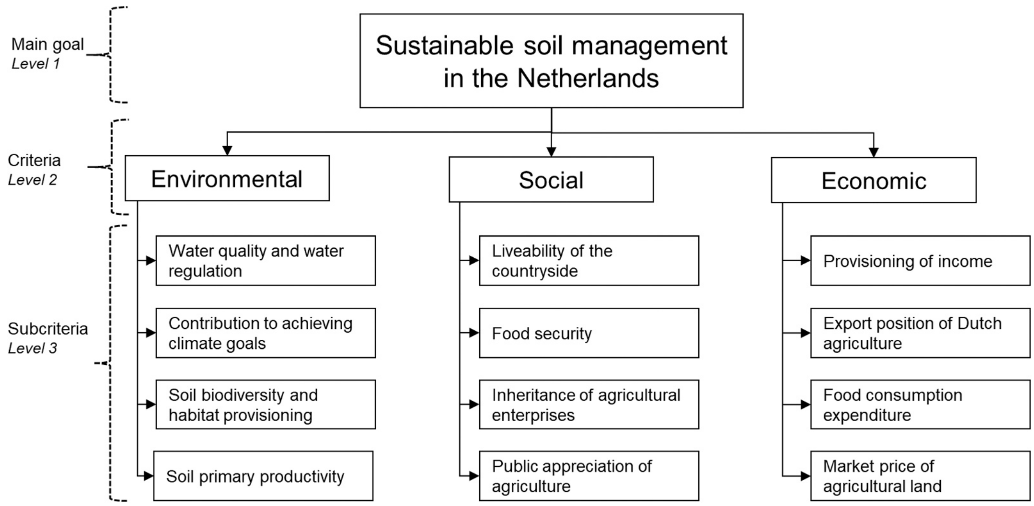


**Fig. 1.** Hierarchical goal tree of criteria for sustainable soil management in the Netherlands.

considered to achieve the overall goal. These criteria are the three pillars of sustainability: environmental, social and economic factors (Ren et al., 2016). This division is common in the application of AHP in natural resources management challenges (Petrini et al., 2016, Kukrety et al., 2013).

Choosing appropriate criteria that fit the context and reflect the concerns of the actors involved is one of the main challenges in multi-criteria decision making studies (Petrini et al., 2016; Garfi and Ferrer-Martí, 2011). Therefore, we defined subcriteria in an iterative procedure based on Gamper and Turcanu (2007) and Koppenjan and Klijn (2004). First, we made a pre-selection of subcriteria based on literature and the role of the actors involved (Petrini et al., 2016; Schulte et al., 2014; Kukrety et al., 2013; Duke and Aull-Hyde, 2002). Secondly, the criteria were validated and revised by the eight experts that also validated the actor inventory. In the last step we defined four subcriteria for each of the criteria based on the consensus among the experts. Table 1 provides a detailed definition of the subcriteria.

In the survey, respondents first made pairwise comparisons of all environmental subcriteria, which entails six comparisons. In a similar way, respondents made pairwise comparisons for the social and economic subcriteria. Finally, the respondents had to make pairwise comparisons of the criteria environmental, social and economic. In all pairwise comparisons the respondent ranked the importance using the AHP rating scheme provided in Table 2. In total, respondents made 21 pairwise comparisons: 3 for the criteria and 18 for the subcriteria.

After the responses were collected, we calculated the actor priorities. Therefore we aggregated the pairwise comparisons of the individual respondents using the geometric mean (Aczél and Saaty, 1983). The result is the pairwise comparison (PC) matrix. From the PC matrix, priorities were calculated based on the geometric mean method (Dong et al., 2010; Saaty, 1990). The overall priority weights were calculated for the subcriteria by multiplying the weight of each subcriterion with the weight of the corresponding criterion. The overall priority weights of all subcriteria sum up to 1 and represent the priority of an actor group towards each subcriterion.

AHP assumes that respondents are consistent in their assessment. However, complete consistency in the pairwise comparisons is rare (Saaty, 1980). The consistency ratio (CR) in the aggregated PC matrices of every actor group was calculated according to the maximum eigenvalue method of Saaty (1980). Saaty (1980) considers values of CR $<0.1$ as acceptable. We chose a CR threshold of 0.3 because the aim of this study was to have a first impression of different priorities among actors, which allows a higher degree of inconsistency. For the sake of inclusiveness, the responses of actor groups that violated the CR threshold

**Table 2**
AHP rating scheme as provided to the respondents in this study, based on Petrini et al. (2016).

| Rating | Importance of criterion A over criterion B |
|---|---|
| 1 | Equally important |
| 3 | Slightly more important |
| 5 | Moderately more important |
| 7 | Strongly more important |
| 9 | Highest degree of importance |

**Table 1**
Definition of subcriteria for sustainable soil management in the Netherlands.

| Subcriterion | Description |
|---|---|
| Water quality and water regulation | The function of the soil in maintaining a good quality of surface water and ground water and the role of the soil in protection against flooding and drought |
| Contribution to achieving climate goals | Restriction of greenhouse gas emission ($CO_2$, $N_2O$, $CH_4$) and the ability of the soil to sequester $CO_2$ |
| Soil biodiversity and habitat provisioning | Diversity and presence of soil life and the role of the soil in the provisioning of a habitat for soil life |
| Soil primary productivity | The capacity of the soil to produce biomass for the use of food, fuel and fiber |
| Liveability of the countryside | Attractiveness of the landscape and surroundings in rural areas, for the purposes of living, work and recreation |
| Food security | Sufficient, safe, nutritious and affordable food |
| Inheritance of agricultural enterprises | Inheritance of agricultural enterprises to the next generation |
| Public appreciation of agriculture | Appreciation of society for the agricultural sector |
| Provisioning of income | The ability to gain sufficient income via wage, profit, rent or interest in the business an actor is working in |
| Export position Dutch agriculture | Value and position of the Dutch agriculture on international scale |
| Food consumption expenditure | Total expenditures by households on food |
| Market price of agricultural land | Market price of land for agricultural production |

were also included in the results. These groups were indicated with an "a" in Table 3, the actors' priority table.

### 2.3. Actors' power-interest

We used power-interest grids, two-dimensional grids with the relative interest and power of actors (Bryson, 2004). We used the following definitions of power and interest in the survey:

#### 2.3.1. Power

A relationship in which actor A can get another actor B to do something they otherwise would not have done (Mitchell et al., 1997). This can occur through various mechanisms such as legislation, financial incentives and social pressure.

#### 2.3.2. Interest

The degree to which actors are concerned about the problem and their subsequent active or passive involvement.

In the survey respondents were asked to assess power and interest on a scale with integer values ranging from 0 to 10. First, respondents were asked to assess their own power and interest in sustainable soil management on arable and dairy farms. Secondly, respondents were asked to assess the power and interest for all other actors of the actor inventory. This procedure yielded two datasets: one dataset with the position of every actor according to their own assessment and one dataset with the position based on the assessment made by other actors.

We made power-interest grids that presented the position of the actors based on their own assessment and the assessment by others. We placed every actor in the grid based on the median of the responses for that actor. For all actor groups with more than eight respondents, a Mann-Whitney test was carried out to check whether the self-assessment of power and interest differed significantly from the power and interest as assessed by others.

### 2.4. Survey design

We developed an online survey using Qualtrics[1]. Prior to its distribution, we tested the quality of the survey through cognitive interviews with five potential respondents in different actor groups. A cognitive interview is performed to test whether potential respondents have the right interpretation of the questions asked in the survey. The survey consisted of two parts. Part A was used to elicit actors' priorities as described in Section 2.2. Part B was used for actors' power-interest. Respondents were asked to fill in both parts.

The inventory consists of a large spectrum of actors. Some include thousands of individuals (i.e. farmers), whereas others include only a few (e.g. only handful leading retailers in the Netherlands). Hence, the actor inventory is very heterogeneous, which impeded representative sampling. Nevertheless, inclusion of at least one individual of all actor groups would allow a first inventory of possible differences between groups. Therefore, emphasis was placed on a broad inclusion rather than on representativeness (Lamarque et al., 2011). For the actors including

**Table 3**
Description of actors, actor roles and actor classification types involved in sustainable soil management in the Netherlands.

| Actor (group) | Acronym | Actor role | Actor type | Reference |
|---|---|---|---|---|
| Arable farmers | AF | Use agricultural land with the primary goal of crop production | Central actor | 2,3,5,6,7 |
| Dairy farmers | DF | Use agricultural land with the primary goal of feed production for dairy cows | Central actor | 2,3,5,6 |
| **Land & capital providers** | | | | |
| Financial institutions | FI | Provide loans to farmers to finance purchase and possession of land | Primary | 3 |
| Land owners | LO | Own agricultural land, but are not the actual users, lease land to farmers | Primary | 1,8 |
| **Input suppliers** | | | | |
| Crop breeders | CB | Breed and distribute plant reproductive material to arable and dairy farmers | Primary | |
| Crop input suppliers | CIS | Supply crop inputs, e.g. crop protection agents, fertilizers and compost to farmers | Primary | |
| Technology suppliers | TS | Produce and distribute mechanisation and installations to farmers and contractors | Primary | |
| Feed suppliers | FS | Supply and or produce concentrates and by-products (e.g. beet pulp) to dairy farmers | Secondary | |
| Intensive livestock farmers | IF | Own limited or no own land and have to dispose manure, mainly to arable farmer | Secondary | |
| **Service providers** | | | | 2 |
| Advisors | AD | Advice farmers and other actors on soil management | Secondary | 3,5,6 |
| Soil sensing providers | SSP | Offer monitoring of soil properties as a service to farmers and other actors | Secondary | |
| Contractors | CT | Carry out field operations commissioned by farmers, e.g. sugar beet harvest | Secondary | |
| Crop insurance providers | CI | Offer farmers insurance against uncertain events, e.g. extreme weather | Secondary | 3 |
| Real estate & land agents | RE | Moderate in the trade and use of agricultural land | Secondary | |
| **Post-farm value chain** | | | | |
| Agricultural purchasers | AP | Purchase and process agricultural products from farmers to ready-to-use products | Primary | 2,3,4,5,8 |
| Distributors & retail | DR | Distribution of ready-to-use products within distribution network or to consumer | Primary | 8 |
| Certification bodies | CEB | Certification of product stream according to a common standard | Secondary | |
| **Policy makers** | | | | 7 |
| Regional government | RG | Develop land management policy on regional level (e.g. at municipality or province level) | Primary | 1,8 |
| National government | NG | Develop land management policy on national level, implemented via various ministries | Primary | 1,5,8 |
| European Union | EU | Develop policy on land management via Common Agricultural Policy (CAP) and other directives | Primary | 5,8 |
| **Representative groups** | | | | |
| Farmers organisations | FO | Represent farmers' interest, mainly in the field of policy making | Primary | 3,4 |
| Agricultural communities | AC | Regional cluster of farmers around certain theme, e.g. nature conservation | Primary | |
| Non-governmental organisations | NGO | Represent societal interest around a certain theme on behalf of a group of citizens | Secondary | 2,5,6,7 |
| **Society** | | | | |
| Urban residents | UR | Citizens that do not live in the direct neighbourhood of agricultural productions systems | Secondary | 2 |
| Rural residents | RR | Citizens that live in rural areas and are directly influenced by agricultural production | Secondary | 2,3 |
| **Environmentally engaged actors** | | | | |
| Water users | WU | Source water in the environment of agro-ecosystems for non-agricultural purposes | Secondary | |
| Water boards | WB | Regional governmental body concerned with management of water streams and water quality | Secondary | 3 |
| Nature managers | NM | Manage natural areas in close neighbourhood of agricultural ecosystems | Secondary | 3 |
| **Other** | | | | |
| Non-agricultural land-users | NAL | Withdraw land from farmers to use it for other purposes (e.g. urbanization) | Secondary | |
| Knowledge institutions | KI | Conduct research and or provide education concerning soil management | Secondary | 1,3,5,6,7 |

Reference numbers list the following citations: Reyers et al. (2009)[1], Butler et al. (2013)[2], Bünemann et al. (2018a) [3], Calker van et al. (2005)[4], O'Sullivan et al. (2018)[5], Barrios et al. (2006)[6], Bouma and Montanarella, (2016)[7], (Schulte et al., 2015)[8].

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| AF: | Arable farmers | TS: | Technology suppliers | RE: | Real estate & land agents | UR: | Urban residents |
| DF: | Dairy farmers | FS: | Feed suppliers | AP: | Agricultural purchasers | RR: | Rural residents |
| FI: | Financial institutions | IF: | Intensive livestock farmers | DR: | Distributors & retail | WU: | Water users |
| LO: | Land owners | AD: | Advisors | RG: | Regional government | WB: | Water boards |
| CB: | Crop breeders | SSP: | Soil sampling providers | FO: | Farmers organizations | NM: | Nature managers |
| CIS: | Crop input suppliers | CT: | Contractors | NGO: | Non-governmental organizations | KI: | Knowledge institutions |

arable farmers, dairy farmers, urban residents and rural residents we aimed at a minimum of ten respondents. For all other actors, our aim was to have at least one respondent. In case we were able to retrieve more responses, a larger number was included as this adds to the representability. We used a combination of judgmental and snowball sampling to send the survey to representatives of the different actor groups. The survey was spread within our network and sent to professional organisations of the different actor groups. The survey was sent out between September 2019 and December 2019.

## 3. Results

### 3.1. Actor inventory

The actor inventory (Fig. 2 and Table 3) is structured around the value chain, with the farmer as the central actor. “Land & capital providers” provide land or a loan to farmers. The long-term relationship and special status of land enable “Land & capital providers” to have formal requirements on the land use by farmers, indicated by the dashed line in Fig. 2. “Service providers” and “Input suppliers” provide physical or non-physical inputs to the farmer. The farmer decides which inputs to use and hence has formal influence. After harvest, most agricultural products enter a post-farm value chain, which commonly consists of subsequent stages before end products are consumed. “Post-farm value chain actors” can have formal influence on the farmer, e.g. by setting production standards.

“Environmentally engaged actors” are influenced by external effects of production, e.g. a drinking water company is influenced by nutrient leaching. These actors often lack formal relationships with farmers. In order to meet their demands on the occurrence of externalities, they seek influence via policy makers or representative groups e.g. “Non-governmental organisations” (Hoffman, 2001; Carroll and Buchholtz, 1996). “Urban residents” and “Rural residents” are both consumers of agricultural products. “Rural residents” are directly influenced by external effects of production. As they have limited power on their own, these actors seek to influence via e.g. “NGOs” and “Policy makers”. “Policy makers” issue and maintain regulations. These translate into formal requirements for farmers and other actors. As one individual farmer has limited influence on policy making, farmers join into “Farmers’ organisations” to increase power. Farmers have formal relationships with “Farmers’ organisations” via memberships.

### 3.2. Actors’ priorities

Based on the survey, we were able to retrieve 139 valid responses for the actors’ priorities. The central actors (arable and dairy farmers) showed a clear priority for ‘farm income’ and other economic subcriteria in Fig. 3.

Except for “Feed suppliers (FS)”, “Soil sampling providers (SSP)” and “Real estate & land agents (RE)” all input suppliers and service providers had ‘income’ as their highest priority, although their priority for income was lower compared to farmers. Although “Feed suppliers (FS)” had the highest priority for the social criterion “farm inheritance”, they also assessed high priorities to economic subcriteria. “Soil sampling providers (SSP)” and “Real estate & land agents (RE)” assessed high priorities to environmental subcriteria. In the post-farm value chain, “Agricultural purchasers (AP)” had a strong priority for economic criteria, especially for the subcriterion ‘income’. “Distributors and retail

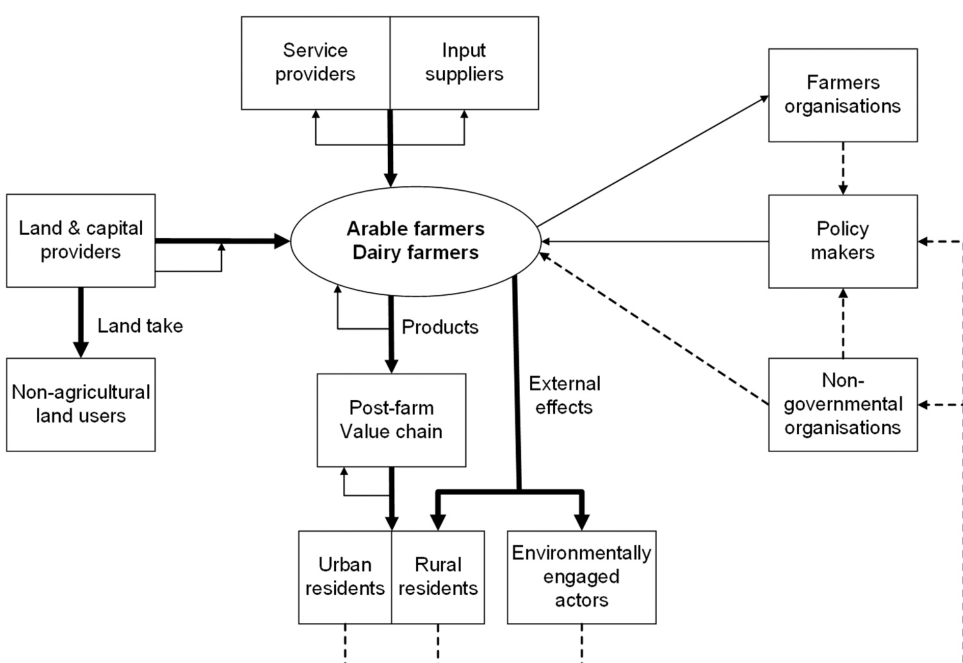


**Fig. 2.** Inventory of actor groups involved in sustainable soil management in agricultural ecosystems in the Netherlands. Bold lines represent a finance-based formal transfer of goods, services or external effects. Normal size solid lines represent formal influence between actors. These arrows branch off from thicker arrows if they represent a formal influence in return for a flow of goods, services or capital. Dashed lines represent informal influence between actors.

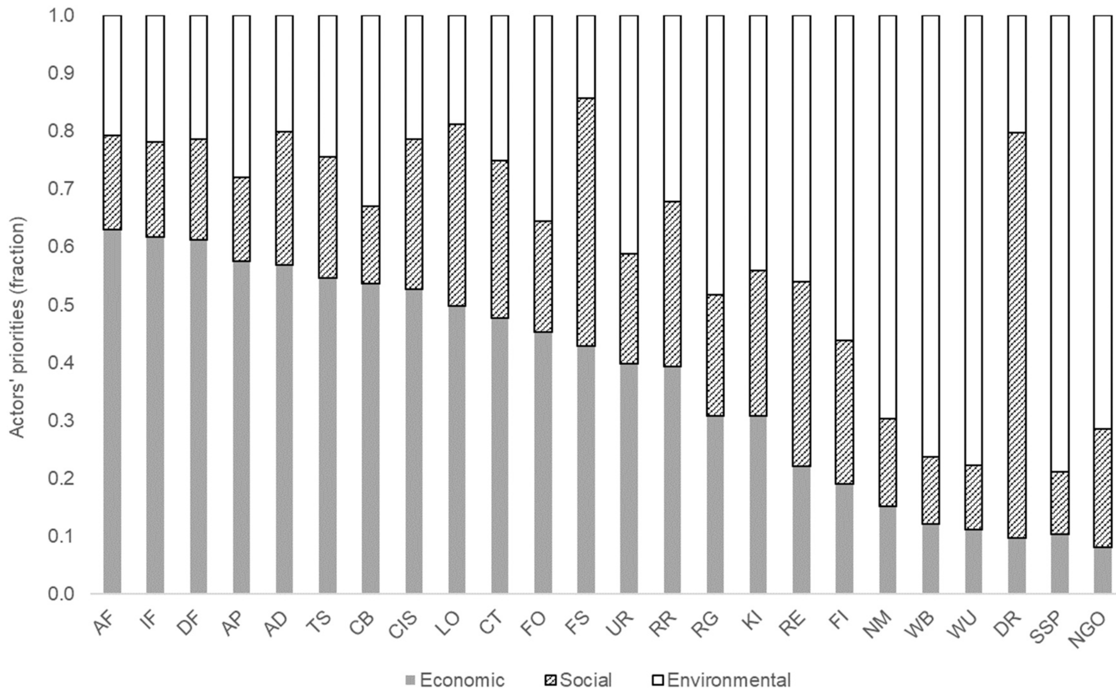


**Fig. 3.** Actors' priorities for criteria of sustainable soil management in the Netherlands. Priorities were elicited using Analytical Hierarchy Process (AHP). Actors are sorted in descending order of their priorities for the economic criterion.

(DR)" showed a deviating priority: they were the only actor to show the highest priority for the criterion 'social'.

Although 'economics' was by far the most preferred criterion in the value chain, "Water users (WU)", "Water boards (WB)"," Nature managers (NM)", "NGOs" and "Regional governments (RG)" preferred the 'environmental' criterion. Within the environmental criterion, "Water users (WU)" and "Water boards (WB)" had the highest priority for the subcriterion "water quality", which can be explained by their actor role. "Nature managers (NM)", "NGOs" and "Regional governments (RG)" had the highest priority for environmental subcriterion "soil biodiversity". Despite its dominant position on the international agenda, the environmental criterion "GHG goals" is only ranked as second highest priority by the actors "Financial institutions (FI)", "NGOs" and "Water boards (WB)" (Table 4).

A chi-square test, using an alpha of 0.5 resulted in the rejection of the null hypothesis assuming equal priority for criteria among actors.

Table 3 and Fig. 3 show that 'economics' is the dominant criterion in sustainable soil management. In particular, the subcriterion related to income was important as 14 out of 24 actors have income as their highest priority. The other economic subcriteria were perceived as far less important, especially by actors who had the highest priority for environmental criteria. The criterion 'social' was not directly associated with sustainable soil management. The social subcriteria were ranked only four times with the highest or second highest priority by the actors "Distributors & retail", "Real estate & land agents", "Feed suppliers" and "Land owners". Fig. 3 clearly illustrates that besides 'economics', 'environment' was the other dominant criterion. An important range of actors including "Financial institutions (FI)" had the highest priority for 'environment'.

### 3.3. Actors' power-interest

Based on the survey we were able to retrieve 131 valid responses for the actors' power-interest. Central actors, i.e. arable and dairy farmers, had high power and high interest. Fig. 4 also illustrates that for farmers there was a small difference between their own assessment and the assessment by others. "European union (EU)", "National government (NG)", "Financial institutions (FI)", "Land owners (LO)" and "Farmers' organisations (FO)" all had high power and considerable interest according to their own assessment. According to the assessment made by others, "Agricultural purchasers (AP)", "Regional government (RG)" and "Distributors & retail (DR)" were powerful actors, while according to their own assessment their power was considerably lower. "Crop breeders (CB)", "Crop input suppliers (CIS)" and "Technology suppliers (TS)" had moderate power according to their own assessment and the assessment by others. Their role as input providers make them rather following actors instead of leading actors. The power-interest grid underpinned "Land owners (LO)" and "Financial institutions (FI)" have a lot of power to impose requirements on farmers. For all actors except "Distributors and retail (DR)" and "Technology suppliers (TS)", self-assessments of interest were higher than the assessments made by others. A possible explanation might be the selection of the survey sample. As sustainable soil management is a specific subject, respondents with an above average interest are more likely to respond. Hence, the interest in sustainable soil management for the actor they represent might turned out higher than estimated by other actors.

According to their own assessment, "Nature managers (NM)", "Knowledge institutions (KI)", "Water boards (WB)" and "Water users (WU)" were secondary actors with a considerable interest but low power (Fig. 5). Based on the assessment of other actors, they indeed had an interest but also relatively high power. An explanation might be the sensitive nature of power: people often are somewhat resistant to admit they have the power to influence decisions. "Urban residents (UR)" and "NGOs" had a much higher interest based on their own assessment than on the assessment made by others. This observation can also be explained by the composition of the sample and nature of the subject: "Urban residents" and "NGO" with an above average interest are more likely to respond, which results in a higher interest than assessed by other actors. "Feed suppliers (FS)", "Soil sampling providers (SSP)" and "Contractors (CT)" had moderate power and interest according to the assessment made by others, which could be explained by their passive role as a supplier.

Table 5 indicates differences between self-assessments of power and interest and those made by other actors using results from a Mann-

**Table 4**
Actors' priorities for consolidated subcriteria of sustainable soil management in the Netherlands. GHG goals refers to Greenhouse Gas Goals. Priorities are elicited using Analytical Hierarchy Process (AHP).Cells with bold underlined values represent the highest priority of every actor. Cells with bold values present the second highest priority. Cells with an underlined value show the lowest priority of an actor group.

| Actor group | Farmers | | LC providers | | Input suppliers | | | | | Service providers | | | | Value chain | | Gov. | Represent. | | Society | | Environmental | | | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AF | DF | FI | LO[a] | CB | CIS | TS | FS[a] | IF | AD | SSP | CT | RE | AP | DR[a] | RG[a] | FO | NGO[a] | UR[a] | RR | WU | WB | NM[a] | KI |
| **Environmental** | | | | | | | | | | | | | | | | | | | | | | | | |
| Water quality | 0.04 | 0.05 | 0.06 | 0.02 | 0.06 | 0.07 | 0.03 | 0.02 | 0.04 | 0.04 | 0.07 | 0.06 | 0.12 | 0.05 | 0.06 | 0.09 | 0.08 | 0.12 | **0.12** | 0.10 | **0.54** | **0.48** | **0.25** | **0.14** |
| CHG goals | 0.01 | 0.02 | **0.16** | 0.02 | 0.05 | 0.01 | 0.07 | 0.03 | 0.01 | 0.02 | 0.11 | 0.02 | 0.03 | 0.03 | 0.02 | 0.16 | 0.04 | **0.17** | 0.08 | 0.04 | 0.10 | **0.13** | 0.05 | 0.06 |
| Soil biodiversity | 0.05 | 0.05 | **0.21** | 0.05 | 0.07 | 0.03 | 0.03 | 0.02 | 0.06 | 0.04 | **0.21** | 0.07 | 0.09 | 0.05 | 0.04 | **0.17** | **0.12** | **0.32** | 0.11 | 0.08 | **0.11** | 0.09 | **0.30** | 0.12 |
| Primary productivity | 0.10 | 0.10 | 0.13 | 0.09 | **0.16** | 0.11 | 0.11 | 0.07 | 0.11 | 0.10 | **0.40** | **0.10** | **0.21** | **0.15** | 0.08 | 0.07 | 0.11 | 0.10 | 0.10 | **0.10** | 0.03 | 0.07 | 0.10 | 0.12 |
| **Social** | | | | | | | | | | | | | | | | | | | | | | | | |
| Liveability countryside | 0.03 | 0.03 | 0.02 | 0.05 | 0.02 | 0.06 | 0.03 | 0.04 | 0.02 | 0.04 | 0.01 | 0.06 | 0.03 | 0.02 | 0.09 | 0.04 | 0.06 | 0.02 | 0.03 | 0.06 | 0.03 | 0.03 | 0.08 | 0.04 |
| Food security | 0.03 | 0.03 | 0.09 | 0.11 | 0.04 | 0.06 | 0.06 | 0.08 | 0.03 | 0.07 | 0.03 | 0.05 | **0.12** | 0.04 | **0.30** | 0.06 | 0.06 | 0.06 | 0.05 | 0.07 | 0.03 | 0.03 | 0.04 | 0.07 |
| Inheritance | 0.04 | 0.05 | 0.08 | **0.08** | 0.03 | 0.13 | 0.05 | **0.20** | 0.05 | 0.06 | 0.05 | 0.07 | 0.08 | 0.04 | 0.05 | 0.06 | 0.04 | 0.10 | 0.06 | 0.09 | 0.03 | 0.03 | 0.02 | 0.08 |
| Public appreciation | 0.06 | 0.06 | 0.07 | 0.08 | 0.04 | 0.02 | 0.08 | 0.11 | 0.06 | 0.05 | 0.02 | 0.09 | 0.08 | 0.04 | **0.26** | 0.05 | 0.04 | 0.03 | 0.05 | 0.08 | 0.03 | 0.02 | 0.01 | 0.06 |
| **Economic** | | | | | | | | | | | | | | | | | | | | | | | | |
| Income | **0.36** | **0.31** | 0.06 | 0.12 | **0.22** | **0.23** | **0.23** | **0.17** | **0.31** | **0.23** | 0.02 | **0.25** | 0.11 | **0.29** | 0.06 | **0.16** | **0.23** | 0.05 | **0.16** | **0.17** | 0.03 | 0.04 | 0.04 | **0.17** |
| Export | **0.10** | **0.11** | 0.04 | **0.16** | 0.13 | 0.05 | 0.09 | 0.08 | 0.09 | 0.12 | 0.02 | 0.08 | 0.06 | 0.12 | 0.01 | 0.03 | 0.06 | 0.01 | 0.06 | 0.07 | 0.03 | 0.02 | 0.02 | 0.04 |
| Food expenditure | 0.08 | 0.09 | 0.06 | 0.07 | 0.08 | **0.16** | **0.13** | 0.09 | 0.09 | **0.13** | 0.03 | 0.09 | 0.04 | 0.09 | 0.03 | 0.05 | 0.08 | 0.01 | 0.11 | 0.08 | 0.03 | 0.03 | 0.04 | 0.05 |
| Market price | 0.09 | 0.11 | 0.03 | **0.15** | 0.11 | 0.08 | 0.09 | 0.09 | **0.13** | 0.08 | 0.03 | 0.06 | 0.02 | 0.08 | 0.01 | 0.07 | 0.08 | 0.01 | 0.07 | 0.08 | 0.03 | 0.03 | 0.06 | 0.05 |
| **Nr of respondents** | 18 | 21 | 2 | 3 | 4 | 1 | 5 | 2 | 7 | 5 | 2 | 7 | 1 | 6 | 1 | 4 | 3 | 4 | 12 | 10 | 1 | 5 | 2 | 13 |

[a] An a in the acronym of the actor group means that the response at the aggregate level was inconsistent using a consistency ratio of 0.3 (Aczél and Saaty, 1983).

Whitney test. For "Urban residents (UR)" the interest differed significantly between the self-assessment and the assessment by others. For "Rural Residents (RR)" the same applies for power.

Table 6 provides the underlying data for the power-interest grids. For both datasets, this table presents the minimum, median ($q_2$) and maximum value. The dataset with assessment of power and interest by other actors had a higher number of respondents, therefore Table 6 also presents the values of first quartile ($q_1$) and third quartile ($q_3$).

The assessment by of power and interest by others shows a variation between 0 and 10 for almost all actors included. Based on the value of $q_1$ and $q_3$ in the assessment by others, the spreading around the median is relatively low for the central actors arable and dairy farmers. A high spreading in the assessment of power and interest by other can be found for "Urban residents (UR)" and "Rural residents (RR)". Spreading in the power-interest assessment by others for "Water users (WU)", "Water boards (WB)" and "Nature managers (NM)" is relatively low.

## 4. Discussion and conclusions

In this study we defined the following research questions: (1) Who are the actors in sustainable soil management in the Netherlands, what are their roles and their underlying relations? (2) What are the priorities of these actors regarding sustainable soil management? (3) What are their power to influence decisions and degree of interest in sustainable soil management and (4) How can this study contribute to implementation of sustainable soil management?

### 4.1. *Outcomes of the study*

The actor inventory showed that beyond farmers a diverse group of actors is involved in sustainable soil management. We identified suppliers of physical and non-physical inputs, post-farm value chain participants, actors influenced by external effects of production and policy makers. Most existing literature categorized actors in sustainable soil management at a more general level. For instance, Bampa et al. (2019) categorized actors in (a) farmers/local land users, (b) regional stakeholders and (c) European stakeholders. Bouma et al. (2012) categorized actors in (a) knowledge institutions, (b) enterprises and business, (c) NGO and society and (d) governments. This study describes actors and their role in sustainable soil management in much greater detail compared to previous studies. Therefore, results provide a clear overview of which actor must be involved in decision making on sustainable soil management.

Actors' priorities for soil sustainability criteria were assessed using Analytical Hierarchy Process (AHP) (Saaty, 1980). Farmers and participants in the value chain around the farmer show a strong priority for economic criteria, especially income. In a study assessing priority for soil functions, O'Sullivan et al. (2018) found that farmers and industry had high priority for primary productivity and nutrient cycling. This aligns with the results of this study, as these functions have a direct relation with income. Nutrient cycling is essential for primary production, which may explain why farmers have a higher priority for this soil function compared to other functions. Wang and Aenis, (2019) used a checklist in which actors could prioritize ecosystem services. In a case study in Southwest China, farmers had a high priority for fresh water and food. Environmentally engaged actors showed a clear priority for environment. Social criteria were less associated with sustainable soil management as only a few actors showed a priority for these criteria. In addition to the actor inventory, actors' priorities add important information on how the different actors are expected to behave in a transition towards sustainable soil management. Common priorities among actors can serve as basis for coalition forming.

Actors' power and interest towards sustainable soil management was assessed using power-interest grids. Teklemariam et al. (2015) recognize power-interest grids as a valuable tool in actor analysis for land deals. In previous literature on sustainable soil management, power and interest

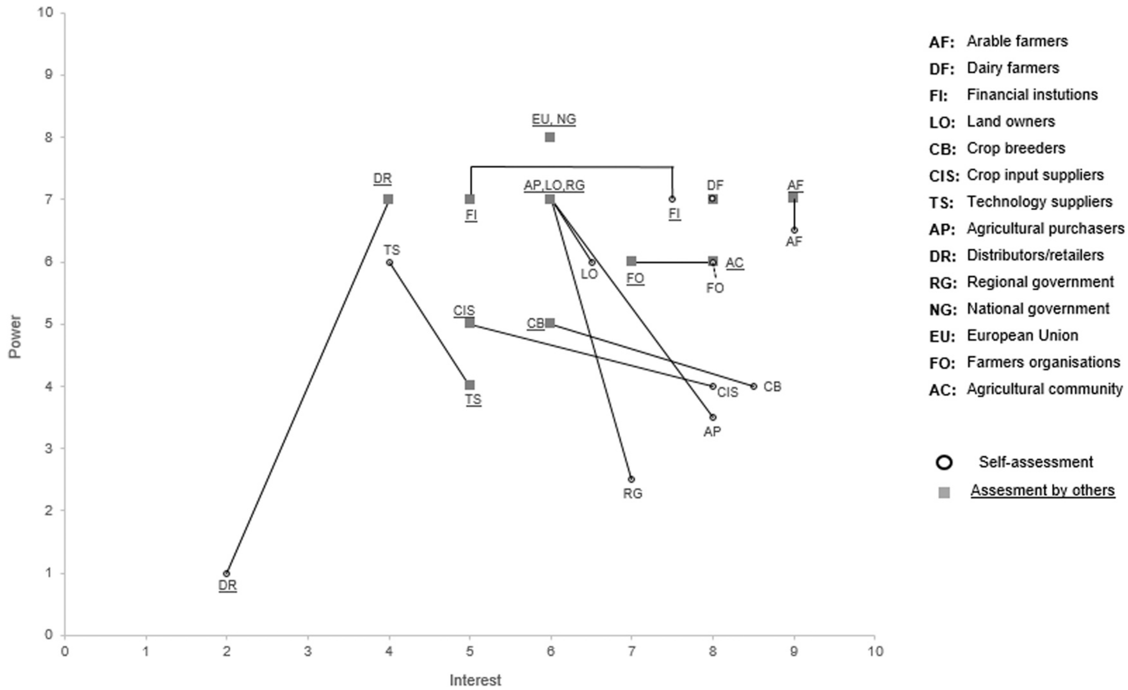


**Fig. 4.** Power and interest grid of central and primary actors in sustainable soil management in the Netherlands. The dots represent the power and interest of the actors according to their own assessment. The grey boxes present the power and interest according to other actors. Black lines connect the assessment made by others to the self-assessment of actors. When the grey box of an actor is not connected, no self-assessment was available.

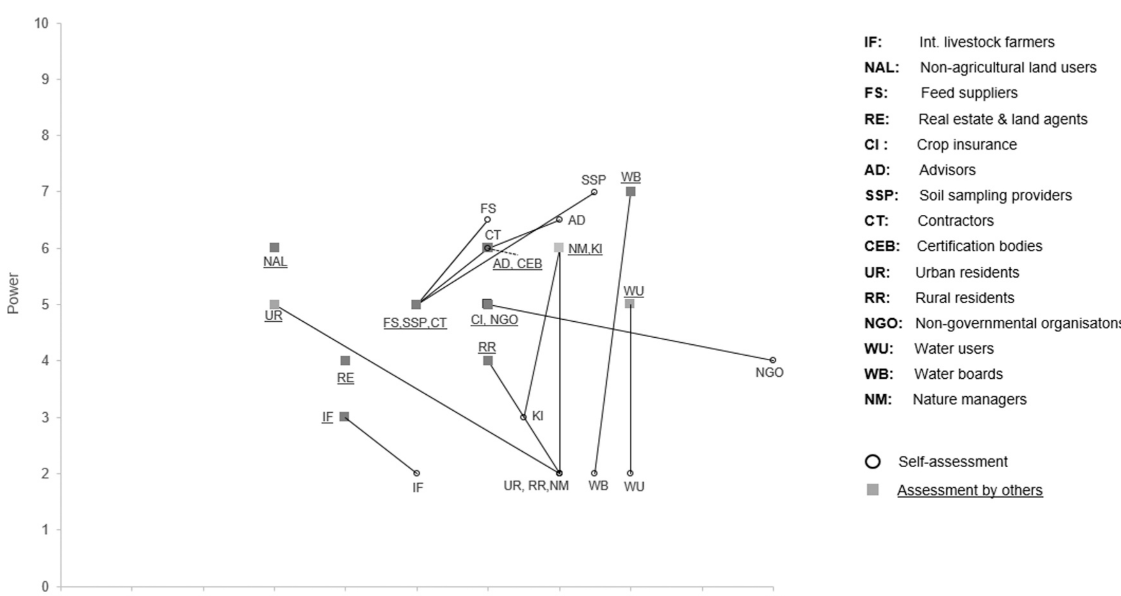


**Fig. 5.** Power and interest grid of secondary actors in sustainable soil management in the Netherlands. The black-white dot represents the power and interest of the actors according to their own assessment. The grey box is the power and interest according to other actors. Black lines connect the assessment made by others to the self-assessment of actors. If the grey box of an actor is not connected no self-assessment was available.

**Table 5**
P values from the Mann-Whitney test on difference between own assessment of power and interest and the assessment of power and interest made by other actors.

| | Arable farmers | Dairy farmers | Urban residents | Rural residents | Knowledge institutions |
|---|---|---|---|---|---|
| Interest | 0.731 | 0.455 | 0.001 | 0.084 | 0.303 |
| Power | 0.167 | 0.443 | 0.069 | 0.004 | 0.059 |

were mainly addressed in a more qualitative way (Rust et al., 2020; Brown et al., 2015; Mumtas and Wichien, 2013). Farmers were confirmed to be the prime actors as they had high power and high interest regarding sustainable soil management. In line with Rust et al. (2020), "Land owners" and value chain actors were found to be powerful actors. We made a valuable addition towards the traditional power-interest analysis as described in Bryson (2004) by splitting actors' self-assessment and the assessment by other actors. This yielded interesting results, i.e. "Agricultural purchasers", "Distributors and retailers" and "Environmentally engaged actors" had limited self-perception of

**Table 6**
Administrative table with minimum (min), first quartile ($q_1$), median ($q_2$), third quartile ($q_3$) and maximum value for power-interest for actors in sustainable soil management. The dataset consists of the self-assessment of power-interest and the assessment made by other actors. For both datasets, the number of respondents (n) is presented.

| | Self-assessment | | | | | | | Assesment by others | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Interest | | | Power | | | | Interest | | | | | | Power | | | | | |
| Actor | min | $q_2$ | max | min | $q_2$ | max | n | min | $q_1$ | $q_2$ | $q_3$ | max | n | min | $q_1$ | $q_2$ | $q_3$ | max | n |
| AF | 4 | 9 | 10 | 2 | 7 | 10 | 15 | 5 | 8 | 9 | 10 | 10 | 111 | 2 | 6 | 7 | 8 | 10 | 111 |
| DF | 5 | 8 | 10 | 4 | 7 | 10 | 17 | 1 | 6.3 | 8 | 9 | 10 | 106 | 1 | 5 | 7 | 8 | 10 | 106 |
| FI | 7 | 7.5 | 8 | 6 | 7 | 8 | 2 | 0 | 3 | 5 | 6 | 9 | 110 | 0 | 5 | 7 | 8 | 10 | 113 |
| LO | 5 | 6.5 | 8 | 6 | 6 | 6 | 2 | 0 | 4 | 6 | 8 | 10 | 112 | 0 | 5 | 7 | 8 | 10 | 112 |
| CB | 8 | 8.5 | 9 | 3 | 4 | 5 | 4 | 0 | 3 | 6 | 7 | 9 | 101 | 0 | 4 | 5 | 7 | 10 | 99 |
| CIS | 8 | 8 | 8 | 4 | 4 | 4 | 1 | 0 | 3 | 5 | 6.5 | 9 | 98 | 0 | 3 | 5 | 7 | 10 | 107 |
| TS | 3 | 4 | 9 | 2 | 6 | 7 | 5 | 0 | 2 | 5 | 7 | 10 | 96 | 0 | 3 | 4 | 6 | 10 | 98 |
| FS | 5 | 6 | 7 | 5 | 6.5 | 8 | 2 | 0 | 2 | 5 | 6 | 8 | 103 | 0 | 3 | 5 | 7 | 10 | 104 |
| IF | 0 | 5 | 8 | 0 | 2 | 2 | 7 | 0 | 2 | 4 | 6 | 10 | 109 | 0 | 2 | 3 | 5 | 10 | 105 |
| AD | 5 | 7 | 8 | 2 | 6.5 | 7 | 6 | 0 | 3 | 6 | 7 | 10 | 102 | 0 | 4 | 6 | 8 | 10 | 105 |
| SSP | 6 | 7 | 8 | 7 | 7.5 | 8 | 2 | 0 | 3 | 5 | 7 | 10 | 102 | 0 | 3 | 5 | 6.5 | 9 | 106 |
| CT | 5 | 6 | 10 | 5 | 6 | 8 | 7 | 0 | 3 | 5 | 7 | 10 | 102 | 0 | 3 | 5 | 7 | 10 | 102 |
| CI | | | | | | | | 0 | 3.5 | 6 | 7 | 10 | 105 | 0 | 3 | 5 | 6 | 10 | 105 |
| RE | | | | | | | | 0 | 2 | 4 | 5 | 9 | 97 | 0 | 2 | 4 | 6 | 10 | 98 |
| AP | 8 | 8 | 9 | 3 | 3.5 | 5 | 6 | 0 | 4 | 6 | 7 | 9 | 101 | 0 | 5 | 7 | 8 | 10 | 101 |
| DR | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 0 | 2 | 4 | 7 | 10 | 106 | 1 | 6 | 7 | 9 | 10 | 113 |
| CEB | | | | | | | | 0 | 3 | 6 | 8 | 10 | 109 | 0 | 4 | 6 | 8 | 10 | 109 |
| RG | 6 | 7 | 8 | 2 | 2.5 | 3 | 4 | 0 | 4 | 6 | 7.5 | 10 | 108 | 0 | 5 | 7 | 8 | 10 | 109 |
| NG | | | | | | | | 0 | 5 | 6 | 8 | 10 | 110 | 1 | 6 | 8 | 9 | 10 | 113 |
| EU | | | | | | | | 0 | 4 | 6 | 7 | 10 | 109 | 1 | 5 | 8 | 9 | 10 | 113 |
| FO | 8 | 8 | 9 | 5 | 6 | 6 | 3 | 1 | 5 | 7 | 8 | 10 | 118 | 1 | 4 | 6 | 7.8 | 10 | 118 |
| AC | | | | | | | | 0 | 6 | 8 | 8 | 10 | 114 | 0 | 4 | 6 | 7 | 10 | 114 |
| NGO | 9 | 10 | 10 | 2 | 4 | 6 | 4 | 0 | 4 | 6 | 8 | 10 | 105 | 0 | 4 | 5 | 7 | 10 | 106 |
| UR | 2 | 6.5 | 9 | 0 | 2.5 | 10 | 12 | 0 | 1 | 3 | 5.8 | 9 | 94 | 0 | 2 | 5 | 7 | 10 | 99 |
| RR | 2 | 7 | 10 | 0 | 2 | 5 | 8 | 0 | 4 | 6 | 7 | 10 | 101 | 0 | 2 | 4 | 6 | 10 | 101 |
| WU | 7 | 7 | 7 | 0 | 0 | 0 | 1 | 0 | 6.5 | 8 | 9 | 10 | 107 | 0 | 4 | 5 | 7 | 10 | 107 |
| WB | 2 | 8 | 9 | 2 | 2 | 5 | 5 | 0 | 6 | 8 | 8 | 10 | 107 | 0 | 5 | 7 | 8 | 10 | 106 |
| NM | 7 | 7 | 7 | 2 | 2 | 2 | 1 | 0 | 6 | 7 | 8 | 10 | 114 | 0 | 4 | 6 | 8 | 10 | 116 |
| NAL | | | | | | | | 0 | 1 | 3 | 5 | 10 | 104 | 0 | 4 | 6 | 8 | 10 | 110 |
| KI | 2 | 6.5 | 9 | 1 | 3 | 8 | 12 | 0 | 5 | 7 | 8 | 10 | 100 | 0 | 3 | 6 | 7 | 10 | 102 |

power, whereas others perceived them as powerful actors. Such a situation might be an indicator for a locked-in situation where nobody takes action. Actors that have low power according to their own assessment may be waiting for others to act. Similarly, when others assess the previous actor with a considerable degree of power, they may wait until this actor undertakes action. Thus, different parties will be waiting for each other to make the first move. Using this method is a valuable approach to detect locked-in situations in other wicked natural resources management problems as well.

### 4.2. *Limitations of the study*

A major point of attention in the development of an actor inventory is the set-up of an unbiased and complete set of actors (Reed et al., 2009; Wang and Aenis, 2019). We applied a stepwise approach, including expert validation, to develop an unbiased and complete inventory of actor types. Nevertheless, some limitations exist. The actor inventory did not address the presence of compound actors. Compound actors are actors represented by different departments that do not necessarily have the same involvement in the problem area, e.g. the actor "national government" consists of different ministries (Koppenjan and Klijn, 2004). Another limitation is that the inventory assumed that a particular actor always can be represented by one actor type, while according to their activities they might fit in multiple actor types.

We used the frequently applied Analytical Hierarchy Process (AHP) to elicit actors' priorities. One of the major drawbacks of AHP is possible subjectivity in the criteria (Petrini et al., 2016). We established criteria in a stepwise approach including expert validation to reduce subjectivity. AHP requires homogenous and independent criteria (Saaty, 1990). Criteria within this study were not completely independent, e.g. the subcriterion primary productivity depends on water quality and regulation, which is another criterion. Dependency in criteria and the ambiguous question procedure of AHP could have been a cause of the inconsistency in actors' priorities (Kukrety et al., 2013). Alternatives, e. g. the Best-Worst Method, may be considered in future research to reduce the inconsistency in responses while simultaneously lowering the cognitive load of the survey (Rezaei, 2015).

The focus of our survey was on inclusiveness of the different actors rather than on representativeness within one actor group. Unfortunately, this resulted in a small sample of primary actors like financial institutions, land owners and distributors and retailers. For the national government and the European Union, we were not able to get a response at all. For a thorough understanding of priorities and positions, a survey appears to be insufficient. Based on the results of the study we could not explain some striking observations such as the high priority of financial institutions for environmental criteria and the low perceived degree of power and interest of distributors and retail. A common approach used in literature is to accompany the survey with qualitative interviews (Raakjær Nielsen and Mathiesen, 2006). In future studies, more attention should be given to the variety of priorities and positions within an actor group. Although the methodology of the actor analysis is sound, one should use some degree of caution in using actors' priorities and actors' power-interest of this study in decision-making. The sample size is too small to generate generalizable results, even in the Dutch context.

### 4.3. *Agricultural Innovation Systems approach for sustainable soil management*

In order to realize future food systems there is a key role for Agricultural Innovation Systems (AIS) (Klerkx and Begemann, 2020). An AIS is concerned with the networks of actors from science, business, civil society and government that coproduce the suite of technological, social, and institutional innovations that co-shape these future food systems (Klerkx and Begemann, 2020). Sustainable soil management can be seen as a prerequisite for such future food systems. Pigford et al. (2018) argue that AIS need to become mission-oriented: these missions need to tackle grand societal and planetary challenges. A recent example of such a mission-oriented agricultural innovation system is the EU mission on soil health (European Commission, 2020). Our study can contribute such innovation processes by identifying the networks of actors and gain insight in the position of actors.

We want to illustrate our contribution to the mission-oriented agricultural innovation system of soil health via the example of the soils' potential to mitigate climate change via carbon sequestration. Once a mission has been defined, according to Klerkx and Begemann (2020), the following question is who are involved and how to address the different involvement of actors. The inventory of actors can be used to identify which actors are involved in an innovation. In this example, the first and crucial actors involved are farmers. Climate goals are mainly issued via policy makers. NGOs can put climate goals on the agenda of policy makers via societal pressure. Farmers changing practices might impact the products they deliver, as well as the inputs they purchase. Subsequently, input suppliers and post-farm value chain participants will be affected. Once the potential actors involved have been identified, common priorities among actors and complementary power-interest bases can serve as a basis for coalition forming. A fertile ground would be to form a coalition of actors with common priorities, high power and high interest. In this example, farmers, input suppliers and value chain participants have a high priority for income. Contradictory to farmers and value chain participants, governments and NGOs have a high priority for environmental criteria. Whereas governments have high power but a relative low degree of interest, NGOs have low perceived power but a high degree of interest. For actors like NGOs, it is especially interesting to collaborate with actors with high power but limited interest, as they might be able to put their interest on the agenda of a powerful actor. To foster collaboration between actor coalitions with contradictory priorities, there might be a crucial role for actors with priorities on both sides. In the example, such a role might be fulfilled by regional governments and financial institutions. Regional governments have a priority for both environmental criteria and economic criteria. Although financial institutions do not show a clear priority for economic criteria, they have direct formal relationships with farmers and high power to influence decisions.

### 4.4. Conclusions

Despite its limitations, this is the first study combining a comprehensive inventory of actors, actors' priorities for soil sustainability criteria and actors' power and interest to influence decisions. As such, this study contributes to the literature, as to the best of our knowledge such an approach has not yet been performed in the field of sustainable soil management. Farmers were confirmed to be the prime actor. Therefore, the main question that arises from this study is: How and by whom can farmers be motivated to act not only in their own interest but also in the interest of other actors towards sustainable soil management? Therefore, the key element of innovations is to create incentive structures around the farmer. Future quantitative research should investigate how these incentives translate to management on farm level. The insights of this paper can provide information on the scale and approach of such quantitative studies. They also allow policy makers to align policies with actor priorities and ongoing private multi-actor collaborations for sustainable soil management.

## Declarations of interest

None.

## Acknowledgments

We would like to thank all respondents who devoted time to complete the survey. We also thank the eight experts that validated the selection of actors and criteria. We thank Hilde Tobi for her help with the analysis of the results and Laurens Klerkx for his help on the innovation system approach. We sincerely thank the three anonymous reviewers for their helpful comments.

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