The Binding Potential of P
An Analysis of the Governance Network for Phosphorus Recycling and Reuse in Wageningen, the Netherlands

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Colophon

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There is no guano comparable in fertility with the detritus of a capital. A great city is the most mighty of dung-makers. Certain success would attend the experiment of employing the city to manure the plain. If our gold is manure, our manure, on the other hand, is gold.

Victor Hugo, 1862
Abstract

Phosphorus is an essential nutrient for worldwide food security. In Europe, it is mainly imported and disappears from the food chain as animal manure, human excreta and organic waste. This causes various environmental, economic and social concerns. While much research on phosphorus focuses on potential solutions in agriculture, this study is part of an interdisciplinary thesis project that explores the limitations and opportunities to foster phosphorus recycling and reuse in urban areas by marrying a technical analysis of the material flows of phosphorus with a sociological analysis of the relevant stakeholder network.

Specifically, this study investigates the network of stakeholders related to phosphorus recycling and reuse in Wageningen, the Netherlands, which is the case study of this overall thesis project. For this purpose, this sub-thesis uses the concept of network governance as an underlying theoretical framework. By applying quantitative Social Network Analysis (SNA), social interactions in the governance network, such as information exchange and collaboration, are systematically assessed and the structural network position of the stakeholders is identified. Furthermore, the perceived influence and expertise of stakeholders are quantitatively analysed. This is combined with a qualitative approach, for which 11 in-depth interviews were conducted that paid special attention to the capacities of municipalities in boosting phosphorus recycling and reuse.

The governance network appears to display multiple channels for communication and close collaboration between a large part of the stakeholders. Its capacity for coordinating joint action is however limited due to the decentralised structure. While employees of the regional water board and scientists affiliated to Wageningen University & Research Centre occupy various key positions in the network, the municipality has only few and weak links to others regarding the topic. The in-depth interviews have shown that phosphorus recycling and reuse is currently no real issue for most municipalities and their capacities to facilitate it are limited.

It would be beneficial for the further governance process if one or few stakeholders gain a broker position in the network in order to be able to facilitate and coordinate collective action between the various stakeholders. The findings suggest that it is more promising and realistic that such collaborative processes are coordinated not on a local, but on a regional level, where municipalities collaborate with other municipalities, water boards, waste management companies, research institutions, business organisations and other relevant actors.

Future research should, among others, pursue a more qualitative approach and explore in detail to what extent the identified key stakeholders are willing and able to systematically facilitate and coordinate phosphorus recycling and reuse and what their potential strategies are to do so.

Keywords: Phosphorus, food security, network governance, social network analysis, cities, Gephi, UCINET
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Jacki

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Matthias

For being my anchor
Uli

Maman
Papfa
Maya

Compadre
Aljaž
Alison
### List of Abbreviations

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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ACV</td>
<td>ACV groep</td>
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<tr>
<td>AGR</td>
<td>AgruniekRijnvallei</td>
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<tr>
<td>ALT</td>
<td>WUR Alterra</td>
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<tr>
<td>ATP</td>
<td>Adenosine triphosphate</td>
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<tr>
<td>BC</td>
<td>Betweenness Centrality</td>
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<tr>
<td>CCP</td>
<td>Cities for Climate Protection</td>
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<tr>
<td>CDM</td>
<td>Commissie van Deskundigen Meststoffenwet</td>
</tr>
<tr>
<td>COLL</td>
<td>Index that measures the number of other individuals in the network who are interested in future collaborations with a certain person</td>
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<tr>
<td>CHI</td>
<td>Community Heterogeneity Index</td>
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<tr>
<td>D</td>
<td>Network density</td>
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<tr>
<td>DC</td>
<td>Degree Centrality</td>
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<tr>
<td>DeSaH</td>
<td>Decentralised Sanitation and Reuse</td>
</tr>
<tr>
<td>DNA</td>
<td>Deoxyribonucleic acid</td>
</tr>
<tr>
<td>ESPC</td>
<td>European Sustainable Phosphorus Conference</td>
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<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>ETE</td>
<td>WUR Sub-Department of Environmental Technology</td>
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<tr>
<td>GMB</td>
<td>GMB BioEnergie</td>
</tr>
<tr>
<td>IM</td>
<td>Ministry of Infrastructure and Environment</td>
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<tr>
<td>INT</td>
<td>Interviewee</td>
</tr>
<tr>
<td>LeAF</td>
<td>Lettinga Associate Foundation</td>
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<tr>
<td>MFA</td>
<td>Material Flow Analysis</td>
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<tr>
<td>MUN</td>
<td>Municipality of Wageningen</td>
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<td>NEVEDI</td>
<td>Dutch Feed Industry Association</td>
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<tr>
<td>NGO</td>
<td>Non-governmental organisation</td>
</tr>
<tr>
<td>NIOO-KNAW</td>
<td>Dutch Institute of Ecology</td>
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<tr>
<td>NMI</td>
<td>Nutrient Management Institute</td>
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<tr>
<td>NP</td>
<td>Nutrient Platform</td>
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<tr>
<td>P</td>
<td>Phosphorus</td>
</tr>
<tr>
<td>$P_e$</td>
<td>Perceived expertise</td>
</tr>
<tr>
<td>$P_i$</td>
<td>Perceived influence</td>
</tr>
<tr>
<td>PRI</td>
<td>WUR Plant Research International</td>
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<tr>
<td>PWVE</td>
<td>Platform Water Vallei en Eem</td>
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<tr>
<td>SNA</td>
<td>Social Network Analysis</td>
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<tr>
<td>SQ</td>
<td>WUR Department of Soil Quality</td>
</tr>
<tr>
<td>STO</td>
<td>STOWA</td>
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<tr>
<td>TNM</td>
<td>Transnational municipal network</td>
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<tr>
<td>TOP</td>
<td>TOP B.V.</td>
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<tr>
<td>TWE</td>
<td>Twence</td>
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List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
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<tbody>
<tr>
<td>U.S.</td>
<td>United States of America</td>
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<tr>
<td>VGW</td>
<td>Van Gansewinkel</td>
</tr>
<tr>
<td>WB</td>
<td>Water Board Vallei and Veluwe</td>
</tr>
<tr>
<td>WTO</td>
<td>World Trade Organisation</td>
</tr>
<tr>
<td>WUR</td>
<td>Wageningen University and Research Centre</td>
</tr>
<tr>
<td>WWTP</td>
<td>Wastewater treatment plant</td>
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1. Introduction

1.1 Problem statement

Phosphorus (P) is a chemical element and an essential nutrient for life that cannot be substituted by any other element – the DNA consists of five elements, of which phosphorus is one. Cells require adenosine triphosphate (ATP) to drive the chemical reactions that allow them to gain energy. It is thus an essential component for plants, animals, and humans to function and grow (Emsley 2002, Schröder et al. 2010). Together with nitrogen and potassium, phosphorus forms an important component of agricultural fertilisers (Cordell, Drangert and White 2009). Next to this, also the animal feed as well as detergent industries use phosphorus as an ingredient for their products. In spite of its key role for global food security and other commodities, phosphorus is not managed sustainably. As a matter of fact, several factors contribute to increasing global phosphorus insecurity (ibid.), which will be elucidated in the following.

Ninety per cent of phosphorus demand is for growing food (Cordell et al. 2009). Historically, the phosphorus required for food production was naturally found in soils and, if needed, (renewable) organic sources of P were applied on soils, such as compost, bone meal manure and human excreta. However, increases in famine and low soil fertility made it necessary to look for alternatives – the introduction of chemical fertilisers in the 19th century meant a breakthrough and made it possible to significantly enhance soil fertility. For this, initially animal bones were used, but also guano deposits1 and later mined phosphate rock, which was the most abundant source of phosphorus to be exploited for the production of inorganic fertiliser (Schröder et al. 2010, Van Vuuren, Bouwman and Beusen 2010). This development enabled high crop yields, which led to a steep rise in population growth. It is stated by various authors that current levels of food production would not be maintained without the availability of inorganic fertiliser (Cordell et al. 2009, Schröder et al. 2010, Van Vuuren et al. 2010). While there has been a clear rise in the application of mineral (inorganic) fertiliser, the use of alternative sources such as animal bones and human excreta has declined in the EU from the 1980s onwards due to health and pollution concerns (Lamprecht et al. 2011). Today, conventional agriculture is therefore highly dependent on a steady supply of mineral phosphorus fertilisers.

A fact which causes geopolitical concern is that recent data shows that close to 75 % of the phosphorus rock reserves, which are currently considered economically extractable, are located in Morocco and Western Sahara territories. In addition to Morocco (including Western Sahara), the U.S. and China are also large producers of phosphate rock (Van Enk et al. 2012). The U.S. however largely requires it for its own agricultural production and China had, until recently, put a high export tariff to secure P for its domestic markets at the expense of foreign competition (Schröder et al. 2010). Although such export tariffs on raw materials such as phosphorus have been ruled against by the World Trade Organization (WTO)2, this case exemplifies that phosphate mining countries are increasingly recognising their geopol-

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1 So called guano deposits are found in the Pacific coastal regions and islands (Peru). These are accumulated bird droppings and are rich in nitrogen and phosphorus – both vital compounds for plant growth. Alexander von Humboldt studied its properties in 1802 and this resulted in the exportation of these deposits, thereby becoming the first external source of fertiliser (Emsley 2002, Keyzer 2010) Guano deposits currently do not play an important role in the phosphate market and are therefore not further discussed in this thesis (Van Enk et al. 2012)

2 http://trade.ec.europa.eu/doclib/press/index.cfm?id=774
Introduction

li
tical position with regard to key resources such as phosphorus and the need for ensuring domestic food security.

Although the agricultural sector is today highly dependent on a steady supply of mineral phosphorus, the rock which it is derived from is not an infinite resource. It is widely acknowledged that phosphorus mined from phosphate rock is becoming scarcer and increasingly difficult to access, causing a rise in costs for the exploitation of the remaining reserves. Although an increase in phosphorus prices might stimulate the market to seek for other physical deposits to extract phosphorus, any rise in cost will undoubtedly affect the prices of food production and consumption. Scholz and Wellmer (2013) therefore state that a complex challenge is ahead in which price spikes need to be mitigated for farmers to ensure that the economic scarcity of phosphorus does not affect food security.

Whilst there are concerns on economic scarcity and degrading quality of phosphate rock, simultaneously there is a growing demand for P due to several factors. First of all, the United Nations (2012) estimate the world population to grow over nine billion by the year 2050, which will result in an increased demand for food and thus fertiliser. Additionally, increasing prosperity and urbanisation in emerging economies such as China and India goes along with dietary changes towards more meat and dairy products that are more phosphorus-intensive (Schmid Neset et al. 2008). Another important reason for the increasing demand of phosphorus is a rise in the use of biofuels and associated energy crops. Due to growing environmental concerns regarding fossil fuels and meeting the energy needs for the future, biofuels are considered an interesting alternative (Cordell et al. 2009, Schröder et al. 2010).

Despite the economic scarcity issues and growing demand, there are losses of phosphorus taking place throughout the entire supply chain; during mining and processing, transport, application on the fields, food consumption and production and waste treatment. Schröder et al. (2010) point out that prior to the industrial revolution and the introduction of mineral fertilisers, the connection between production and consumption of food was much closer in space and time and thus allowed for more closed-loop agricultural practices. Following the introduction of mineral fertilisers, higher yields were achieved and there was no necessity for recycling the waste product anymore.

The lack of recycling and reuse of nutrients also has harmful effects on the environment. Phosphorus rock also consists of cadmium and uranium that pose concern due to their toxicity and radioactivity respectively (Schröder et al. 2010). Moreover, mineral fertilisers can contain hazardous heavy metals such as phosphogypsum – full removal of these heavy metals is usually considered too expensive. As a result, soils, groundwater and eventually food become contaminated, deteriorating its overall quality (Keyzer 2010, Schröder et al. 2010). There is concern that the quality of P rock further declines if high grade ores are depleted, because the lower grade ores contain higher concentrations of heavy metals (Schröder et al. 2010). This is expected to lead to an increase in the price due to the need for further processing to remove these constituents (ibid.). Furthermore, harmful effects to the environment can occur if too much phosphorus is discharged in surface waters; either directly, or through excessive application of fertilisers that leads to leaching and run-off into ground- and surface waters. In addition, the insufficient removal of phosphorus in wastewater treatment plants (WWTP) or the lack of a WWTP also contributes

3 For food production, which represents the primary demand of phosphate rock, Cordell et al. (2009) give an overview of the losses at each stage.
to discharge of phosphorus to surface waters. This results in harmful accumulation of nutrients, which eventually causes eutrophication. According to Rosmarin (2004), around 25 per cent of all phosphorus mined since 1950 have ended up in water bodies or in a landfill. This finally brings us to an interesting paradox and a unique problem of phosphorus: on the one hand there is an increased scarcity of phosphorus and on the other hand there is a harmful excess of phosphorus in water bodies (Cordell et al. 2009, Elser and Bennett 2011). This underlines the need for a more sustainable use of this nutrient.

1.2 Definition of research gap

Phosphorus losses take place in both rural and urban areas. While much research on phosphorus flows has focused on losses and potential solutions in the agricultural sector, Kalmykova et al. (2012) stress that urban areas are often neglected and marginalised due to the magnitude of agricultural phosphorus flows. Cities however form a key step in the flow of phosphorus within the global food system. They concentrate the demand for food and thus for P. Consequently, cities are highly dependent on a continuous supply of phosphorus and accordingly vulnerable to potential shortages in the supply chain of this resource. On the other hand, cities also concentrate the production of P-rich waste, particularly through human waste (urine and faeces) as well as organic (food) waste. As the world becomes more urbanised, with at least 6.3 billion people being estimated to live in urban areas by 2050 (United Nations 2012) and the food production and consumption chain become increasingly concentrated in and around these urban centres, cities are and will continue to be evolving into phosphorus ‘hotspots’ (Cordell et al. 2009, Schmid Neset et al. 2008). Hence, there is significant potential for cities to recycle their phosphate-containing waste and thereby contribute to (urban) food security by decreasing the dependence on mined phosphate and associated price fluctuations. As stated by Cordell et al. (2009), urine for instance could provide more than half of the phosphorus that is needed for the fertilisation of cereal crops. A study by Kabbe (2014) for instance shows that phosphorus in sewage and other biosolids in the Berlin metropolitan area amounts to over 3,000 tons of P per year, which, if recovered, could provide around % of the mineral fertiliser need of the surrounding Brandenburg region. In another study about the phosphorus flow through the Twin Cities Watershed, Baker (2011) shows that if P would be recycled and deliberately exported to surrounding farmlands, it would be enough to support around half of the supply for the metropolitan area.

Cordell et al. (2011) stress the complexity of phosphorus management, which arises from multiple interlinkages with other resources (e.g. nitrogen, carbon, land, water) and requires taking other global environmental and social challenges into consideration. These include climate change, fossil fuel energy scarcity, water scarcity, land-use changes, population growth, urbanisation trends as well as eutrophication. Accordingly, future trends and drivers within food, sanitation, water, energy and environmental management sectors will influence the feasibility of establishing phosphorus recovery and reuse systems and make it necessary to seek for synergies. In cities, these sectors “interact with the very highest density of intersections and inextricable interdependencies” (Beck and Villarroel Walker 2013). Also, cities are hubs of knowledge and innovation. Hence, they play a crucial role in finding and implementing synergies between the described sectors. Furthermore, it is common to the above-mentioned challenges that

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4 As there is hardly any agricultural production and thus no demand for mineral fertiliser in Berlin itself, the study assumed that the fertiliser would be utilised in the surrounding Brandenburg area.

5 The Twin Cities Watershed embraces most of the Minneapolis-Saint Paul metropolitan region in the US.
Introduction

while looking at the global picture is pivotal, it is just as important to consider local variability and differences between various levels that accrue from different ecological and social contexts (Metson 2013). Phosphorus flows in cities can differ significantly from flows on a regional or national level, especially in more developed countries, where agriculture is often more disconnected from cities. For instance, Kalmykova et al. (2012) show that the amount of phosphorus in the organic solid waste fraction can be much higher than estimated – for the case of Gothenburg in Sweden, it accounts for some 40% of the total amount of phosphorus flowing through the city. In contrast, studies on a global scale rather suggest that the vast majority of P, namely 75% to 90%, in urban areas is contained in sewage sludge. The authors therefore argue that the current nutrient management strategies of the municipality of Gothenburg that have so far focused on the recovery of phosphorus from sewage sludge, have to be revised accordingly to also consider the stream of P in organic waste.

For urban, regional or national phosphorus management strategies to be effective, it is therefore important to take the differences between urban, regional, national, and global phosphorus flows into consideration and thereby better understand the specificities, role and contribution of cities.

Acknowledging this need, the interdisciplinary thesis project that this study is part of intends to explore the limitations and opportunities to foster phosphorus recycling and reuse in urban areas. The joint project, which has been carried out by my thesis colleague Alison Jenkins and me, is based on the notion that exploring these limitations and opportunities requires a careful analysis of both the technological and social aspects connected to the urban transition towards sustainable phosphorus use. Bulkeley and Betsill (2005: 42f.) point out that “most analyses of urban sustainability attempt to document the extent to which cities are, or are not, becoming more sustainable through the use of indicators, flows, footprints and so on, and the practical challenges which are being encountered in putting the sustainable cities agenda in place.” While studies with such a focus were undoubtedly important, “such work has tended to reduce the analysis of sustainable urban development to a technical matter of institutional restructuring, traffic management, architectural design and the development of green technologies” (Whitehead 2003, p.1187 in Bulkeley and Betsill 2005). In their report on urban resource flows and the governance of infrastructure transitions, Hodson et al. (2012) stress that the role of cities in systemically reshaping resource flows and the organisation of infrastructure are generally not well understood. This is largely due to the insufficient attention that has been given to “the fact that the design, construction, and operation of infrastructures […] create a sociotechnical environment that plays an important role in shaping, and potentially reshaping, how resources are procured, used, and disposed of by the city” (Hodson et al. 2012: 791). Accordingly, they argue that determining the limits and opportunities for reshaping resource flows in cities requires an understanding of the current state of material flows and the technical and social organisation of infrastructures as well as an assessment of the existing or potential socio-technical capability to shape resource flows.

To cover the technological and infrastructural aspects of phosphorus recycling and reuse in urban areas, Jenkins (2014) therefore conducted a Material Flow Analysis (MFA) in order to track the flow of phosphorus through a city’s food system, using the example of the City of Wageningen in the Netherlands. Based on the results of her analysis, she developed a number of strategies for effective recycling and reuse of phosphorus in Wageningen and investigated their potential impact with regard to the reduction of phosphorus losses.
However, analysing the material side of phosphorus flows brings us only half way. As Mol and Dieu (2006) point out, these kinds of analyses do not provide insights, understanding and strategies on how to successfully and sustainably govern these resources flows. They “pay little or no attention to social systems and social network themselves [such as the social interactions and dynamics, the power relations governing these material flows, or the non-material (money, information, etc.) flows that parallel these material and energy flows.]” (ibid.: 304). Hence, a sociological contribution to the analysis of phosphorus flows that accounts for the above aspects is a necessary complement to the material flow analysis. In this study, I will therefore address the social and governance aspects by analysing the network of stakeholders relevant for recycling and reuse of phosphorus flows in Wageningen, the Netherlands. For this purpose, the concept of network governance will be used as a conceptual framework. It is based on the notion that single agency top-down centralised systems, in which the state is the central actor who makes political decisions, are poorly suited for managing natural resources (Carlsson & Sandstroem, 2007). This is because natural resource problems are so complex, that it is virtually impossible for only one or few actors to possess the full range of knowledge that is needed to adequately govern natural resources. Instead, informal decision-making arrangements, in which various actors from different parts of society collaborate with each other, are assumed to be pivotal for the success of natural resource governance. As the term suggests, the concept of network governance basically regards these arrangements as social networks, in which the involved actors rely on each other, are interconnected and cannot carry out their decisions alone anymore (Khan 2013). Research in the field of social networks and natural resource governance further shows that not only the existence of social networks is a common denominator of successful natural resource governance processes, but that it is above all the structure of these social networks that matters (Bodin and Crona 2009, Bodin and Prell 2011b, Carlsson and Sandström 2007). Structure here refers to the pattern of interactions among the members of social networks, that is, the way how they are connected and communicate with each other.

In this thesis, I will use Social Network Analysis (SNA), a technique that is capable of analysing this structure of social networks in a quantitative and systematic manner. SNA investigates the structure of communication and interaction between network members and can thereby make conclusions about the way various resources such as information, knowledge and money flow through the network. Applying SNA will allow me to uncover those network structures that enable or constrain communication and collaborative processes between stakeholders towards more phosphorus recycling and reuse in Wageningen. Furthermore, this study will pay attention to the capacities and interests of the Municipality of Wageningen to facilitate more phosphorus recycling and reuse.

For the overall thesis project, the specific case of the Netherlands is investigated: Dutch soils are mostly saturated with phosphorus, which has led to severe eutrophication issues (Cordell et al. 2009, Smit et al. 2010). In addition, there is a high dependency on phosphorus imports in the form of fertilizer and animal feed (Smit et al. 2010). Although phosphorus flows on the national level are well researched, to our knowledge, there have not been any analyses of Dutch cities conducted with regard to phosphorus flows and the potentials and limitations for recycling. Within the Netherlands, Wageningen is chosen as a case study due to its relatively small size, making the study feasible in terms of time and budget available for a Master thesis. Furthermore, it is the centre of the Regio FoodValley, an agri-business region

6 http://regiofoodvalley.nl/
in the Netherlands where international food companies, research institutes, and Wageningen University and Research Centre are concentrated. This makes the city of Wageningen – as a hub of knowledge and a focus on food and agriculture – an interesting case to study from the perspective of phosphorus flows.

As a preparation for this joint thesis project, a comprehensive literature review on phosphorus issues both on a global level as well as in the Netherlands was conducted. The global situation has already been covered in the section 1.1. Since a detailed discussion of phosphorus issues in the Netherlands is not necessary for the understanding of the results of this study, it was decided to attach that literature review as additional information in the Annex. For a more thorough overview of phosphorus issues in the Netherlands, in which the case study of this thesis is embedded in, therefore see Annex 1.

1.3 Objectives and research questions

Based on the above research gaps, this thesis aims to investigate limitations and opportunities to advance recycling and reuse of phosphorus flows of Wageningen, the Netherlands from a social network perspective.

This overall research objective is divided into five sub-objectives:

- To identify the stakeholders that are relevant for recycling and reuse of phosphorus flows of Wageningen
- To examine how the structural features of the relevant stakeholder network enable or constrain more recycling and reuse of phosphorus flows of Wageningen
- To investigate how the network members are perceived in terms of their influence and expertise regarding recycling and reuse of phosphorus flows of Wageningen
- To explore the interests and capacities of the Municipality of Wageningen with regard to advancing recycling and reuse of phosphorus
- To identify which stakeholder are potentially capable of facilitating more phosphorus recycling and reuse in Wageningen.

Accordingly, the main research question of this study is:

What are, from a social network perspective, limitations and opportunities to advance recycling and reuse of phosphorus flows of Wageningen, the Netherlands?

Again, this research questions is divided into five sub-research questions:

1. Which stakeholders are part of the governance network relevant for recycling and reuse of phosphorus flows of Wageningen?
2. What is the status of key indicators characterising the structure of the governance network, specifically measures of
   a. Network cohesion
   b. Sub-structuredness
   c. Stakeholders’ centrality?
3. How are the network members perceived in terms of their influence and expertise regarding recycling and reuse of phosphorus flows of Wageningen?

4. What are the interests and capacities of the Municipality of Wageningen with regard to advancing recycling and reuse of phosphorus?

5. Based on the above results, which stakeholders are potentially capable of facilitating more phosphorus recycling and reuse in Wageningen?

1.4 Research strategy and methodologies

At the centre of this study lies the question of how the structure of the governance network relevant in terms of phosphorus affects the opportunities for phosphorus recycling and reuse in Wageningen. This requires quantitative research methods that allow collecting comparable social network data in a standardised way. Next to this, investigating the particular role of the Municipality of Wageningen in terms of phosphorus recycling and reuse and exploring its interests, drivers, capacities and obstacles calls for a more open and explorative, that is, qualitative research approach that enables me to explore these perspectives about which little is known so far. Hence, I chose a mixed- or multi-methods research design in which both quantitative and qualitative methods of data collection were employed. The network data for the quantitative Social Network Analysis have been collected by means of desk research, snowball sampling and an online network survey. The qualitative data were gathered by conducting in-depth interviews with key informants from various sectors relevant in the field of phosphorus.

1.5 Importance of the research

In March 2013, the first European Sustainable Phosphorus Conference took place in Brussels. In 40 interactive table sessions, various topics such as recycling technologies in manure, organic waste and water treatment as well as smart cooperation were discussed. The importance and usefulness of the research carried out by this study are underlined by the conclusions from the latter table session (emphasised passages indicate aspects that especially fit to this study):

“A fundamental requirement for business case development is involving and bringing together parties throughout the phosphorus value chain, across different sectors and member states. In that way knowledge and experience can be effectively disseminated, supply and demand can be connected, different waste streams can be integrated and markets and logistics can be combined. To achieve cooperation between these differing types of organizations and industries, parties must trust each other. For that purpose it is advised bringing together and closing local value chains, and setting up national and/or regional nutrient platforms. In that way the entire value chain can be smartly governed and used to attain the necessary changes in policies and regulations. The creation of a European phosphorus platform would facilitate achieving these goals on a European level.” (European Sustainable Phosphorus Platform 2013: 2)

1.6 Structure of the report

This thesis is structured as follows: Chapter 2 will explain the conceptual framework that has been used for this study. Subsequently, the research design and methodologies are outlined in chapter 3. Chapter 4 gives a brief overview of the case study Wageningen. In chapter 5, I will then present my results from
the quantitative network study as well as the qualitative study. Chapter 6 will discuss the findings and will compare them to literature. Finally, chapter 7 draws conclusions, answers the research questions and gives some recommendations for future research.
2. Conceptual framework

In this chapter, I will elaborate on the theories and concepts that form the theoretical and conceptual fundament of this study. First of all, I will start by introducing the multi-level and network governance as concepts that have gained increasing attention in natural resource governance (2.1). The subsequent section will discuss the importance of social networks for outcomes of natural resource governance (2.2). Finally, I will give an overview of social network concepts as well as the relevant technique to analyse them, Social Network Analysis (SNA) (2.3).

2.1 Multi-level network governance for natural resource management

Sustainable management of natural resources requires finding appropriate institutions and management systems. Overwhelming evidence from numerous studies suggests that top-down centralised systems are less suitable for this challenging endeavour (Berkes 2009, Carlsson and Sandström 2007). Most natural resource problems are too complex to be adequately addressed by the formal problem-solving structures and processes of government. This is because administrative boundaries of both policy levels and policy sectors are definitive, whereas natural resource problems span across various scales (Carlsson and Berkes 2005, Folke 2007). In this case, scales not only include the geographic domain (spatial scale) or administrative boundaries (jurisdictional scale), but – in the light of long-term challenges like climate change and food security – also the character and intensity of externalities that are associated with, for example, the loss of phosphorus out of the food system (temporal scale). For instance, the decisions of a district level authority to not separately collect and recycle solid organic waste of a new settlement has far-reaching consequences that contribute to the continued demand for environmentally harmful extraction of phosphorus in other parts of the world, eventually leading to potential global food insecurity. Such consequences are however far beyond the territorial competences of the respective authority. Furthermore, Schröder et al. (2010) point out how institutional structures around phosphorus are fragmented, in such a way that there is a mismatch between the physical flow of phosphorus through the food system and the institutional structures. “For instance, while phosphorus physical flows directly from the food humans consume to urine and faeces, there are very few institutional relationships between the food consumption (or food security) sector and the sanitation sector” (ibid.: 98). This mismatch between the attributes of government systems and resource systems that they are supposed to govern has been denoted ‘the problem of fit’ (Galaz et al. 2008, Gatzweiler 2006), which is “the archetypical scale problem for environmental issues” (Termeer, Dewulf and Van Lieshout 2010: 2).

The search for appropriate institutional arrangements that meet the challenge to close this gap has led to the formulation of various concepts, such as multi-level governance and network governance. Essentially, they have two basic ideas in common: First, governance systems that are designed to deal with the abovementioned complexities often rely on multi-level arrangements, including local, regional, national, supra-national and global levels (Olsson et al. 2007). Here, control and power traditionally exercised by central states is reallocated into three directions: (1) upwards to international actors and organisations such as the EU and the WTO; (2) downwards to regions, cities, and communities, for instance reflected by the growing number of transnational municipal networks (Kern and Bulkeley 2009); and (3) outwards to civil society and non-state actors such as NGOs (Termeer et al. 2010). Multi-level governance thus particularly refers to the increased fragmentation of the nation-state and deals with the hori-
horizontal and vertical re-organisation of its functions (Hooghe and Marks 2003). The stimulation of interactions across the different tiers of governance and between various centres of authorities that are nested, quasi-autonomous and operating at multiple scales is emphasised by the term ‘polycentric institutions’ and is considered to offer added potentials to deal with complex multi-scale environmental problems (Galaz et al. 2012, Ostrom 2010, Roe 2009).

Not only has the state ceded power to other levels and actors, governments are also increasingly dependent on other actors for policy development. Hence, a second denominator of the abovementioned concepts is that in order to cope with the complexity of natural resource systems, institutional arrangements and related management systems need to establish multi-actor structures in which various actors from different parts of society (both public and private) are participating (Carlsson and Sandström 2007). This is because information and knowledge for natural resource management is dispersed among individuals and organisations in society, which is why it is difficult if not impossible for one or few people to have the range of knowledge required for it (Olsson et al. 2007). Hence, linking and involving a diversity of actors across a multitude of administrative and geographical levels is considered to be vital (Folke et al. 2005, Ostrom 2010). Cash et al. (2003) particularly emphasise the importance of linkages or interfaces between communities of experts (knowledge communities) and communities of decision makers (action communities). According to their findings, effective institutional systems that foster sustainability frequently consist of organisations or actors that play an intermediary, “boundary spanning” role between these science and policy arenas.

These considerations entail that the various stakeholders in multi-actor structures are interdependent and cannot carry out their decisions alone anymore – which is a key feature of networks. Networks can be described as a form of governance next to hierarchies and markets: While hierarchies are based on strong chains of command in a top-down manner, markets are self-organising and based on free transactions between actors. In contrast, networks are characterised by and rely on linkages between public and private actors, which can be both organisations and individual persons (Bäckstrand and Kronsell 2010 in Khan 2013). This dimension is stressed by the concept of network governance (Bogason and Musso 2006, Carlsson and Sandström 2007, Provan and Kenis 2008). One common form of this are public-private partnerships, which are based on the assumption that they facilitate the achievement of public policy objectives and represent an attractive alternative to full privatisation (Galaz et al. 2008). They increasingly gain importance in areas such as climate change and biodiversity conversation but also food security and nutrient governance, as the numerous examples of national Nutrient Platforms in the Netherlands, Belgium, Germany and on the European level show. Other organisational forms covered by network governance include stakeholder participation and informal personal relationships between individuals.

Network governance plays an increasingly important role on the urban level as well, such as in urban climate politics. In cities around the world, new forms of governance are tested that incorporate collaboration and partnerships with businesses and civil society actors. This can be attributed to the limited control of local governments over the implementation of mitigation and adaptation measures. Furthermore, they lack authority to enforce actors to comply with policies. It therefore becomes crucial to reach consensus among different local actors around climate policy goals so as to successfully implement them (Bulkeley and Betsill 2005, Khan 2013).
In this context, particularly the emerging research field of urban transition studies that explores the role of cities in transitions towards sustainable development highlights networks as a central form of governance. The idea of socio-technical niches that act as “protected” spaces for novel technologies embraces the small network of actors learning about new and novel technologies and their uses. Hence, “the constitution of networks and the expectations of a technology they present are important in the creation of niches” (Hodson et al. 2012: 794). Accordingly, Geels (2011) shows that urban sustainability transitions are typically a result of interactions between a diversity of local actors such as politicians, civil servants, business actors and user groups. The transitions occur owing to the different interacting motives and incentives of the involved actors, rather than being guided by a single purpose.

Establishing social networks of various actors that operate across multiple scales and are based upon a different logic than political-administrative hierarchy is thus an inherent idea of network governance. The role of social networks for natural resource governance has gained increasing importance throughout the last years (Bodin and Crona 2009, Bodin and Prell 2011b, Carlsson and Sandström 2007), which is the subject of the next chapter.

2.2 Social networks and natural resource governance

Contemporary science in the field of social-ecological systems suggests that network governance processes are often difficult to achieve in practice. To adequately address natural resource problems, it is thus critical to better understand how collaborative barriers can be overcome. As a response to this challenge, a social relational approach has been proposed that seeks to uncover how patterns of social relations among actors enable and constrain actors and processes (Bodin, Crona and Ernstson 2006, Bodin et al. 2011). This approach studies individuals and organisations not as social units that are independent from each other, but in the context of their relations with other social actors. Following the notion of ‘structural embeddedness’ (Granovetter 1985), it seeks to shed light on these relationships and on how the patterns and structure of these relationships affect attitudes, perspectives and behaviours towards outputs of natural resource governance (Bodin et al. 2011). With these conceptual aims, the approach emphasises the role of social networks for these outputs.

Recent research has identified the existence of social networks as a common and important factor for cases where various different actors have collaborated with each other and successfully solved natural resource problems and dilemmas (Bodin and Crona 2009). As shown by Scholz and Wang (2006 in ibid.), social networks can in some cases be even more important for effective enforcement and compliance with environmental regulations than the existence of formal institutions. Bodin and Crona (2009) identify four ways how social networks can improve collaborative governance processes – they can help (1) generate, acquire and disseminate various types of information and knowledge about the systems that are supposed to be governed, (2) mobilise and allocate key resources for effective governance, (3) actors to commit to common rules and thereby foster their willingness to engage in monitoring and sanctioning programmes, and (4) solve conflicts.

However, Carlsson and Sandström (2007) stress that not only the existence of networks matter for the outcome of natural resource governance. The performance of how well social networks can provide the mentioned ‘benefits’ also highly depends on the network structure, that is, the structural pattern of relations of a social network. This structure is conceived of as imposing both enhancing and inhibiting so-
social processes that underpin the outcome of natural resource governance, such as knowledge transfer, information sharing, consensus building and power relations. “The structure of relations among actors and the location of individual actors in the network have important behavioural, perceptual, and attitudinal consequences both for the individual units and for the system as a whole” (Knoke 1990 in ibid.: 39). It thereby emphasises the notion that the behaviour and knowledge of actors is not just dependent on themselves and their closest contacts, but also on the contacts of their contacts. Network structure thus represents an important independent variable that explains performance and outcomes of collaborative processes in natural resources governance. Hence, important insights about social relations can be unravelled by the structural qualities of networks. In other words, studying social networks is a way to “uncover the social fabric” of natural resource governance (Heinrup 2012).

This thesis builds on the above-described social relational approach and particularly on previous work done in the field of social networks and natural resource governance (Bodin and Crona 2009, Carlsson and Sandström 2007, Ernstson et al. 2010, Heinrup 2012, Luthe, Wyss and Schuckert 2012, Newig, Günther and Pahl-Wostl 2010, Prell, Reed and Hubacek 2011, Vignola, McDaniels and Scholz 2013). In applying this approach, I aim to identify how the relationships among individuals enable or constrain action towards recycling and reuse of phosphorus flows of Wageningen. This is assumed to also provide insights on how to engage the various stakeholders in the further governance process.

But what exactly are social networks and how can they be analysed in terms of their structure? These questions will be elucidated in the following section.

2.3 Social network concepts and Social Network Analysis (SNA)

Social networks consist of a set of actors – also referred to as ‘nodes’ – that are tied to each other through ‘edges’. Nodes can be individuals or organisations, whereas edges can represent exchanges of either tangible resources such as material and financial streams, or rather intangible resources such as information/knowledge flows and mutual trust. Social networking is therefore a matter of resource exchange, that is, “a series of interactions between two (or more) actors in which a transaction of resources takes place” (Lin 2001: 143 in Carlsson and Sandström 2007). Due to the mutual resource dependency, actors need to negotiate and adapt to the strategy of others – social networking activities are therefore often described as bargaining games. This also highlights that networks “can be regarded an outcome of purposive action taken by self-interested individuals [...] actions emanate from the urge to maintain or procure resources of various kinds; such as money, information, knowledge or legitimacy” (Carlsson and Sandström 2007: 38). Networks are further seen as a crucial source of individuals and organisation for knowledge acquisition and learning about innovations, opinions, perspectives of others, with knowledge being thought of as being embedded in and transmitted through social ties among and between actors (Hughes and Mutyala 2012).

Social networks can be represented in sociological graphs, so-called “socio-grams”. These graphs are graphical illustrations or network maps showing social relationships among individu-
als or organisations in a bounded group. In these network maps, each individual or organisation is represented by a node, and an edge (straight line, also called tie) represents the relationship that connects the two nodes (see Figure 1). The latter can however be illustrated if a relationship exists between two individuals or organisations. Furthermore, it is useful to describe social networks as being composed of “directed” ties, since most social processes involve (sequences of) directed actions or flows of resources (Hanneman and Riddle 2005). For instance, it might be the case that a certain individual or organisation only sends information or money to other stakeholders in a network, but does not receive any of these resources. Graphs that take the direction of ties into account are referred to as “directed graphs” and use the convention of connecting nodes with arrows that have arrow heads, indicating who is directing the tie toward whom (ibid.).

A well-developed method for investigating the relations within social networks that has emerged as a key technique in modern sociology is Social Network Analysis (SNA). SNA is a quantitative approach for empirically analysing and mapping social relations and structures, which originates from the fields of social anthropology and sociometry. The methods applied in SNA are used to identify “the role and influence of different stakeholders and categories of stakeholders according to their positions within [a] network” (Prell, Hubacek and Reed 2009: 501). The technique has been applied in a variety of scientific disciplines, reaching from studies into community power over global trade and international regime studies to health prevention and online communities (Holman 2008). Only recently, it has become popular in research on natural resource governance (Bodin and Prell 2011b).

The biggest strength of SNA lies in the way in which it shifts the focus from attributes of actors to relationships and flows and information, knowledge and other resources between them. In doing so, SNA allows to look inside the network and identify which stakeholders are well and which are poorly connected within the network, who is active in terms of communication, how strong the relations are, which actors are powerful, which linkages are missing and how information and resources are shared across the network (Hanneman and Riddle 2005, Wasserman and Faust 1994). Hence, SNA can complement the qualitative information on actors’ attributes, interests and perspectives acquired by means of stakeholder analyses, which has been criticised for overlooking the role communication networks can play in categorising and understanding stakeholder relationships (Prell et al. 2009). Or, as Salancik (1995: 345 in Holman 2008) puts it: “Network analysis corrects a tendency in organisational theory to focus on the trees rather than the forest, on the actions of individual organisations rather than on the organisation of their actions”.

Hence, several studies suggest that SNA can be useful in “understanding the characteristics of social networks that increase the likelihood of collective action and successful natural resource management” (Prell et al. 2008: 443). A better understanding of the social network of interest in a certain area also results in an advanced understanding of how stakeholders in that area can be supported so as to effectively tackle issues of natural resource governance.

SNA employs various algorithms from which a number of measures can be derived that analyse the network on different levels: Namely, the “macro” or “global” level that focuses on the overall structures

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7 Conversely, network graphs, which do not take the direction of the tie into account, are referred to as “undirected” graphs.
Conceptual framework

which the individual network members are embedded in and which seeks to describe the network population as a whole by the patterns of relations that constrain the opportunities of the individual stakeholders; the “meso” or “local” level that pays particular attention to the potential division of the network into sub-groups, which can be critical to understand how individuals, sub-groups and the network as a whole are likely to behave; the “micro” or “individual” level emphasises structural network features of individual members and thereby, for instance, aims to identify those who may have key positions within the network (Hanneman and Riddle 2005).

**Overall network structure**

A useful measure to analyse the overall structure of a network is its density. *Network Density* measures the number of existing ties in the network in relation to the total number of possible ties and is thus a common measure in SNA of how well connected a network is (Cheliotis 2010, Wasserman and Faust 1994). A density score of 1 means that 100% of all possible ties are realised in the network, a density of 0.5 that half of the ties are present, etc. The larger the network, the less likely it has a high density because of the rapid increase possible linkages (Hanneman and Riddle 2005). Density does however not say anything about the distribution of linkages among the network members. Two networks can have the same density but different degrees of interconnectedness (Heinrup 2012). As an addition to network density, *Degree Centralisation* can be applied to analyse to what extent only a few or even one node possesses all of the network ties. A centralisation score of 1 corresponds to complete centralisation, meaning that only one node holds all ties in the network (Wasserman and Faust 1994). In other words, the measure tells how “unequally well connected” the network actors are (Sandström and Carlsson 2008). Figure 2a and b illustrate two archetypical network typologies with a centralisation of 1 and 0, respectively.

![Network Illustrations](https://via.placeholder.com/150)

**Figure 2:** Illustration of (a) centralised "star" network, (b) decentralised "circle" network, and (c) bridging function. Network (a) has a centralisation value of 1, since node A has 5 connections while the others only have 1 tie each. Node A therefore has by far the highest *Degree Centrality* value. In contrast, network (b) has a centralisation value of 0 – all nodes have an equal number of links, which is why the network is completely decentralised. In network (c), node A has a high *Betweenness Centrality* (will be explained in more detail further below), since it lies on the shortest path between the members of the two sub-groups (consisting of nodes BGH and DEF, respectively). Node A therefore connects these otherwise disconnected sub-groups, i.e. every communication between members of these sub-groups goes via node A.  

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8 Network illustrations have been created with the Social Network Analysis software Gephi.
**Sub-groups and communities**

Figure 2c already hints to the possibility that social networks consist of various sub-groups. In SNA, there are various measures available to identify these sub-structures of a network.

The level of cohesion refers to the existence of sub-groups and how they are related to each other (Wasserman and Faust 1994). If a network has a high *structural cohesion*, it lacks clearly distinguishable sub-groups, which can have positive impacts on collaboration within the whole network. In case the network has a low cohesion, this capacity can be limited.

The *clustering coefficient* is a measure for the average probability that network members are part of a closed triplet or ‘clique’, which can be interpreted as a collaborative group (nodes BGH and DEF in Figure 2c form such cliques). The global clustering coefficient gives an overall indication of the degree to which nodes of a network tend to cluster together, while the local version indicates how single nodes are embedded within their ‘neighbourhood’. A high clustering coefficient increases the speed with which information spreads within the network (Luthe et al. 2012).

Another way to detect potential community structures of a network is the *modularity coefficient*. It is an algorithm that measures the degree to which a network is divided into modules or communities that have dense ties among its members but sparse connection to other actors.

But “regardless of how groups are defined and identified, the underlying assumption is that groups distinguish themselves from the rest of the network through their internal tie distribution, i.e. they make up more or less distinguishably islands in the relational landscape” (Bodin and Crona 2009: 368). If a network lacks connections between these groups, it is thought to have one or several *structural holes*, which are defined as the absence of connection within a network, or the presence of weaker connections. This can have negative effects on the diffusion of information between actors and between different sets of actors (Carlsson and Sandström 2007). Actors who are able to bridge such holes in the social structure, like node A in Figure 2c, are assumed to play key roles in a network and gain strategic advantages because they are able to access new and more diversified sets of resources.

**Key actors**

A measure to identify actors who occupy such bridging positions is *Betweenness Centrality*. It is determined by how often a certain node lies on the shortest path between two pairs of nodes, i.e. how often a person is the most direct route between two actors in the network. A node gets an especially high Betweenness value if it bridges weakly connected nodes in the network with well-connected ones. Hence, the Betweenness Centrality measure gives an indication of which actors are gatekeepers or mediators, who connect otherwise disconnected actors or groups of actors and without whom the network would thus fall apart. These ties are referred to as bridging or bonding ties (Bodin and Crona 2009).

*Degree Centrality* measures the number of direct connections a certain node possesses. It is a measure of an actor’s degree of connectedness, which can be used as a proxy for his or her communication activity. It thus gives an indication on which actors are central in terms of spreading information and influencing others in their immediate surroundings. It is thus also used as an indicator for influence and prominence within the network (Bodin and Crona 2009, Cheliotis 2010, Hanneman and Riddle 2005).
Hence, Degree and Betweenness Centrality can be utilised to detect potentially influential and powerful key actors in a network. Having many contacts and being the broker between many actors implies occupying a favourable structural position in the network (Bodin and Crona 2009). Actors with high Betweenness Centrality values are able to control the flow of resources such as information and money by either blocking or enabling the links between other network members. Furthermore, central actors access more resources by being connected to many actors. The more heterogeneous these actors are, the more diverse these resources are (Carlsson and Sandström 2007, Heinrup 2012). With regard to natural resource governance, it is assumed that the more central an actor is, the better he or she is integrated in the network and is thus able to influence the governance process (Lienert, Schnetzer and Ingold 2013). However, Castells (2009) points out that the function of any actor within a network, including the central ones, still depends on the programmes and purpose of the network and on the actors’ interaction with others in the network. This makes clear that the centrality of actors – just like the structure of the network as a whole – is subject to dynamic change over time. An actor that occupies a favourable position in a governance network at a certain time of the governance process might play a peripheral role once the network’s programme and purpose change.
3. Research design and methodology

When selecting a research design, it is crucial to choose an approach that both fits the research questions and is practical in the specific research setting (Maxwell (1996) in Keim (2011)). At the centre of this thesis lies the question of how the structure of the governance network relevant in terms of phosphorus affects the opportunities for phosphorus recycling and recovery in Wageningen. This required quantitative research methods that allowed me to collect comparable social network data in a standardised way. Next to this, investigating the particular role of the Municipality of Wageningen in terms of phosphorus recycling and reuse and exploring its interests, drivers, capacities and obstacles called for a more open and explorative, that is, qualitative research approach that enabled me to explore these perspectives about which little is known so far. Qualitative research methods would further allow me to consider the subjective perspective of the actors involved (Flick 2006).

Based on these considerations, I chose a mixed- or multi-methods research design in which both quantitative and qualitative methods of data collection are employed (Bryman n.d.). Recognising that different methods have their own strengths and weaknesses, they were combined to complement each other and provide different ways of framing the research questions and of analysing the results (Sloane and O’Reilly 2012). Morgan (1998 in Bryman (n.d.)) develops a classification of multi-method research based on two principles: “whether the quantitative or the qualitative research method is the main approach to gathering data, and which research method preceded the other” (ibid.: 6). Following this pair of distinction he distinguishes four types of multi-methods studies\(^9\) (underlining indicates the principal method):

- **Qual. → Quant.**: An example is when a researcher conducts qualitative interviews so as to develop hypotheses that are subsequently tested by a quantitative approach.
- **Quant. → Qual.**: An illustration would be when a survey is conducted and certain individuals are selected based on the outcomes of this survey for further, more intensive research using a qualitative approach.
- **Quant. → Qual.**: An example would be that a quantitative survey study is followed by a qualitative approach in order to illuminate some of the factors that may be responsible for certain outcomes of the survey.
- **Qual. → Quant.**: This could be a study in which an interesting relationship between variables is identified by means of an ethnographic study and is then tested on external validity (outside of the specific case) conducting a survey.

The social network perspective is the core contribution of this thesis, which is why the quantitative methods were the principal approach to gathering data. Prior to that, the qualitative method (in-depth interviews) was employed so as to gather an overview of the topic and to grasp the different perspectives of the various actors (see section 3.1.3 for a more detailed discussion). Furthermore, the interviews were used as a snowball sampling tool and were therefore inherently linked to the quantitative approach. The research design employed in this study therefore comes closest to the first type outlined above (Qual. → Quant.).

\(^9\) qual → quant; quant → qual; quant → qual; qual → quant (underlining indicates the principal method); for a more thorough description see Bryman (n.d.)
In this chapter, I first elucidate the methods of data collection, including the key stages essential to a SNA (3.1.1 and 3.1.2) and the conduction of in-depth interviews (3.1.3). In the subsequent chapter, the strategy of data preparation and analysis (3.2) are introduced.

### 3.1 Methods of data collection

In the following, the methods of data collection employed in this thesis are explicated in detail as well as the difficulties and challenges that were encountered while conducting them. The first section describes how the boundaries for the network analysis were specified. In the second chapter, I introduce the network survey that was conducted in order to gather relational data. Finally, the use of in-depth interviews is explained.

#### 3.1.1 Defining the network boundaries

In order to answer research question 1 (Which stakeholders are part of the governance network relevant for phosphorus recycling and reuse in Wageningen?), a first step was to define the boundary of the governance network. In other words, I had to make a decision on who will be considered part of the network and who not.

Defining the network boundary is one of the key stages in any empirical network research (Sloane and O’Reilly 2012). Laumann, Marsden and Prensky (1983) distinguish between two major approaches used to set network boundaries: the *nominalist* approach in which network closure is imposed by the researcher’s conceptual framework; as well as the *realist* approach in which the investigator adopts the boundaries experienced by the actors composing the network – in other words, the actors set the boundaries themselves. For instance, a study would employ a nominalist approach if data was gathered from all users of and all other stakeholders regarding phosphorus within a given geographic area. In contrast, a study that applied snowball sampling to gather network data would be realist. I followed an approach applied by Sloane and O’Reilly (2012), in which I combined the use of an initial list of stakeholders with a snowball sampling process (which will be explained in detail below). Although this approach only yields a sample of the whole network of stakeholders relevant within the context of this study, it proved feasible given the resources available within the scope of this thesis. Furthermore, this method was more suitable considering that there is no formal network in the case of phosphorus recycling and recovery in Wageningen, but where particularly members of an informal network needed to be identified (Sandström 2011). As Sloane and O’Reilly (2012, p.625) point out, the approach also “combines aspects of the ‘outside view’ given by a nominalist boundary specification with the ‘inside view’ given by a realist one”.

*Criteria for selecting actors/stakeholders*

For the purpose of this thesis, stakeholders were distinguished from actors in the following way as suggested by Cordell (2010: 43): “Actors are conceptual entities defined by certain roles in which they act within a system. […] For example actors can act as beneficiaries, victims, customers, owners, guardians or observers. Stakeholders are defined as specific real-world groups, organizations or significant individuals, within a conceptual actor category. Stakeholders directly or indirectly influence (or are influenced by) the situation or phenomena under investigation.” This includes those who potentially affect or are affected by the situation or phenomena as well as voluntary and involuntary influences. Based on this definition, an actor in the case of phosphorus recycling may be a wastewater treatment company (de-
fined by the act of processing wastewater), while a specific stakeholder within this actor category is the Water Board Vallei and Veluwe. As I expected the network to be rather small (given the focus on Wageningen), I wanted to consider individual persons in the network analysis (instead of organisation) to get a fine-grained picture of the governance network (the usefulness of this approach will be discussed in chapter 6.2). In this thesis report, I therefore use the terms ‘stakeholders’ and ‘individuals’ exchangeably. For a discussion on the relation between individuals and organisations the extent to which individuals can freely decide to deal with P recycling and reuse, see chapter 6.2.

First, an initial list of relevant actor groups was created with the help of literature as well as two Wageningen-based researchers with expertise in the field of phosphorus recycling and reuse (INT. SQ, 2013; INT. PRI, 2013). To search for appropriate individuals that represent stakeholders within the identified actor groups, criteria-based purposive sampling was applied (Prell et al. 2011). The individuals ought to meet the following criteria:

- Their decisions have a direct influence on phosphorus flows of Wageningen or
- They advocate for and have primary information/expertise on phosphorus recycling and reuse and are based in Wageningen or
- They are named at least three times by other persons in the network during the snowball sampling as being relevant for P recycling and reuse in Wageningen

**Literature review and snowball sampling**

Based on these criteria, relevant stakeholders were then identified through two parallel and complementary processes (Vignola et al. 2013). First, I reviewed relevant policy documents, reports, studies as well as minutes of meetings. Here, I looked for stakeholders either actively engaged in and advocating for phosphorus recycling and reuse or holding responsibilities in areas relevant to it, such as wastewater treatment or waste management.

Second, this list was complemented by names gathered through a “snowball sampling” or “chain referral” approach. This is a technique in which a set of selected individuals are asked to name other people of whom they think are relevant for the purpose of the study. The new stakeholders named are then also contacted and again asked for new names. This procedure is repeated until no new names come up or one decides to stop (for reasons of time and resources or because the additional stakeholders being named are marginal to the studied group). Snowball sampling can be particularly useful for tracking down ‘special’ populations, that is, small sub-sets of people that are embedded in large numbers of other actors. A typical example for such a special population are business contact networks (Hanneman and Riddle 2005). Parts of the network of interest for this thesis were assumed to essentially represent such networks – professionals who are linked together through their common interest in the ‘business’ of phosphorus recycling and reuse.

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10 For the case of phosphorus, Cordell et al. (2011) lists the following actors as being relevant: phosphate mining companies, fertilizer manufacturers and distributors, agri-business sector, farmers, food producers, distributors and retailers, dieticians and nutritionists, consumers/householders, water and sanitation service providers, environmental managers, policy-makers and entrepreneurs. Lommen (2010) identifies the following actors for the case of phosphate recovery and reuse in the Netherlands: Governments (European, national, provincial, and local level), research institutes, advisories, supply industry, institutions that could potentially recover phosphate, potential phosphate users, network organisations, and others.
However, since stakeholders who are connected to each tend to recommend each other back and forth (Heinrup 2012), the snowball sampling method tends to overstate the “connectedness” and “solidarity” of groups of people (Hanneman and Riddle 2005). It thus carries the risk of missing out sub-sets of stakeholders who are connected to each other but not to the starting point of the snowball sampling procedure. This was especially relevant in case of phosphorus management, since the sector was assumed to be rather disconnected. Hence, one important question to answer was where to start “rolling the snowball”. In order to avoid this pitfall, the snowball sampling was initiated at nine different starting points, within seven different organisations representing six different actor categories (Table 1).

**Table 1: Initial contacts for the snowball sampling method.**

<table>
<thead>
<tr>
<th>Actor category</th>
<th>Organisation</th>
<th>Contact person</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local government</td>
<td>Wageningen municipality</td>
<td>Alderman for climate, economy, finance and culture</td>
</tr>
<tr>
<td>Wastewater treatment sector</td>
<td>Water board Vallei and Veluwe</td>
<td>Strategic adviser</td>
</tr>
<tr>
<td>Waste management sector</td>
<td>ACV groep</td>
<td>Director</td>
</tr>
<tr>
<td></td>
<td>Van Gansewinkel</td>
<td>Project Manager Business Development</td>
</tr>
<tr>
<td>Animal feed producer</td>
<td>AgruniekRijnvallei BV</td>
<td>Nutritionist</td>
</tr>
<tr>
<td>Networks &amp; partnerships</td>
<td>Nutrient Platform</td>
<td>Secretary</td>
</tr>
<tr>
<td>Research institutions</td>
<td>Wageningen University (3)</td>
<td>Professor as well as project leader at Environmental Technology department; Researcher at Soil Quality department</td>
</tr>
<tr>
<td></td>
<td>Plant Research International</td>
<td>Senior researcher in Agrosystems Research</td>
</tr>
</tbody>
</table>

In total, 63 individuals were named during the entire snowball sampling process from October until December 2013. A wave-system was used to keep track of who named who (see Table 2). That is, the process was carried out in five waves, with the initial contacts making up the first “wave”. The contacts they named made up the second wave, and so on (cf. Heinrup 2012). Of the 63 individuals, 51 match the criteria outlined above. Of these 51 persons, 44 were contacted and asked to mention other people they considered being relevant and having a stake in the context of phosphorus recycling and reuse in Wageningen – the rest (seven individuals) was mentioned too late so that I could not ask them for further contacts anymore.\(^{12}\) 11 people were asked for relevant contacts during semi-structured interviews (see section 3.1.3). Another 30 were first contacted via email – if they had not responded to the email request within one week, they were sent a reminder or were telephoned. Eventually, 16 of these people

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\(^{11}\) Although in the Netherlands the water boards are formally regional government bodies, they are here counted as a separate sector.

\(^{12}\) Nonetheless, six of these seven persons are PhD students or Post-Docs employed at two Wageningen University chair groups that are already represented in the eventually analysed network.
responded and provided contacts. Four persons also provided further contact by means of the name generator integrated in the network survey (see section 3.1.2).

When contacted, four people did not consider themselves being relevant for phosphorus recycling and reuse in Wageningen and/or recommended another person instead. Hence, 40 people were eventually included in the network analysis.

Table 2: The snowball sampling procedure, showing the number of names gathered in each wave. Note that the names were collected via email, through interviews and by means of a name generator integrated in the network survey, with some respondents only responding after a couple of weeks – the waves do thus not reflect a chronological order of the collection procedure. The difference between the numbers of new names per wave and those asked for new names in wave 3 and 4 derives from the fact that not all new stakeholders were matching the criteria (and were thus declared irrelevant for this study) or did not regard themselves as relevant.

<table>
<thead>
<tr>
<th>Wave</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of names per wave</td>
<td>10*</td>
<td>17</td>
<td>37</td>
<td>19</td>
<td>5</td>
</tr>
<tr>
<td>Number of new names per wave</td>
<td>10* → 15 → 28 → 10 → 0 → STOP</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asked for new names</td>
<td>10</td>
<td>15</td>
<td>12</td>
<td>7</td>
<td>-</td>
</tr>
</tbody>
</table>

* Initial contacts for snowball sampling, see Table 1.

The persons I contacted in the fourth wave recommended only five names, of which all were already mentioned in earlier waves. I therefore concluded that the population of interest had been targeted.

3.1.2 Network survey

In order to gather relational data, an online survey on the survey platform SurveyMonkey® was created that contained a list of 43 persons<sup>13</sup>. The survey was informed by approaches, concepts and questions of previous literature (Borgatti 2010, Hanneman and Riddle 2005, Vignola et al. 2013, Borgatti et al. 2009) and was pre-tested to check and ensure its usefulness for the research questions.

Specifically, the respondents were asked to indicate their relations to the listed stakeholders based on the following five questions:

- Please check the corresponding box beside those stakeholders from which you receive information relevant in the field of phosphorus recycling and reuse.
- Please check the corresponding box beside those stakeholders to which you provide information relevant in the field of phosphorus recycling and reuse.

<sup>13</sup> Three of them were eventually removed since I realised that they either did not meet the criteria or they notified that they do not consider themselves relevant for this study.
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- On a scale from one to four please rate how influential you perceive each of the stakeholders in the list to be in terms of phosphorus recycling and reuse (where 1 is very low influence and 4 is very high influence).\(^{14}\)
- On a scale from one to four please rate how knowledgeable you perceive each of the stakeholders in the list to be in terms of phosphorus recycling and reuse (where 1 is very low expertise and 4 is very high expertise).
- Please check the corresponding box beside those individuals with whom you would like to collaborate and exchange information in the field of phosphorus recycling and reuse in the future.\(^{15}\)

Next to the provided list of stakeholders, the respondents were given the chance to add other names they regarded as relevant in terms of phosphorus recycling and reuse in Wageningen in every question and indicate their relation to them (for a detailed overview of the survey see Appendix 2).

Those who had not replied to the survey within ten days were sent a reminder.

After a first review of the results I realised that the first two survey questions regarding information exchange were differently interpreted by the respondents. Some respondents indicated to exchange information with certain other network members if it was merely indirect, for instance by reading reports of those others, without actually having ever been in personal contact with these people. In contrast, I intended to target only at direct information exchange via email, telephone, meetings, etc. Based on this, I concluded that it would provide a more nuanced picture of the network if I would know the intensity of the interaction between network members. I therefore phoned and emailed all the survey respondents again and asked them to specify their connections to the stated contacts according to the following ranking:

- ‘1’ corresponds to infrequent information exchange, e.g. via email
- ‘2’ corresponds to informal contact, i.e. talking to each other on networking events, company visits, occasional telephone contact
- ‘3’ corresponds to collaboration on a regular basis, e.g. in joint projects

I told the respondents that I would use this ranking as a proxy for the intensity of the interaction between network members.

3.1.3 In-depth interviews

In-depth interviews “is a qualitative research technique that involves conducting intensive individual interviews with a small number of respondents to explore their perspectives on a particular idea, program, or situation” (Boyce and Neale 2006, p.3). Although they are one of the most common qualitative research methods (Mack et al. 2005, Mayring 2002), there are some limitations and pitfalls associated to interviews such as time intensity, proneness for bias because of respondents’ stake in the phenomenon under study and non-generalizability of the results due to the small sample-size. In spite of that, in-

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\(^{14}\) Influence was explained to refer to the stakeholder’s opinion about the ability of the other stakeholders to affect one’s own organization. Examples included the ability to take overarching decisions (e.g. in terms of policy and regulations), being an important stakeholder in the sector, dissemination of information and knowledge.

\(^{15}\) The respondents were asked to only tick the box if they were willing to actively engage and invest time and resources in the information exchange/collaboration.
depth interviews were chosen as a research method because they use an open-ended, discovery-oriented process and allow for probing and discussion of issues and perspectives. Further, in-depth interviews get at an interpretive perspective, that is, they are aimed to elicit connections, relationships and contradictions the interviewee sees between particular events, phenomena and developments (Mack et al. 2005). This enables the researcher to gather rich background information and insights in a short period of time and is particularly useful when the studied subject is complex, ill-defined and ‘messy’ as is the case with the phosphorus situation (Cordell 2010, Guion, Diehl and McDonald 2011, Lommen 2010).

As described in section 3.1.1, the names for the network study were partly gathered during interviews with stakeholders. In this sense, these interviews were an inherent part of the snowball sampling process and used to generate new names for the social network analysis. More importantly, however, they served as a method to elicit a more in-depth, nuanced and dynamic picture of stakeholder’s perspectives, drivers, interests, challenges and obstacles regarding phosphorus recycling and reuse. This qualitative data was intended to complement the survey data, which only provides a snapshot of the stakeholder network at the time of the survey and is thus very static. As such, it lacks a dynamic dimension, since it does not provide any information of the network’s ability to foster phosphorus recycling and reuse in the future. The interviews were thus primarily aimed to gather information that would help me to interpret and better understand the complex reality around phosphorus recycling and reuse issues and the implications of the quantitative SNA data (Mack et al. 2005).

In-depth interviews are usually conducted with the help of interview guidelines. Guideline-based interviews are also called semi-structured interviews (Flick 2006, Guion et al. 2011). The interview guideline comprises a set of pivotal questions setting the frame of the interview (plus a number of sub-questions) and is supposed to ensure that major subjects are addressed during the interview so as to make the findings comparable. At the same time, the semi-structured design facilitates ad-hoc questions and responses in case the interviewee touches upon an interesting topic. Questions are often answered before they are deliberately addressed by the interviewer. What matters is that the guideline and its questions are not strictly worked off in a specified order, but that the interview resembles a natural conversation (Meuser and Nagel 1991).

Selection of interview partners
The interviewees were identified as part of the snowball sampling process and selected so as to cover a diversity of perspectives regarding phosphorus recycling and reuse. The interviewees represented the following social actors:

- Local government (1)
- Network of local governments and water board (1)
- National government (1)
- Wastewater treatment sector (1)
- Organic waste management (1)
- Sludge processing (1)
- Animal feed producer (1)
- Network organisation (1)
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- Research institutions (3)

Preparation of the interview guideline
For the above reason, the interview guideline took the form of an extended topic list, addressing the following broad topics: the importance of phosphorus and nutrients (and their recycling and reuse) within the activities of the interviewee’s organisation; the (potential) role of cities and local/regional governance arrangements regarding phosphorus recycling and reuse; actors and stakeholders that are relevant for phosphorus recycling and reuse in cities in general and in Wageningen specifically; drivers and motivations as well as barriers and obstacles for the interviewee’s organisation to (not) deal with this topic; the potentials for a match of supply and demand of recycled and recovered phosphorus. For an example of such a topic list, see Appendix 3.

Before conducting the interviews, the interview guideline was adapted to the specific profile and topics relevant for the respective institution or interview partner. In other words, although similar questions were used in most of the interviews to ensure better comparability, every interview had an emphasis on different issues (Mayring 2002). Furthermore, during the field research the interview guideline was – in the tradition of an iterative research process – slightly modified according to knowledge gained in previous interviews.

Conduction of interviews
All in all, I conducted 11 interviews, of which 9 were conducted together with my thesis colleague Alison Jenkins and 2 alone. Seven interviews took place in the working environment of the interviewees and 4 were held via telephone. The interviews lasted between 30 minutes and two hours.

Challenges and difficulties
A challenge faced was the fact that the interviews were conducted in a foreign country and foreign language, meaning that the entire research environment was foreign to me. These aspects can affect the received answers and the way I comprehended them. In a few cases – especially when the interviewees used rather technical vocabulary – this caused misconceptions, leading to the fact that a further thematic elaboration which would have been interesting regarding the research question did not take place. However, in the case of the interviews that were conducted together with my Dutch thesis colleague, those misunderstandings could at least afterwards be sorted out.

3.2 Data preparation and analysis

3.2.1 Quantitative social network data
The response rate of the network survey was 82.5% (n=33). Among the people that I had interviewed before, the participation rate was 100%; for non-interviewed persons it was 68.2%. This shows that those people I had personal contact with before and who had thus received a more thorough explanation of my study were more willing to respond to the survey. Of the 33 respondents, 31 responded to my additional request and provided data on the strength of interaction with other network members.

The relational data gathered with the survey was transferred into a symmetrical matrix (i.e. adjacency matrix) with 40 rows and 40 columns – in other words, each respondent filled up one row and one column. The data was first converted into binary data (Yes=1 and No=0) and then assigned to the respec-
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tive cells in the adjacency matrix (Hanneman and Riddle (2005); see Table 3 for an example). I then confirmed the interaction by checking whether a stated outward or inward information flow is confirmed as an inward or outward information flow by the receiver or sender. In 36 cases, this was not the case. After I received the additional data on the strength of interaction between network members, the data was transformed into ordinary data (1, 2, 3).

Table 3: Example of a 3x3 adjacency matrix with ordinary coded relational data.\(^\text{16}\)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Henk de Vries, Org. X</td>
<td>-</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Jan Janssen, Org. Y</td>
<td>3</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>Ella Molenveld, Org. Z</td>
<td>1</td>
<td>2</td>
<td>-</td>
</tr>
</tbody>
</table>

To analyse and visualise the data, I used Gephi and UCINET, two commonly used open source software programmes for analysing and visualising network graphs. I applied network algorithms for structural analysis of network features such as density, modularity, as well as Betweenness Centrality. To extend the analysis, I calculated the mean perceived influence ($P_i$) and perceived expertise ($P_e$) regarding P recycling and reuse in Wageningen attributed to each stakeholder by the others in the network. Next to this, I calculated a simple indicator for each network member that measures the number of other individuals in the network who are interested in future collaborations with that person (COLL). I also developed a new indicator to measure the degree to which a node $n_i$ bridges action and knowledge communities: the Community Heterogeneity Index (CHI). It is defined as:

\[
CHI_i = \frac{\sum_{t}^{n} t_i OthComm}{\sum t}
\]

where $t_i OthComm$ measures the number of ties to the other community (action and knowledge community, respectively), expressed in the index as a proportion of the total number of ties in the network.

3.2.2 Qualitative data

During the interviews, notes were taken which afterwards served as a basis for a comprehensive minute of the interviews. In these minutes, single bullet-points that addressed the same subject but were stated in different moments during the interview were headlined and summarised content-wisely. The minutes were then sent to the interviewees, who were asked to either confirm the correctness of the information and statements or to add/correct information where necessary. When all interviews were conducted, a thematic comparison was conducted in which headlines and central statements of the various interviews were compared and same topics were combined (cf. Meuser and Nagel (1991)\(^\text{17}\)). This last step was aimed to highlight certain statements or topics that were disregarded in the first step in order to put them into their larger context.

\(^{16}\) The names in the matrix are fictive.

\(^{17}\) This process was inspired by the systematics for evaluating semi-structured interviews suggested by (Meuser and Nagel 1991). It comprises the following six elements: 1. Transcription; 2. Paraphrase; 3. Headlines; 4. Thematic comparison; 5. Sociological conceptualization (empirical generalization) as well as 6. Theoretical generalization.
4. Introducing the case: Wageningen

Wageningen is a small town in the province of Gelderland, the Netherlands, covering an area of 32.36 km². In 2012, it counted 37,049 inhabitants with a population density of 1,215 inhabitants per km² (CBS, 2012). Wageningen experiences population growth, as the population has grown to 37,407 inhabitants per January 2013 (Gemeente Wageningen, 2013a). In 2012, around 44 % of the inhabitants were younger than 30 as a large part of the population consists of students from national and international backgrounds (CBS, 2012). Studies conducted by the Central Bureau of Statistics in 2008, showed that household incomes in Wageningen are fairly similar to, or slightly above, general Dutch statistics, which makes Wageningen representative of the average Dutch city (CBS, 2011). Due to its relatively small size and the associated low level of complexity concerning phosphorus flows, it represents a suitable and comprehensible case study for analysis.

Although Wageningen until in the twentieth century was known for its brickworks and cigar industry (Gemeente Wageningen 2013b), it is currently an important part of 'Regio FoodValley' and considered a knowledge hub on food, health and life sciences (Regio FoodValley, 2013a). This development was kick-started in 1876, when a school for agriculture was built, that attracted knowledge and people. The school of agriculture grew into what is now known as Wageningen University – an internationally acclaimed higher education institution with a focus on food, agriculture and life sciences (Gemeente Wageningen, 2013b, Wageningen UR, 2013). Together with associated research institutes such as Alterra and IMARES, Wageningen University and Research Center (WUR) is formed (Wageningen UR, 2013). In addition to WUR, Hogeschool Van Hall Larenstein - another higher education institution focusing on similar topics – is also located in Wageningen. Furthermore, headquarters of Food Valley NL are also based in Wageningen. Food Valley NL is an overarching organisation that aims to stimulate innovation in the agrifood sector by bringing business together with academic research and governmental institutions (Food Valley NL, 2013). This unique context allows the municipality to profile itself as city of life sciences (Gemeente Wageningen, 2013c).

In addition to being a hub of academic knowledge, Wageningen is positioned in an agricultural setting and closely located to municipalities that are involved in food production, consumption and innovation. The municipality of Barneveld specialises in intensive livestock industry and is known worldwide for its expertise and innovation on poultry farming, egg-sorting machines and meat processing. Nijkerk has many agrifood business, such as Arla Foods, a company that specialises in the production of dairy products. The municipality of Ede is more similar to Wageningen, as it has an emphasis on building knowledge. The focus is not on academic research, but instead providing young people with practical knowledge. Moreover, an important international research institute on food, the NIZO Food Research, is also based here (Regio FoodValley, 2013a).

Due to this local context and focus, Regio FoodValley was established. This is a collaboration between eight municipalities, namely: Wageningen, Ede, Barneveld, Nijkerk, Renswoude, Rhenen, Scherpenzeel en Veenendaal (Figure 3).

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18 In 2012, the total amount of students was around 7,700 of which 5,330 live in Wageningen (Apollo, 2012)
Introducing the case: Wageningen

Figure 3: The boundaries of Regio FoodValley (Regiokaart modified from Regio FoodValley, 2013a)

The aim of Regio FoodValley is to further strengthen, facilitate and stimulate the region’s strategic position concerning food related knowledge and innovation by actively inviting new talent and businesses to settle in the region. As its vision for the region, Regio FoodValley focusses on providing a facilitating role for companies, accommodate between required labour and education, improve mobility and accessibility to the region, innovation in the agricultural sector and enhance quality of the living environment (Regio FoodValley, 2013b, Regio FoodValley, 2013c).

The close vicinity of Wageningen to agricultural areas and its tight connection to a region that is focused on food and agriculture is expected to pose many opportunities for Wageningen to develop potential linkages for the recycling and reuse of phosphorus.
5. Results

In this chapter, I will present results from the online survey and the quantitative analysis of the network data. Besides this data that forms the basis for the SNA, qualitative information collected by means of in-depth interviews and literature review will also inform the data analysis. First, I will explain which stakeholders are part of the governance network relevant for phosphorus recycling and reuse in Wageningen, elaborating on their roles and competences and how they are involved in the governance network (research question 1; section 5.1). Second, the network will be analysed in terms of its structural properties from a global, local and individual perspective and the results regarding perceived influence and expertise of the network members will be presented (research question 2 and 3; section 5.2). Third, I will analyse the role of the municipality of Wageningen with regard to phosphorus recycling and reuse in Wageningen (research question 4; section 5.3).  

5.1 Who is in the network? – Description of the stakeholders

The network analysed for this study consists of 40 individuals, who represent 18 organisations from various sectors (or actor categories) such as local government, research & knowledge institutions, wastewater treatment and animal feed producers. An exhaustive list of all stakeholder organisations and the distribution of network members between these can be found in Table 4.

Following the approach of Cash et al. (2003), the organisations listed in Table 4 can be assigned to either knowledge or action communities (see chapter 2.1). In the case of phosphorus recycling and reuse, knowledge communities consist of organisations that produce scientific and regulatory information, while those in the action communities are more closely linked to decisions that directly affect the flow and (re)use of phosphorus (cf. Vignola et al. 2013). In total, 63% and 37% of the stakeholders in the P network can be assigned to the knowledge community and action community, respectively.

Table 4: List of organisations represented in the network, showing the distribution of people between them, the corresponding actor categories as well as the community they belong to.

<table>
<thead>
<tr>
<th>Sector (Actor category)</th>
<th>Organisation</th>
<th>Label</th>
<th>No. of people</th>
<th>Community</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local government</td>
<td>Municipality of Wageningen</td>
<td>MUN</td>
<td>3</td>
<td>Action</td>
</tr>
<tr>
<td>National government</td>
<td>Ministry of Infrastructure and Environment</td>
<td>IM</td>
<td>1</td>
<td>Action</td>
</tr>
<tr>
<td>Wastewater treatment&lt;sup&gt;20&lt;/sup&gt;</td>
<td>Water Board Vallei and Veluwe</td>
<td>WB</td>
<td>5</td>
<td>Action</td>
</tr>
<tr>
<td>Research institutions</td>
<td>WUR Sub-Department of Environmental Technology</td>
<td>ETE</td>
<td>3</td>
<td>Knowledge</td>
</tr>
<tr>
<td></td>
<td>WUR Department of Soil Quality</td>
<td>SQ</td>
<td>1</td>
<td>Knowledge</td>
</tr>
<tr>
<td></td>
<td>WUR Alterra</td>
<td>ALT</td>
<td>7</td>
<td>Knowledge</td>
</tr>
</tbody>
</table>

<sup>20</sup> Although in the Netherlands the water boards are formally regional government bodies, they are here counted as a separate sector.

Sub-research question 5 will be discussed in chapter 6.1.
<table>
<thead>
<tr>
<th>Networks / Partnerships</th>
<th>WUR Plant Research International</th>
<th>PRI</th>
<th>2</th>
<th>Knowledge</th>
</tr>
</thead>
<tbody>
<tr>
<td>STOWA</td>
<td>STOWA</td>
<td>STO</td>
<td>3</td>
<td>Knowledge</td>
</tr>
<tr>
<td>Lettinga Associate Foundation</td>
<td>LEAF</td>
<td>LEAF</td>
<td>2^{21}</td>
<td>Knowledge</td>
</tr>
<tr>
<td>Nutrient Management Institute</td>
<td>NMI</td>
<td>NMI</td>
<td>3</td>
<td>Knowledge</td>
</tr>
<tr>
<td>Dutch Institute of Ecology</td>
<td>NIOO</td>
<td>NIOO</td>
<td>2</td>
<td>Knowledge</td>
</tr>
<tr>
<td>Sludge processing</td>
<td>GMB BioEnergie</td>
<td>GMB</td>
<td>1</td>
<td>Action/Knowl.</td>
</tr>
<tr>
<td>Waste management</td>
<td>Twence</td>
<td>TWE</td>
<td>1</td>
<td>Action</td>
</tr>
<tr>
<td>Waste collection</td>
<td>ACV groep</td>
<td>ACV</td>
<td>1</td>
<td>Action</td>
</tr>
<tr>
<td></td>
<td>Van Gansewinkel</td>
<td>VGW</td>
<td>1</td>
<td>Action</td>
</tr>
<tr>
<td>Animal feed production</td>
<td>AgruniekRijnvallei</td>
<td>AGR</td>
<td>1</td>
<td>Action</td>
</tr>
<tr>
<td>Advisories</td>
<td>TOP B.V.</td>
<td>TOP</td>
<td>1</td>
<td>Knowledge</td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

**Research institutions**

A large group of individuals in the network (n=23) is made up of researchers, working for 9 different research institutions. With 7 representatives, especially Alterra of Wageningen UR is highly represented in the network. During the snowball sampling, the employees referred to each other back and forth, which is why the institute might be slightly overrepresented in the network. Their actual involvement in phosphorus recycling and reuse issues varies considerably, particularly regarding issues of urban P flows. While most of the employees deal with P management mainly from an agricultural point of view, some of the scientists are or were part of the Scientific Committee of the Manure Act (Commissie van Deskundigen Meststoffenwet, CDM), which consults the Dutch Ministry of Economic Affairs, Agriculture & Innovation on issues such as whether new fertiliser products (such as struvite recovered from wastewater) may be sold as fertilisers in the Netherlands (cf. Lommen 2010). Others have been initiating projects on urban phosphorus cycling in the Netherlands (for more information, see Reinhard et al. 2013) and have published on phosphorus fertilisers from by-products and waste (e.g. Oenema et al. 2012).

The department of Soil Quality of Wageningen University addresses different aspects of phosphorus management, also mainly from an agricultural and soil sciences perspective. The research of the employee represented in the network focuses on phosphorus flows in the Netherlands and Europe and options for closing the P loop in agriculture. He has been closely involved in the organisation of the first European Sustainable Phosphorus Conference (ESPC) that took place in 2013 in Brussels and is an active participant in the phosphorus recycling and reuse community. Additionally, he has been involved in the development of the European Phosphorus Cycle Working Group (EPCWG), which aims to promote sustainable phosphorus management practices across Europe.

21 The two LeAF employees are actually also affiliated with the sub-department of Environmental Technology, and two of the ETE employees are at the same time employees of LeAF. However, during the snowball sampling process they were mentioned by others as employees of LeAF and ETE, respectively, which is why they have been assigned to the respective organisation here.
member of the Dutch Nutrient Platform (see under sub-headline ‘Networks & partnerships’), where he has recently proposed to establish a working group on local/regional phosphorus cycling.

*Plant Research International* of Wageningen UR is represented in the network by two employees. They focus on nutrient cycles in agricultural systems (P recycling from manure, manure policies, etc.), but have also mapped the phosphorus flows in the Netherlands through agriculture, industry and households (Smit et al. 2010). Furthermore, one of them has co-founded the Dutch Nutrient Platform.

The sub-department *Environmental Technology* of Wageningen University has worked extensively on anaerobic digestion and nutrient recovery from wastewater. Employees have been involved in the Decentralised Sanitation and Reuse (DeSaH\(^\text{22}\)) demonstration project Sneek I, in which a new collection of wastewater is tested. Moreover, they also published on phosphorus fertilisers from wastewater. One employee is also part of the working group New Sanitation of STOWA (see below).

*Lettinga Associates Foundation* (*LeAF*) is a research and consultancy organisation in the field of, among others, wastewater treatment and purification as well as recovery and reuse of nutrients from wastewater. It is a spin-off of and located at the sub-department Environmental Technology of Wageningen UR. LeAF was also involved in a project conducted by a consortium of Wageningen UR institutes that explored potentials and solutions for closing the loop on, among others, phosphorus in the metropolitan area of Amsterdam. The study was commissioned by the Municipality of Amsterdam and focuses on the potential measures the municipality can take to accelerate the creation of a circular economy in the city (Reinhard et al. 2013).

The *Dutch Institute of Ecology* (*NIOO-KNAW*) is located in Wageningen and has developed and implemented an innovative sanitation system in its new building, in which black water from toilets is digested and the effluent (which contains phosphorus and nitrogen) is used for growing algae in a photo-bioreactor. For this small-scale pilot project, NIOO collaborated with the Water Board Vallei and Veluwe, which is responsible for water quality management on that site and which wanted to assess whether (elements of) the concept could also be implemented elsewhere within their region of responsibility.

The *Nutrient Management Institute* is also located in Wageningen and provides research and expert advice on nutrient cycles as well as recycling and reuse of phosphorus-containing waste streams. NMI has signed the Dutch Phosphate Value Chain Agreement and is member of the Nutrient Platform.

*STOWA*, the Foundation for Applied Water Research, is the research platform of Dutch water authorities and develops and disseminates tailored knowledge on demand of its members. The two research programmes “Water chain” and “Wastewater systems” increasingly address topics regarding nutrient recovery, such as phosphorus containing products deriving from the municipal wastewater chain or potential models that create synergies between wastewater treatment plants (WWTP) and processing of manure from pig farms (*STOWA 2011, STOWA 2013*). STOWA has also established a working group on New Sanitation (‘Koepelgroep Nieuwe Sanitatie’) that conducts research and initiates pilot projects within this field.

\(^\text{22}\) DeSaH is the abbreviation for the Dutch term ‘Decentrale Sanitatie en Hergebruik’.
Wastewater treatment
The second biggest group represented in the network are employees of the Water Board Vallei and Veluwe (n=5), which is responsible for the purification of domestic and industrial wastewater from Wageningen. Homeowners are responsible for transporting the wastewater to the property boundary. At the WWTP in Renkum, the water board purifies the water and ensures that the effluent complies with the discharge standards for surface waters defined by Rijkswaterstaat. For this service, water boards charge a water purification levy. The water board has a key role in determining whether the phosphorus in wastewater is recovered or not. As part of a range of sustainability objectives, Dutch water boards increasingly deal with nutrient recovery from wastewater through implementing multiple technologies at WWTPs (Lommen 2010). Within this context, the Water Board Vallei and Veluwe regards itself as an innovative and pioneering water board that sets new standards, for instance because of the development and implementation of the Nereda technology\(^23\) in the WWTP Epe that is now being exported to other countries (INT. WBB, 2013). An employee of the water board who is also represented in the network is one of the driving forces behind the Grondstoffenfabriek, an initiative of the water boards to apply cradle-to-cradle principles to the water chain and to recover nutrients (particularly phosphorus) from wastewater.\(^24\) In this context, the WWTP in Amersfoort is currently being rebuilt into a ‘factory’ that produces energy and nutrients such as phosphorus and nitrogen from wastewater and sewage sludge.\(^25\)

In spite of these recent efforts regarding nutrient recovery, in the WWTP Renkum, P is not recovered separately. Instead, the wastewater is divided into an effluent and sewage sludge; the P-containing effluent is then discharged via the Rhine and the sewage sludge goes to the WWTP in Ede, where it is de-watered and subsequently further processed at GMB (see below).

Two other employees of the water board that are represented in the network are members of the Platform Water Vallei and Eem, a network organisation in which the Water Board Vallei and Veluwe and some 16 municipalities from the region (including Wageningen) collaborate to improve the functioning and coordination of the (waste) water chain. Currently, issues such as phosphorus recycling do not yet have a high priority in the network. However, the Platform has only recently developed a new strategic plan, which emphasises innovation and sets out to stimulate a transition from linear thinking to circular thinking in the wastewater chain. The document states: “As municipalities and water board we want to contribute to make society more sustainable. [...] We no longer regard wastewater as a residual product, but as a resource for the production of clean water, energy, nitrogen and phosphate” (Platform Water Vallei en Eem, 2014: 9-10, my translation). For this purpose, the platform intends to initiate pilot projects – among others in the field of new sanitation – for which various actors will be brought together.

Local government
The municipalities are responsible for transporting the wastewater from the property boundary to the WWTP. Since they own and maintain the sewers, they also determine (in consultation with the project developer and the water boards) what kind of sewage system (vacuum system, separated or non-


\(^{24}\) [http://www.grondstofffabriek.com/](http://www.grondstofffabriek.com/)

\(^{25}\) [http://www.omzetpuntamersfoort.nl/](http://www.omzetpuntamersfoort.nl/)
separated system) is implemented in a new development. The municipalities contribute to the zoning plan of new developments and grant the construction permits.

In terms of organic waste, the municipality can influence the extent to which phosphorus is recycled via its waste policy plan (‘Afvalbeleidsplan’). The latest waste policy document that was developed in 2012 emphasizes the various possibilities for the municipality to influence the circular economy and the way resources and nutrients are recovered. The policy sets out to increase the amount of waste that is separated and usefully applied by 65% by 2018, compared to 57% in 2011 (Gemeente Wageningen 2012). Next to this, the municipality tries to indirectly influence the amount of P ‘consumed’ by promoting a more plant-based diet with its “flexitarian” campaign (Gemeente Wageningen, pers. comm., 6 November 2013). Additionally, the municipality seeks to set a good example, for instance by installing vacuum toilets in the new town hall that will be built in 2014.

National government

The Dutch Ministry of Infrastructure and Environment (I&M) has actively initiated and facilitated the realisation of the Dutch Phosphate Value Chain Agreement (Ketenakkoord Fosfaatkringloop) that has been signed by more than 20 organisations and companies. The agreement aims to create a sustainable market in which as many reusable phosphate streams as possible will be returned to the cycle (‘secondary phosphorus market’) and in which this secondary phosphate – as long as there is a P surplus in the Dutch market – is exported. For this purpose, the I&M appointed a full-time Phosphate Value Chain Director from 2011 to 2013 who coordinated the process and connected different stakeholders throughout the value chain with each other. Since the actors throughout the phosphorus value chain are now well connected to each other, the position of the value chain director who connects and facilitates was no longer necessary (Passenier, 2013); the respective person has become President of the European Sustainable Phosphorus Platform and is no longer active regarding P on a national level. I&M has now become an ‘ordinary’ member of the Nutrient Platform.

The former Phosphate Value Chain Director was present at a workshop organised by Wageningen UR which aimed to identify potential measures to close the loop on phosphorus in the metropolitan area of Amsterdam (Thoden van Velzen et al. 2013). Moreover, representatives of the Dutch national government were also present at the symposium “Phosphorus in a Local Circular Economy”, which took place in Berlin in January 2014 and which explored challenges and opportunities involved in the transition from a linear production system to a closed-loop economy at the local level, in particular the cities of Berlin, Amsterdam and Ghent. This shows that the national government also takes an interest on developments regarding phosphorus recycling and reuse on the local level.

26 In Wageningen, however, the municipality can prescribe the exact setup of the sewer system only to a limited extent, which will be discussed more thoroughly in section 6.3.1.

27 During the snowball sampling, the person was however mentioned by a number of other network members in his function as former Director Value Chain Phosphate. When contacted during the snowball sampling, he referred me to the new contact person at the Ministry for Infrastructure and Environment (I&M) who deals with phosphate issues and who also represents I&M at the Nutrient Platform. Instead of including the person that was named during the snowball sampling (the former Phosphate Value Chain Director), I therefore decided to include the new contact person at I&M in the Social Network Analysis.
Results

Networks & partnerships
The Dutch Nutrient Platform is a cross-sectoral network of currently more than 30 Dutch organisations which are concerned about the issue of phosphorus depletion and the way society deals with nutrients in general. The members represent a broad range of actors from the entire phosphate value chain as well as knowledge institutes, both national and local governments and NGOs. Essentially, the activities of the platform aim to (1) harmonise legislation regarding the application of secondary phosphate products, such as struvite and (2) develop and facilitate regional business cases which enable the reuse and reuse of phosphate. The platform only has a ‘light’ secretariat, which means that the members exert a great influence on the strategy and activities of the platform. The secretariat helps implement the action plan, facilitates communication between the members and coordinates the external communication.

The Nutrient Platform was also represented at the aforementioned symposium in Berlin and supports the Municipality of Amsterdam in its efforts to implement its phosphorus strategy.

Sewage sludge processor
GMB BioEnergie is a company that provides services in the areas of composting, anaerobic digestion of organic waste streams, processing of liquid and dewatered sludge of WWTPs, biological drying and nutrient recovery. As such, it also processes the sewage sludge of the WWTP in Renkum. At their processing plant in Zutphen, GMB biologically dries the sludge and processes it into bio granulate, which is potentially suited to be used as a soil conditioner in agriculture. Currently, however, this is not permitted by Dutch law, which is why the bio granulate is incinerated among others in German power plants. The residual ashes are used in road constructions (INT. GMB, 2013).

GMB developed the urine processing plant SaNiPhos®, in which phosphate and nitrogen is recovered from urine. The bulk of this is rest urine from ‘Moeders voor Moeders’, the rest is collected at large events such as music festivals. For the latter, GMB has been in contact with the Municipality of Amsterdam, whose objective is to extend phosphorus recovery to all events and festivals by conditioning event permit delivery to separate urine collection and development of a centralised infrastructure to store the urine and recover struvite (ibid.). GMB is also a member of the Nutrient Platform.

Waste collectors
Solid waste in Wageningen is collected by a number of solid waste management companies. In this research, ACV groep as the largest waste collector in terms of amounts of waste as well as Van Gansewinkel (see under ‘Waste processors’) were considered in the analysis.

The ACV groep provides solid waste management services in Wageningen and collects solid waste of households and companies, which includes vegetable, fruit and garden waste. If the municipality intends to change something regarding the collection or processing of waste (for instance a higher proportion of separated waste as planned in its latest waste policy document), it has to discuss that and make agree-

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28 Currently, the only city government represented in the Nutrient Platform is the Municipality of Amsterdam.
29 Other companies that collect waste in Wageningen include Van Beelen, Van Happen, Sita, Dusseldorp, Ter Horst, Remondis, Van Brenen en Wolfswinkel (Jenkins (2014)). They were however not contacted and excluded from the analysis in this study mainly due to time constraints. Also, since they do not provide comprehensive waste collection services in Wageningen (i.e. only a small number of companies each), they were not assumed to play an important role regarding P recovery and recycling in Wageningen.
Results

Waste collector(s) play a crucial role in e.g. implementing a more effective separation of P-containing organic waste.

Waste processors
After collection, ACV groep transports the organic waste to the waste processing plant of Twence in Hengelo, where it is anaerobically digested to biogas and compost. The compost is used as soil conditioner and is mainly sold on the Dutch market. Twence has signed the Dutch Phosphate Value Chain Agreement and is member of the Nutrient Platform. Together with the Dutch Waste Management Association, the company encourages and supports municipalities to increase and optimise separate collection of organic waste (INT. TWE, 2013).

Van Gansewinkel collects and processes solid waste from Wageningen University. The organic waste fraction is composted and then used as soil conditioner in horticulture and agriculture. Van Gansewinkel has signed the Dutch Phosphate Value Chain Agreement and is member of the Nutrient Platform.

Animal feed producer
AgruniekRijnvallei is a Wageningen-based cooperation of Dutch livestock, arable and fruit farmers that produces and sells various agricultural products such as animal feed (production), mineral and organic fertilisers and pesticides (only trade). As such, it is a trade hub for large quantities of phosphorus and a potential purchaser of recycled phosphorus products such as struvite.

Others
Another member of the network is an employee of the Wageningen-based consultancy TOP BV, that works in the fields of food design, process development and innovation management. He promotes the issue of phosphorus depletion in various media such as on blogs or in the documentary ‘Save our children’ by the Dutch artists Tinkebell.

5.2 Uncovering the social fabric – Structural patterns of the governance network
In this section, I will on the one hand present the results from the quantitative analysis of the network data. In doing so, I will differentiate between three levels of analysis: the “macro” or “global” level focuses on the overall structures which the individual network members are embedded in and which seeks to describe the network population as a whole by the patterns of relations that constrain the opportunities of the individual stakeholders; the “meso” or “local” level pays particular attention to the potential division of the network into sub-groups, which can be critical to understand how individuals, sub-groups and the network as a whole are likely to behave; the “micro” or “individual” level emphasises structural network features of individual members and thereby, for instance, aims to identify those who may have key positions within the network (Hanneman and Riddle 2005). On the other hand, the results of the quantitative analysis will be, where applicable, complemented by qualitative findings from the interviews.

5.2.1 The large picture: Overall network features
Figure 4 shows a map of the analysed network with all nodes (n=40) and edges. The map gives a first visual impression of the structure of the network, which can be further analysed quantitatively. One way
to evaluate the overall network structure is to calculate its density. *Network density* is a common measure in SNA of how well connected a network is (Wasserman and Faust 1994). If the ties among network members are measured with binary data (0 for no tie and 1 for an existing tie), density is expressed as the number of existing ties in the network in relation to the total number of possible ties. However, if the ties are valued by strength as done in this study (1 to 3), density is usually defined as the sum of the values of all ties divided by the number of possible ties (Hanneman and Riddle 2005). That is, collaborative and thus stronger ties are weighted higher than weaker ties. In the investigated network, the 40 individuals share 372 linkages of a possible 1560 linkages, meaning that 23.8% of all possible linkages are present (which would result in a density of 0.238). However, if the strength of these ties is taken into account, the network has a density value of 0.521 (the average tie strength in the network is 2.2), which is a fairly high number (cf. Cheliotis 2010).
Results

Figure 4: Map of the network containing all stakeholders (n=40) and linkages of three strengths (1 = sporadic information exchange; 2 = informal contact; 3 = collaboration). The size of the nodes indicates their betweenness centrality, the colour indicates organisational affiliation. The arrows specify the direction of the tie, i.e. whether the flow of information/collaboration is rather uni- or bi-directional.\textsuperscript{30}

\textsuperscript{30} A uni-directional collaboration, at first sight, might sound paradoxical. However, although individuals can be formally collaborating with each other, it can be only one party who provides information to another (e.g. employee to supervisor or contractor to client).
The network has a degree centralisation value of 25.91% (Out-Degree: 27.26%, In-Degree: 24.56%). First of all, this indicates that there are stakeholders in the network, who have more linkages than others. This is illustrated by the sloped line in Figure 5. In other words, the number of linkages per network member is not equally distributed over all network members (in case of an equal distribution the line would run horizontally to the x-axis). The relatively low centralisation value however also suggests that the network does not have a typical core-periphery-structure, where a few network members have an extraordinarily high number of linkages and make up the core of the network, while the rest of the network (the periphery) has only a few linkages mainly to the core. In fact, a core-periphery test for the P network test reveals that the core is made up by a majority of the network members (n=23), who have a high density of ties among themselves. The other 17 individuals have a very low density of ties among themselves, with most of them being mainly connected to the core (Figure 6).

![Figure 5: Network degree centralisation of the Wageningen P network. Individual stakeholders are shown on the x-axis, number of links per stakeholder on the y-axis.](image)

The average geodesic distance between two nodes in the network is 2.1 (SD 1.0). That is, on average, a person is 2.2 linkages or ‘steps’ away from any other person in the network. Given that the network has a rather decentralised structure, this is a relatively low number, meaning a relatively high connectedness. However, the diameter, i.e. the largest geodesic distance, of the network is 7. In terms of closeness, these figures suggest that although the majority of network members are well ‘knit together’ and can quickly reach each other, some persons are very far away from each other.

Another indicator of network cohesion is the reciprocity, which expresses the degree of mutuality and reciprocal exchange in a network (Cheliotis 2010). The reciprocity rate of the network is 0.656, which means that of all pairs of actors in the network that have a connection, 65.6% share a reciprocal link.

31 In that case, the curve in Figure 2 would follow a power-law distribution with a high gradient on the left side and a long tail toward the right side of the graph.
32 Note that the number on the x-axis do not correspond the an ID number of the stakeholders.
A network property that is related to cohesion is the resilience of a network to the removal of its nodes. In order to function properly, the majority of social networks rely on their connectivity, that is, the existence of ties between pairs of nodes. If nodes are removed from a network, the path length between the remaining pairs of nodes will become longer and the network will become disconnected, eventually leading to the collapse of the network. A number of different approaches to assess the resilience of networks have been reviewed by Newman (2003). Essentially, one can either focus on ties and test their vulnerability or target nodes and remove them either at random or based on Degree Centrality or Betweenness Centrality. Here, I first investigated a scenario in which key individuals were to disappear from the network, so as to test how this affects the overall network cohesion. For this purpose, two tests were made in which nodes were removed one by one according to their initial Degree Centrality and betweenness centrality value. Following the approach of Albert et al. (2000, through Newman 2003), changes in average and maximum length of the shortest path between pairs of nodes (also

As a reminder: Degree Centrality measures the number of linkages a stakeholders has and is thus an indicator of how well connected he/she is. Betweenness Centrality measures the bridging position of a stakeholder. According to Newman (2003), there is one study in which degrees were recalculated following the removal of each node. However, most of the studies he found that investigated the issue of network resilience removed the nodes in order of their initial (degree or betweenness) centrality value in the network before any removal.
known as average geodesic distance and diameter, respectively) were used as indicators of resilience. The results for the removal based on Degree Centrality are shown in Figure 7.

As can be expected from the rather low degree centralisation value, the network shows a high resilience to the removal of individuals with high Degree Centrality. Until 38% of the nodes are removed, only medium changes in average and maximum length of shortest paths occur – the parameters increase continuously and not abruptly which would be the case in a network that is highly dependent on a few key individuals. An additional isolate next to the two that are already present in the normal network appears when the first five nodes are removed. At 48% removal, however, another isolate appears and the network falls apart into three (new) smaller networks. This is also when both the average geodesic distance and the diameter drop sharply. The results suggest that the network does not rely only on a few single key individuals in order to remain its function.

Figure 7: Changes in average geodesic distance and diameter as indicators of the network’s resilience to the removal of key individuals. Decreases in average geodesic distance and diameter, like at 38% node removal, happen when a node at the end of a chain of nodes is removed (cf. Heinrup 2012).

In a next step, I investigated the resilience to the removal of specific classes of ties. About 26% of the links in the network are weak links. Removal of these weak ties (tie strength of 1) results in only two isolates (thus only one additional isolate). Another 26% of links in the network are links of medium

\[35\] The results of the removal based on nodes’ betweenness centrality differed only to a small extent and are thus not seperately shown here.
strength. When both weak and medium ties are removed (strength 1 and 2), there are four isolates and the group of municipal employees becomes an isolated cluster. The rest of the ties, and thus a considerable part of the network (48%), is built on strong reciprocal connection between its members.

5.2.2 Local islands: Groups and sub-structures

Sub-groups
A useful way to depict the structure of a network and to detect potential sub-groups is the concept of modularity. It is an algorithm that measures the degree to which a network is divided into clusters or communities on the basis of the density of ties between nodes. The modularity algorithm identified five modularity groups in the network (three sub-groups and two isolates), which can be seen in Figure 8.

The first sub-group in the top-right corner of the network map consists of the four employees of the municipality plus the employee of the ACV group. The second sub-group, located just next to it, consists of 16 persons from six different organisations. Interestingly, all its members mainly deal with phosphorus in the context of nutrient recovery from domestic or industrial wastewater. The sub-group thus represents a thematic community, in which a denser web of interactions comes as no surprise. The third sub-group in the lower left corner is the largest sub-structure of the network, consisting of 18 individuals from 8 organisations. In terms of thematic emphasis, this sub-group is slightly more diverse than sub-group 2 – most of its members deal with P recycling in an agricultural context, that is, recycling P from organic matter such as manure and compost as well as issues revolving around the appliance of the recycled P fertiliser on agricultural soils. The employees of the Nutrient Platform and the Ministry for Infrastructure and Environment are however not so much specialised on one of these areas and address a broader range of issues regarding P recycling and reuse.

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36 According to the modularity algorithm, ETE1 belongs to sub-group 2 (thematic community around P recovery from wastewater). However, since ETE1 has a lot of ties to members of sub-group 3, the node is located in between both sub-groups.
Results

Figure 8: The three sub-groups plus two isolates. Node colour indicates sub-group.

The members of the described three sub-groups are all connected and thus form the giant component of the graph.\(^3\) Next to this, there is the employee of the animal feed producer AgruniekRijnvallei, who is not connected to any of the other network members and is therefore an isolate. The company works towards reducing the amount of phosphorus that is excreted in the livestock’s manure by adding the enzyme fytase to the animal feed and by revising existing standards for the amount of P in animal feed. The use of recycled phosphorus products in their animal feed is not relevant for AgruniekRijnvallei at the moment. Additionally, only small amounts of P-containing solid organic waste are generated during the production process and are subsequently processed to biogas and a soil conditioner in a biodigester. These are the reasons why the company is not involved in the P network. According to the employee interviewed, phosphorus depletion is more of a national issue, which is why, if at all, the Dutch Feed Industry Association NEVEDI would be the appropriate stakeholder to deal with the topic (INT. AGR, 2013).

\(^3\) In network theory, a “component” is a set of nodes (people) that are all connected to each other, directly or indirectly. If a network has a “giant component”, that means almost every node is reachable from almost every other. The presence of several components in a graph, as is the case in the P network (giant component plus two isolates), indicates that the network is disconnected (Wasserman and Faust 1994).
Results

For these reasons, the involvement of AgruniekRijnvallei in the governance network does not seem relevant and will therefore not be considered in the further analysis.

The second isolate of the network is the representative of Van Gansewinkel, who is not connected to any other network member either. Although the company is member of the Nutrient Platform, it is not actively dealing with phosphorus recycling in Wageningen specifically (Van Gansewinkel, pers. comm., 18 December 2013).

Another measure to identify the degree of sub-structuredness is the clustering coefficient. The average clustering coefficient of the network is 0.5. This is low compared to the theoretically possible value of 1, but significantly higher than the average clustering coefficient of 0.193 of a randomised version of this network, which was computed as a null model based on the randomised connection of all given nodes with a probability of 40%. This makes the network a small-world graph, meaning that most nodes are not neighbours of each other, but are able to connect with a small number of steps to the entire network (Castells 2009, Hanneman and Riddle 2005).

**Bridges between sub-groups**

As can be seen in Figure 4, the employees of the municipality have only few and weak ties with other stakeholders regarding P recycling and reuse. In terms of sub-group 2, MUN2 and MUN3 have mainly contact to representatives of the water boards, however these ties are only of strength 1 and 2, there is no collaboration regarding P recycling and reuse going on. MUN3 also receives information from one employee of each NIOO-KNAW and LeAF. WB2, WB5 and MUN2 are bridging actors between the ‘wastewater’ community and the municipality – they are all members of the Platform Water Vallei and Eem. One of the four employees from the municipality (MUN4) also has a connection to a member of sub-group 3. Based on these findings, it becomes clear that the municipality is closer to members of the ‘wastewater’ community than to sub-group 3, which is also reflected by their structural position in Figure 8.

By far most of the linkages between the three sub-groups occur between sub-group 2 and 3. The members of sub-group 2 and 3 share various linkages with each other. The Nutrient Platform and NMI have mainly links to the Water Board, GMB and STOWA. The individuals affiliated to WUR research institutes (ETE, LeAF, Alterra, PRI, SQ) are generally well connected to each other. Most importantly, there are a couple of individuals in sub-groups 2 and 3 that are especially well connected to a diversity of organisations of the other sub-group and can thus be seen as “bridging actors” between the sub-groups, particularly GMB1, STO3, ETE2, ETE3 (all sub-group 2) as well as ALT7, ALT5, PRI1, and NP1 (all sub-group 3).

**Bridges between action and knowledge communities**

As mentioned in section 5.1, the members of the network can be split up into an action and a knowledge community. Cash et al. (2003: 8086) point out the “importance to effective science advising of ‘boundary work’ carried out at the interface between communities of experts and communities of decision makers”. In other words, to effectively apply science and technology for the promotion of sustainable development, they argue, institutions or processes need to be found that play a bridging role between the science and policy/management arenas. Having this in mind, what bridges do exist between the action and knowledge community in the P network?
Approaching this question from the perspective of the three main sub-groups gives a distinct picture: The members of sub-group 1 can be solely assigned to the action community; the 16 stakeholders of sub-group 2 can be assigned to both the action community (6) and knowledge community (10); the third sub-group consists of 18 members and is, with two exceptions, mainly a knowledge community (only TWE1 and IM1 belong to the action community). In order to investigate the ties between action and knowledge community, I calculated the Community Heterogeneity Index (CHI) for each of the three sub-groups, which is the ratio of the number of edges per node to another community over the total number of edges in the network (Table 5). It is striking that particularly sub-group 2 has a significantly higher score than the two other sub-groups, which indicates a much stronger interaction between decision-makers and scientists in this sub-group. This is also illustrated in Figure 9, which only shows the ties that bridge the action and knowledge community and in which a much denser web of ties can be seen between the members of sub-group 2.

![Figure 9: Illustration of the network showing only the ties that bridge action and knowledge community. Node size indicates CHI value, colour indicates sub-group.](image)

---

38 The Nutrient Platform was also assigned to the knowledge community. Although its goal is to enhance collaboration between various stakeholders in the phosphorus chain and some of its members are part of the action community, the organisation itself is not linked to decisions that directly affect the flow and (re)use of phosphorus.
Another striking finding is that most of the members of sub-group 3 have surprisingly few ties to members of the action community. One reason for that is that the research of many of the Wageningen-based scientists, especially those of Alterra and PRI, focuses on the national or European level (INT. SQ, 2014; WUR Alterra, pers. comm., 29 November 2013). Thus, there is little incentive or need for them to connect with stakeholders that have an influence on the local or regional level. The employee of PRI interviewed for this study states that local or regional partnerships with and between different stakeholders can only play a role for specific regional issues, such as extreme algae blooms. Phosphorus would however mainly be a national/global issue, which cannot be solved by local/regional partnerships (INT. PRI, 2013).

As can be seen from the network map, the employees of the municipality have very few connections to the knowledge community regarding P recycling and reuse. We also see that there are a couple of individuals who concentrate the majority of cross-community linkages. They belong to the action community and are part of sub-group 2. This will be further explored in the following section.

5.2.3 Experts, brokers, outsiders – Individual stakeholder positions
In this section, I investigate three different dimensions of the stakeholders’ position in the network. First of all, I present the findings of three network centrality measures. This is followed by an analysis of the scores for stakeholders’ perceived influence and expertise regarding P recycling and reuse in Wageningen. I will then look at which network members want to collaborate with whom else in the network. The various network parameters of all stakeholders are presented in Table 6. In a last step, I will assess potential correlations between all these parameters.

Centrality measures
Table 7 shows the ten most central network members by their degree of Degree Centrality (DC), Betweenness Centrality (BC) and Community Heterogeneity Index (CHI). Following up on the last section, the individual CHI values interestingly reveal that four of the five representatives of the Water Board Vallei and Veluwe are among the most active and central network members in terms of interacting with members of a different community (in their case the knowledge community), having an average CHI value that is almost as four times as large as the rest of the network (this is also reflected by their node size in Figure 9). Apart from them, the employee of GMB, the Nutrient Platform as well as scientists of STOWA, ETE and NIOO are among the Top 10 in terms of bridging knowledge and action communities. These individuals can therefore be seen as the ‘glue’ that connect ‘science’ and ‘practice’ in the network.

Six of the most degree-central network members are scientists from Wageningen UR. Apart from that, there is also the representative of the Nutrient Platform, two employees of the Water board and the employee of GMB BioEnergie among the most degree-central stakeholders. Apart from the two isolates, the members of sub-group 1 (municipality employees and AVC group) are the least connected stakeholders in the network.

Table 5: Average CHI per sub-group.39

<table>
<thead>
<tr>
<th>Sub-group</th>
<th>Average CHI</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.269</td>
</tr>
<tr>
<td>2</td>
<td>1.294</td>
</tr>
<tr>
<td>3</td>
<td>0.474</td>
</tr>
</tbody>
</table>

39 Values have been calculated by taking the mean of the CHI values of every sub-group member.
Table 6: Network structural parameters on individual stakeholder level, indicating Degree Centrality (DC), Betweenness Centrality (BC), Perceived Influence (Pi), Perceived Expertise (Pe), percentage of contacts with stakeholders from different community (CHI), number of network members who are interested in information exchange/collaboration (COLL) (n=40). Ordered by Betweenness Centrality values.

<table>
<thead>
<tr>
<th>ID</th>
<th>DC</th>
<th>BC</th>
<th>CHI</th>
<th>Pi</th>
<th>Pe</th>
<th>COLL</th>
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</thead>
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<td>7</td>
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<td>1.635</td>
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<td>11</td>
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<tr>
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<td>3.58</td>
<td>14</td>
</tr>
<tr>
<td>SQ1</td>
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<td>6</td>
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<td>2.00</td>
<td>1</td>
</tr>
</tbody>
</table>
Results

Table 7: The ten most central individuals in terms of Degree Centrality, Betweenness Centrality and Community Heterogeneity in the Wageningen P network.

| Stakeholder | Sector                  | Factor | | Stakeholder | Sector                  | Factor | | Stakeholder | Sector                  | Factor |
|-------------|-------------------------|--------|-------------|-------------------------|--------|-------------|-------------------------|--------|-------------|-------------------------|--------|
| ALT5        | Research institution    | 21     |             | AL45                    | Research institution | 15,2   |             | WB1                     | Wastewater treatment | 3.270  |
| SQ1         | Research institution    | 20     |             | WB2                     | Wastewater treatment | 136,9  |             | GMB1                    | Sludge processing    | 2.997  |
| ETE2        | Research institution    | 20     |             | ETE2                    | Research institution | 105,5  |             | WB4                     | Wastewater treatment | 1.907  |
| PRI2        | Research institution    | 18     |             | SQ1                     | Research institution | 104,2  |             | WB3                     | Wastewater treatment | 1.635  |
| WB1         | Wastewater treatment    | 17     |             | AL45                    | Research institution | 91,2   |             | NP1                     | Networks & partnerships | 1.635 |
| LEAF1       | Research institution    | 17     |             | MUN2                    | Local government | 75,7   |             | STO2                    | Research institution | 1.362  |
| NP1         | Networks & partnerships | 16     |             | WB1                     | Wastewater treatment | 69,0   |             | ETE2                    | Research institution | 1.090  |
| ETE1        | Research institution    | 16     |             | MUN4                    | Local government | 65,8   |             | STO3                    | Research institution | 1.090  |
| GMB1        | Sludge processing       | 15     |             | GMB1                    | Sludge processing | 59,1   |             | NIOO2                   | Research institution | 1.090  |

Table 8: Correlations among governance network parameters regarding stakeholder’s Degree Centrality (DC), Betweenness Centrality (BC), Perceived Influence (Pi), Perceived Expertise (Pe), percentage of contacts with stakeholders from another community (CHI), number of network members who are interested in information exchange/collaboration (COLL) (n=40).

<table>
<thead>
<tr>
<th></th>
<th>DC</th>
<th>BC</th>
<th>Pi</th>
<th>Pe</th>
<th>CHI</th>
</tr>
</thead>
<tbody>
<tr>
<td>BC</td>
<td>0.562**</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pi</td>
<td>0.398*</td>
<td>0.164</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pe</td>
<td>0.739***</td>
<td>0.096</td>
<td>0.350</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>CHI</td>
<td>0.367*</td>
<td>0.362*</td>
<td>0.547**</td>
<td>0.255</td>
<td>-</td>
</tr>
<tr>
<td>COLL</td>
<td>0.587***</td>
<td>0.347</td>
<td>0.811***</td>
<td>0.427*</td>
<td>0.596***</td>
</tr>
</tbody>
</table>

* Correlation is significant at the .05 level (two-tailed)
** Correlation is significant at the .01 level (two-tailed)
*** Correlation is significant at the .001 level (two-tailed)
Looking at Betweenness Centrality, we see that it has a slightly different composition than Degree Centrality; employees of the municipality and the water boards are of higher centrality with regard to Betweenness. The first position is taken by an employee of Alterra (ALT4) who is not among the top 10 in terms of Degree Centrality, but who lies on the shortest path between sub-group 3 and an employee of the municipality who is positioned in the periphery of the network. The second position is taken by an employee of the Water board (WB2), who is the bridge between sub-group 2 and, again, two employees of the municipality. Together with the representative of the Nutrient Platform, of GMB BioEnergie and three other scientists affiliated to Wageningen UR, these individuals are the main gatekeepers of the network.

Perceived influence and expertise

Table 9 shows the ten individuals that have the highest scores in terms of perceived influence and expertise on P recycling in the network. As can be expected, the analysis reveals that most of the individuals with a high perceived influence belong to the action community, above all WB1 who is also one of the leading figures of the Grondstoffenfabriek, a joint initiative of the Dutch water boards to recover nutrients from wastewater. Related to that, all but two of the top 10 network members with a high perceived influence are part of sub-group 2, the thematic community around phosphorus recovery from wastewater. Also, two employees of the municipality and the representative of the Ministry of Infrastructure and Environment are on this list. Positions 2, 3 and 4 are however occupied by scientists from Wageningen UR and STOWA.

In contrast to the list of perceived influence, the list of perceived expertise is dominated by scientists from Wageningen UR and thus members of the knowledge community. Again, WB1 (the only member of the action community on this list) receives a relatively high score. The list is headed by SQ1, who also has one of the highest Degree Centrality value in the network.

Table 9: The ten network members with the highest values in terms of perceived influence and expertise regarding P recycling and reuse in Wageningen.

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Sector</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>WB1</td>
<td>Wastewater treatment</td>
<td>3.31</td>
</tr>
<tr>
<td>ETE2</td>
<td>Research institution</td>
<td>3.13</td>
</tr>
<tr>
<td>STO3</td>
<td>Research institution</td>
<td>3.07</td>
</tr>
<tr>
<td>STO2</td>
<td>Research institution</td>
<td>3.07</td>
</tr>
<tr>
<td>IM1</td>
<td>National government</td>
<td>3.00</td>
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<tr>
<td>GMB1</td>
<td>Sludge processing</td>
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</tr>
<tr>
<td>MUN1</td>
<td>Local government</td>
<td>2.80</td>
</tr>
<tr>
<td>WB2</td>
<td>Wastewater treatment</td>
<td>2.77</td>
</tr>
<tr>
<td>MUN3</td>
<td>Local government</td>
<td>2.75</td>
</tr>
<tr>
<td>NIOO2</td>
<td>Research institution</td>
<td>2.73</td>
</tr>
</tbody>
</table>

<table>
<thead>
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<th>Stakeholder</th>
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<th>Factor</th>
</tr>
</thead>
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<td>SQ1</td>
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<tr>
<td>ALT1</td>
<td>Research institution</td>
<td>3.86</td>
</tr>
<tr>
<td>PRI1</td>
<td>Research institution</td>
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<td>ETE2</td>
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<td>ALT7</td>
<td>Research institution</td>
<td>3.50</td>
</tr>
</tbody>
</table>

Collaboration

So far, the analysis has focused on the current situation and the status quo of the governance network (or, more precisely, on the situation at the moment of data collection). But how could the network
Results

evolve in the future? In order to approach this question, I asked the respondents to indicate which stakeholders they would like to exchange information or collaborate with in the future. Figure 10 shows these collaborations “of interest” and gives an impression of how the network would look like if the network members realised their plans and established these additional linkages (right map). This potential future network is more compact and has less clearly visible sub-groups, as the network members move structurally closer together (network cohesion parameters such as average and maximum length of the shortest path would decrease altogether; likewise, the average number of linkages per node, and thereby, the network density would increase\(^4\)). Particularly the employees of the municipality would be better connected to the rest of the network, with MUN2 gaining a more central position in terms of betweenness. The representative of the animal feed producer AgriNeckRijnvallei would still be on the periphery of the network – only one respondent (SQ1) indicated interest in a collaboration.

In general, the stakeholders seem to have an interest in extending their contacts beyond their own community (action and knowledge community, respectively). For instance, there are 6 scientists from Wageningen UR and NIOO-KNAW who expressed an interest in collaborating with employees of the municipality. Likewise, especially MUN2 wants to get in contact with scientists and other members particularly from sub-group 2, the thematic community around phosphorus recovery from wastewater. Another striking results is that especially members of sub-group 2 seem to be demanded as partners for future information exchange/collaborations.

Correlations between network parameters

In order to assess how the various network parameters relate to each other, I calculated the correlations between them. There is, for instance, a high correlation between a person’s popularity and her/his Degree Centrality as well as his or her individual CHI value (see Table 8), suggesting that being demanded for future collaboration might be associated with a central position in the network and the capacity to bridge across action and knowledge community. Related to that, the correlation analysis also shows that Degree Centrality is significantly and positively correlated to a person’s perceived expertise.

\(^4\) Respondents were asked to only tick the box if they were willing to invest time and resources in the collaboration.

\(^4\) Network parameters of the potential future network (figures in brackets indicate values of the current network): Average path length: 1.85 (2.10); Network diameter: 5 (7); Average clustering coefficient: 0.497 (0.516); Average modularity coefficient: 0.207 (0.333); Average degree: 11.64 (9.41); Graph density: 0.36 (0.248).
Figure 10: The left map shows all the linkages that network members would like to establish or maintain in the future (a considerable part of the connections that the respondents stated an interest in do already exist). Node size corresponds to the number of other network members who stated an interest in collaborating with the respective person in the future. In other words: The more people indicated they would like to collaborate with this person in the future, the larger the respective node. The map thereby gives an impression of which individuals are prioritised for future collaborations or information exchange.

The right map is an overlap of the ties of the left map and all the linkages from the actual network (see Figure 4). If we assume that the already existing ties remain in the future, this map gives an impression of how the network would look like if the network members realised their plans and establish all the new linkages they stated an interest in. In the right map, node size again indicates Betweenness Centrality.

\[42\] Note that the ties are directed ties and only express an interest of one person in a collaboration, which is not necessarily reciprocated by the other person.
5.3 Role of the municipality concerning P recycling and reuse

In this section, I analyse the interviews conducted for this study regarding obstacles of and opportunities for a stronger engagement of the municipality of Wageningen in phosphorus recycling and reuse.

5.3.1 Obstacles for the municipality

The results of the Social Network Analysis show that the employees of the municipality are poorly connected to the rest of the network. Why is that? As the interviews conducted for this study show, this has several reasons.

First of all, phosphorus recycling and reuse currently only play – if at all – a minor role for the municipality (INT. MUN, 2013; INT. WBa, 2013). An employee of the Water Board Vallei and Veluwe who is also a member of the Platform Water and Eem points out that “civil servants are often occupied with practical and operational tasks in a clearly defined range of duties, which leaves little time and space to freely pick up something exotic like phosphorus recycling. It needs to be officially defined as a policy objective of the municipality – otherwise it’s not gonna happen.” In case such policy objectives are absent, the personal ambition and initiative of a civil servant is crucial: “There needs to be someone who finds it nice to deal with the topic” (ibid.).

Moreover, Wageningen is a so-called “regiegemeente”, which means that the municipality tries to outsource as many tasks (such as waste collection) as possible. As a consequence, the municipality lacks control on those tasks: If it has certain policy objectives, say in the field of organic waste, the municipality cannot just implement them itself, but needs to negotiate and make agreements with the relevant stakeholders – in this case ACV groep (INT. MUN, 2013). Likewise, the municipality has no control over solid waste originating from private companies (non-household sector). They can contract any waste collection and processing company for their waste streams. The municipality has also insufficient control over new construction projects such as the new settlement ‘Kortenoord’ in the West of Wageningen. There, the developer is obliged to implement a separated sewer system, that is, one sewer for storm water runoff and one sanitary sewer, which increases the concentration of P in the sanitary sewer (the less storm water, the higher the P content). However, there are no uniform standards in the Netherlands that prescribe what colours are used for the pipes – every municipality thus uses different colours. Even within the same municipality, it is possible that different colours have been used over the past decades; after all, the infrastructure has been there already for several decades. Additionally, there is often additional infrastructure by other parties which can lead to confusion. These differences in the pipe colours can – if accidently not correctly handled by the project developer – easily result in a waste stream being discharged in the wrong sewer. Although the municipality contributes to the zoning plan and grants the construction permits, INT. MUN (2013) points out that such details are hard to prescribe on a policy-level by the municipality.

According to INT. WBa (2013), another obstacle for a more active engagement of municipalities in P recovery from wastewater is the open question of who owns the nutrients. Since it is the water boards that would earn money from P recovery by selling the end product such as struvite, the municipalities would be likely to raise the question of how the financial gains from selling those products are to be distributed among the water board and the municipality. In other words, “there is no financial incentive for municipalities to become active and stimulate recovery of phosphate from wastewater” (INT. WBa,
2013a). One potential measure for the municipality to do so would be to separate the sewer system. As a matter of fact, this is what the water boards demand from the municipalities in the long run as the design of the sewer system it determines the P concentration in the wastewater stream\textsuperscript{43} – “because improvements can be made at the WWTP, but they actually need to be realised at the source, that is, by separating the sewer system. But it is the municipalities who are responsible for that, which is why agreements with the municipalities are so important.” (INT. WBB, 2013) However, INT. LeAF (2013) highlights that “if the municipalities don’t see the value of investing in and renewing the sewage system, then it gets difficult for the water boards.”

Currently, the municipality of Wageningen does indeed not feel urged to act in that direction: “As the municipality, we have a stable and well-working wastewater treatment – so we don’t see the urgency to change anything on that. The WWTP gets a constant stream of waste and can therefore do its job well.” (INT. MUN, 2013). The last point highlights that the municipality and the water board have different responsibilities, which comes along with different and thus potentially conflicting interests and stakes.

5.3.2 Opportunities

Another potential reason why Wageningen and other municipalities have not yet started promoting nutrient recycling is pointed out by INT. IM (2013) who argues that municipalities have a need for expertise. INT. LeAF (2013) adds to that: “Municipalities need to know what they can do – otherwise they won’t become active”. The question is however where this knowledge of how municipalities can exert influence on phosphorus recycling and reuse should be collected, developed and disseminated. INT. WBA (2013) thinks it does not make sense to do that on the level of every single municipality, because this would not likely to be effective. Instead, a network such as the Platform Water Vallei and Eem might be a suitable level for such an endeavour, because “you need to develop this expertise on a different scale, and with 16 municipalities you reach that scale where it does make sense.” (ibid) According to INT. WBA (2013), it is thus a realistic perspective for the platform to employ someone in the long run (within five years) who specialises on the topic of nutrient recovery. This person would then develop a strategy and organise the process, for instance purchasing a urine tank that is jointly used by the municipalities participating in the Platform Water Vallei and Eem (PWVE), while the operating tasks would still be conducted by the municipalities.\textsuperscript{44} In contrast to the employee of the municipality, INT. WBA (2013) regards the trend towards ‘regiegemeentes’ more as an opportunity in this context, as this process can help show civil servants the value of “letting things go to a higher scale” (ibid.).

At the PWVE, issues related to phosphorus recovery are already sometimes dealt with. Questions then revolve around the advantages and drawbacks of different technological approaches (end-of-pipe solutions or starting at the source, i.e. by means of a separated sewage system?), around ownership matters (Who owns the resources and nutrients that would be recovered?) as well as financial responsibilities.

\textsuperscript{43} In a separated sewer system, storm water and wastewater flow through separate sewer pipes. The less storm water is discharged together with the wastewater, the higher the P content will be in the wastewater that eventually arrives at the WWTP. A higher concentration of P in the wastewater is beneficial for the production of struvite.

\textsuperscript{44} This is one of the measures discussed in the study of Jenkins (2014). The urine stored in the tank could be used for struvite production by companies such as GMB BioEnergie. However, Wageningen only has one major event per year (Liberation Day), which is why purchasing an own urine tank would make little sense. By using such a tank jointly with other municipalities of the PWVE, this measure might however become viable.
(Who makes the necessary investments?). Answers on these sorts of questions have not yet been found at the PWVE (INT. MUN, 2013).

Although INT. MUN (2013) does not expect that nutrient recovery will become an issue of major importance for the municipality, the interviewee emphasises that the municipality is open for measures such as collecting urine at peak events (such as Liberation Day) and storing it in a urine tank commonly used together with other municipalities in the PWVE. Furthermore, the municipality seeks to set a good example and promote possibilities, for instance by installing vacuum toilets in the new town hall that will be built in 2014.
6. Discussion

The following discussion is structured along two lines: First, I will discuss the implications of the network structure on the function of the governance network and on the influence of certain stakeholders therein. I will also discuss what the implications of my findings are, both for the network members and in a larger context. Second, I will critically reflect on the methods used in this study and discuss the associated limitations of my findings.

6.1 Implications of the network structure

Collective action and centralisation

The results have shown that the network is characterised by a relatively high overall density \( (D=0.521) \) and low average path length (2.1). This can be especially attributed to the large core \( (n=23) \), whose members have a high density of ties among each other. Hence, the core of the network displays multiple and short channels for communication, which means that information can be transmitted very easily and quickly within this core (Newig et al. 2010). According to the literature on social network analysis and natural resource governance, this also means that at least the core of the network has a high potential and capacity for collaborative action (for an overview, see Bodin and Crona 2009). As Bodin and Crona (2009) point out, several studies have shown that increased possibilities for communication and the resulting increase in the level of trust between actors lead to increased levels of collective action. This positive relationship between density and collective action is confirmed by the fact that the vast majority of the relations among the core members are collaborative ties. However, in a comparative case study of four networks within the higher education policy sector, Sandström and Carlsson (2008) observed that joint action indeed benefitted from increased tie density, but that it was of particular importance that many ties existed between actors who belong to different sectors of society or who represent various professions. Based on the analysis of the P network, it becomes clear that this “requirement” is not really met by the core of the network – 19 out of the 23 members are researchers working for various research institutions. The core has thus low capacity to coordinate joint action and mobilise different resources (from) outside the research community (Prell 2011, Sandström and Carlsson 2008).

However, when evaluating the density of the network one has to bear in mind that 35% of the reported ties between stakeholders are non-reciprocated or asymmetric ties. Some social network scholars argue that those asymmetric ties may be unstable (Hanneman and Riddle 2005), which may especially apply to weak links (strength 1) that are not reciprocated. Hence, the overall network density might not be as strong as it seems.

In spite of the low average path length and thus relatively high cohesiveness among the core members, the large diameter (maximum path length) however also indicates that there are some stakeholders in the network who are structurally far away from each other (e.g. ACV groep and Twence). Information from these individuals regarding P recovery then has to be bridged by several different stakeholders until it reaches its recipient and can thereby become distorted (Newig et al. 2010).

The rather low centralisation of the network (25.91%) points to flat or no hierarchies in the network, which means there is hardly any central coordinating unit that indirectly connects the communication
flow (Sandström and Carlsson 2008). As suggested by Bodin et al. (2006), whether this has beneficial or detrimental effects on natural resource governance may differ depending on the phase of the governance process. For instance, mobilising and coordinating various stakeholders at the beginning of a process may require higher degrees of network centralisation, while engaging them to resolve complex problems and processes may be favoured by less centralised networks. Considering that urban phosphorus or nutrient governance in general is still a highly uncertain and new field (Stockholm Environment Institute 2011) and the governance process is thus still in its infancy, a more centralised network with a central unit that coordinates communication would therefore be beneficial at this stage. This has for instance been the case in Amsterdam, where it was particularly the municipality that connected various stakeholders and facilitated a collaborative process towards more P recycling and reuse (Gemeente Amsterdam, pers. comm., 21 January 2014).

However, highly centralised networks have been found to be more vulnerable to removal of central stakeholders than less centralised networks due to their reliance on a few strongly connected individuals (Frank et al., 2007 in Bodin and Crona 2009, Newig et al. 2010). As shown by the resilience test, one advantage of the low centralisation of this network is that it would be only to a small extent affected by losing its highly connected nodes. Information exchange and collaboration could then still take place, only slightly less efficient and direct.

**Role of the sub-groups**

Although the core of the network has a high structural cohesion, the network as a whole is less cohesive and consists of clearly distinguishable sub-groups. Even the core members actually belong to two different sub-groups (2 and 3) as illustrated in Figure 8 (results chapter). As Bodin and Crona (2009) point out, various factors can contribute to the formation of sub-groups in networks. One reason is that social relations generally come with a cost, first for establishing them and then for maintaining them (Granovetter 1973 in Ernstson et al. 2010), and social actors have limited resources, energy and time to maintain too many concurrent relations. Another reason can be specialisation (Bodin and Crona 2009, Hanneman and Riddle 2005). The latter is especially well visible in terms of sub-groups 2 and 3, which clearly form sub-groups based on thematic specialisation. Sub-group 2 consists of individuals who deal with the recovery of phosphorus from wastewater, while the majority of the members of sub-group 3 deal with phosphorus in an agricultural and soil management context. Taking this perspective, also sub-group 1 can be considered a thematic sub-group – compared to the sub-groups, its members (the municipality and the representative of ACV groep) are characterised by the fact that they currently do not explicitly deal with and network regarding phosphorus recycling and reuse.

Bodin and Crona (2009) discuss benefits and drawbacks of the presence of sub-groups in a network. On the one hand, relational ties within cohesive sub-groups, also referred to as bonding ties, stimulate trust, reciprocity and thus cohesion within communities, which are deemed important for consensus building, conflict resolution as well as generation and transfer of tacit knowledge, three critical prerequisites for natural resource governance (Ostrom 1990 in Bodin and Crona 2009). Especially the latter ben-

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45 This is confirmed by the predominance of reciprocated ties over asymmetric connections in the network, which according to (Hanneman and Riddle 2005) suggests a more “equal” network with little hierarchies.
efits from a high degree of continuous and persistent information exchange. Regarding generation and transfer of knowledge regarding P recovery and reuse, the benefits of the sub-groups is therefore two-fold: they may (1) enhance knowledge development itself by enabling channels for communication and interaction among similar others and (2) contribute to the development of a diversity of knowledge by allowing the knowledge generation in different sub-groups (Bodin and Crona 2009). On the other hand, related to the assumption that network density has (mostly) positive effects on collaborative processes, it can be concluded that if there are clearly distinguishable sub-groups present in the network, the density of linkages between the sub-groups can be regarded as low. This could have negative effects on the capacity for collaborative processes among sub-groups (Granovetter 1973 in Bodin and Crona 2009). In the analysed network, this is certainly the case for sub-group 1 and 3, who have only one direct link with each other and who therefore have a very limited capacity for collaborations with special regard to P recycling and reuse. Generally, the analysis has shown that the municipality (sub-group 1) has only a few and weak links with scientists from both sub-group 2 and 3. However, as Bodin and Crona (2009: 368) stress, “if actors connecting subgroups have the willingness, capacity and motivations to coordinate subgroup activities towards a common goal, this limitation could be overcome”. In the P network, there are especially two of these individuals, namely WB2 and ALT4, who connect sub-group 1 to sub-group 2 and 3, respectively. These linkages, also known as bridging ties, can provide access to various external resources and are often required to help different actors initiate and support joint action (Granovetter 1973, Newman and Dale 2007, Lin 2002 in Bodin and Crona 2009). Thereby, bridging ties can help avoid sub-groups tending towards a state of homophily, the tendency of groups to form from actors of similar kinds and then become increasingly uniform with time (Newman and Dale 2007).

Based on the above considerations, two aspects become clear: First, the three different sub-groups in the network should interact, especially the interaction between sub-group 1 with sub-group 2 and 3, respectively, should be intensified regarding P recycling and reuse. This could be facilitated by the two bridging individuals WB2 and ALT4. Second, although it would be beneficial for the network to have a higher centralisation and overall cohesion at this stage that allow for more coordinated and centrally facilitated collaboration processes towards a common goal (P recycling and reuse), in order to be conducive for this goal in the long run, the network needs to balance between an overall structural cohesion as well as the presence of sub-groups (Bodin and Crona 2009).

**Actors’ influence or power**

Although the investigated network is made up of individuals from various organisations which hold multiple perspectives on P recycling and reuse, these individuals occupy very different positions in the network, which comes along with different degrees of influence. Some individuals occupy certain central positions in the network, due to a high Degree or Betweenness Centrality or high CHI index (number of tie to members of another community, thus either action or knowledge), by which they are better situated to access or provide valuable information or other resources which can give them an advantage over others. Also, they may be able to exert influences over others in the network (Bodin and Crona 2009). In the governance network regarding P recycling and reuse, this could for instance mean that a certain stakeholder, due to his/her central position, is able to selectively provide information and thereby promote certain new technologies and more sustainable P management practices that the person is in favour of (or block information that he/she does not perceive as interesting). As has been shown in
this study, the number of ties an individual possesses (Degree Centrality) highly correlates with the expertise the person is awarded by others in the network. Hence, the higher stakeholders’ expertise is perceived by others, the more connections they tend to have. And this expertise (or reputation) can be argued to be seen as one type of influence or power that is of relevance in the study of social networks. Such actors who have a high perceived expertise and a high communication activity have a higher chance of being heard and thereby be more influential in setting the agenda of a network (Ernstson et al. 2010). This type of influence is therefore akin to what Castells (2009) has theorised as the ‘programming’ power in networks – the power to determine the organisation and processes of (sub-)networks as well as the goals assigned to it, largely by controlling the way how issues and information are perceived (Collister 2010). It is well illustrated by node ETE2, who is highly connected and scores high in terms of both perceived expertise and influence. Also the individuals who have a high Betweenness Centrality and connect sub-groups with each other (bridging ties) exert influence in the network – in Castells language they are the holders of ‘switching’ power, in the sense that they are able to connect and ensure cooperation between different (sub-)networks by identifying like-minded networks that share common goals and combining resources with them (Castells 2009). However, a central position does not always lead to a high perceived influence, which is illustrated by node ALT4. A reason for this can be that the person is not really perceived by most others to be part of the network, or to have expertise or a stake in the area of P recycling and reuse in Wageningen.

The examples of nodes ETE2 and ALT4 also show that the type of influence which derives from a central network position or reputation does not (necessarily) relate or lead to actual influence in decision-making and implementation processes\(^\text{46}\) (Bodin and Crona 2009), which is another type of influence that needs to be considered in the analysis of social networks. Conversely, an individual can just as well be influential without necessarily occupying a central position, for instance if the individual or its organisation has formal authority (ibid.). A good example for the latter in the P network are the two employees of the municipality MUN1 and MUN3 as well as IM1 from the Ministry of Infrastructure and Environment.

All in all, these considerations show that there are several dimensions of influence or power in social networks, which can derive from or relate to a person’s structural network position, reputation or formal authority. I argue that all these different forms of power should be taken into consideration in the further institutionalisation of the governance process, since they are all necessary to advance P recycling and reuse in Wageningen – the individuals who exert these forms of power mutually rely on each other in order to be capable of realising more P recycling and reuse.

**Platform Water Vallei en Eem as a bridging organisation?**

The results and the above discussion have shown that the network consists of individuals who exert influence in the network in different ways. Some actors are central in terms of degree, some in terms of betweenness, others bridge different sub-groups or action and knowledge communities. In this network,

\(^\text{46}\) As scientists, neither ETE2 nor ALT4 actually possess any formal decision-making power. However, a reason why ETE2 is awarded such a high perceived influence might be the research activities of that person is explicitly practice-oriented (or can be classified as ‘applied science’) and has, among others, led to the initiation of the DeSaH demonstration project Sneek I (see section 5.1).
there is thus not one central individual who stands out and combines all these network features, in contrast to other empirical cases (e.g. Heinrup 2012).

As discussed above, a more centralised structure would however be beneficial for facilitating and coordinating joint action regarding more P recycling and reuse in Wageningen, at least in the beginning of the governance process. This has various reasons, which have been partly outlined above already. The reason I want to highlight here is the cross-scale and cross-level nature of governance of natural resources in general and for sustainable phosphorus management in particular (e.g. Cash et al. 2006, Scholz et al. 2013, Ulrich 2011). Following Cash et al. (2006: 2), scale is defined as “the spatial, temporal, quantitative, or analytical dimensions used to measure and study any phenomenon, and ‘levels’ as the units of analysis that are located at different positions on a scale.” Sustainable phosphorus management involves components that range from the local level (e.g. sewage infrastructure; presence of certain industries) to the regional level (wastewater treatment systems; economic clusters), to the national (population densities; laws and incentives) and finally to the supra-national (EU phosphorus policies) and global levels (secondary phosphorus markets). The individuals and their organisations in the P network also work on different geographical and spatial levels: e.g. the municipality on the local, the water board on the regional, and scientists often deal with P management on a national or even European level.

Several scholars have emphasised the role of so-called “bridging organisations” in linking across these scales (e.g. Berkes 2009, Folke et al. 2005). As Hahn et al. (2006) put it, bridging organisations provide an arena for vertical and horizontal collaboration and lower the transaction costs of these collaborations. They are key brokers in information and knowledge sharing networks and can act as “boundary agents”, i.e. helping to create collaborative partnerships between science, policy and practice (or action and knowledge communities), which is widely regarded as one of the most influential factors behind successful establishment of co-management structures (Bodin and Crona 2009, Cash et al. 2003). They are further suited to coordinate and manage network activities and thereby help finding the network a strategic direction. Hodson et al. (2012) describe how bridging organisations (or, as they call them, intermediary organisations) can create a context for discussing competing priorities, help to access new external knowledge into a particular regime, and either provide capacity that is lacking to manage a transition or help mobilise untapped internal capacity. A bridging organisation can be setup by either creating a new body or utilising an existing organisation (Plastrik and Taylor 2005).

In the context of this study, the question arises who could act as such a broker that provides an arena for various actors to collaborate? Considering that there is not one central stakeholder in the network, but several individuals with different centralities, an answer “might lie in the possibility that scale-crossing brokers can be organizations of collaborating individuals” (Ernstson et al. 2010: 16). An organisation that lies at a strategically interesting position for this task is the Platform Water Vallei en Eem (PWVE). The platform serves as an arena for several municipalities in the region and the water board to discuss issues related to the wastewater chain. As part of its recently developed strategic plan (‘Umbrella plan’), the platform strives to be trend-setting by initiating and conducting innovative pilot projects as well as stimulating, facilitating and coordinating by connecting municipalities, water boards and other relevant actors such as business organisations (Platform Water Vallei en Eem 2014). The employees of
the water board Vallei and Veluwe (such as WB1 and WB2; the latter is also an active member of PWVE) occupy network positions that enable them to actively act as an interface or bridging actor between scientists, business community (for instance GMB BioEnergie), other partnerships such as the Nutrient Platform as well as the Municipality of Wageningen. Additionally, the water boards and the individuals that are part of the P network have already acquired substantial experience and expertise in the field of phosphorus recovery from wastewater, for instance with the realisation of the energy and resource “factory” in Amersfoort (Omzetpunt Amersfoort). According to INT. LeAF (2013), the water boards in general have developed an open-minded culture to new and innovative approaches and are open to new kinds of collaborations. This is for instance reflected in the aforementioned projects that investigated opportunities for synergies between water boards and pig farmers in order to process manure at WWTPs (STOWA 2011, see also section 6.1).

With these intentions and “qualifications”, the Platform Water Vallei en Eem could potentially evolve into a bridging organisation capable of advancing P recycling from wastewater originating from Wageningen. Even if the Platform may not be a scale-crossing broker for P recycling and reuse yet, it could attain such a position by strategically networking with other actors (Ernstson et al. 2010). Against this background, the PWVE could be a suitable stakeholder to facilitate and coordinate the implementation of strategies for P recovery from wastewater of Wageningen that were developed by Jenkins (2014). For this purpose, PWVE could be a stakeholder that fosters communication and collaboration between other stakeholders such as Wageningen-based scientists and the Municipality of Wageningen – as the results of section 5.2 show, there is certainly interest for information exchange between some individuals in the network (see Figure 10).

This more regional approach would also be in line with potential developments taking place at the Nutrient Platform: there, the introduction of a working group on regional partnerships has recently been proposed (INT. SQ, 2013).

Implications of finding...
What are the implications of all these findings, both for the network members and in a larger context?

...for the network members
For the network members, the findings can provide a useful “bird’s eye view” on how the network that they form part of looks like. The findings can also make the network members more aware of their ‘neighbourhood(s)’ within the network. This can enable them to make strategic decisions on whom to consult or connect to regarding certain matters in the field of P recycling and reuse and on how to disseminate information in an efficient way. In that sense, the approach of this study and its findings can encourage a network perspective among the stakeholders and assist those who wish to attain a more central role in the process towards more P recycling and reuse in achieving this objective.

47 For an overview of strategies and practices for how actors could reach a scale-crossing broker position, see (Ernstson et al. 2010).
...in a larger context

In this study, I have taken a local perspective on sustainable phosphorus management to explore what role cities can play in arriving at a more sustainable phosphorus use and how particularly municipal governments can facilitate this. However, following the notion of multi-level governance, it is important to realise that the local is not a ‘black box’ that is disconnected from the global, international and national and sub-national contexts (Geels 2011). Bulkeley and Betsill (2005) criticise that many analyses of urban sustainability ignore the complex interactions of economic, social and political process across different levels and systems of governance. They argue that this “framing means that suggested measures to improve urban sustainability are frequently bounded by the idea of being ‘local’ solutions, and the role and influence of policy and politics taking place outside the urban arena are largely ignored” (ibid.: 48).

Based on this, the findings presented here should be viewed in a larger context. If one finding is that municipalities have limited possibilities and incentives to facilitate more P recycling and reuse, it becomes necessary to engage with the processes at multiple scales of governance that shape this local capacity or political will to act. After all, the implementation capacity of municipalities largely depends on other administrative levels in terms of legislation, resource allocation and the institutional framework (Khan 2013). Many of these wider political, economic and social processes lie beyond the scope of this thesis, such as the generally bad budgetary situation of municipalities and the associated trend towards ‘regiegemeentes’.

48 Some of these processes however particularly concern phosphorus governance, which I briefly want to discuss in the following.

One of the most fundamental reasons for a lack of action (not only at the municipal level) is highlighted by Lommen (2010). In his study about the Dutch actor-network around P-recycling, he concludes that there is an absent of a real problem – P scarcity has not yet been experienced by any actor such as agriculturalists or the phosphate industry (especially not in the Netherlands, where there is a surplus phosphorus). The sum of the individual drivers for P-recycling projects like energy-, CO2- and water savings would not suffice to act as a real trigger to scale up these projects. 49 Furthermore, phosphorus recycling is currently still way too expensive; companies such as GMB BioEnergie and Twence do not generate their income with the phosphorus-containing end-products, i.e. struvite and compost, respectively (INT. GMB, 2013; INT. NP, 2013). This can be largely attributed to the fact that prices of mineral fertilisers – even in spite of occasional spikes in recent years – are still comparatively low. Accordingly, there is currently no demand for recycled P fertilisers such as struvite in the Netherlands (INT. PRI, 2013). There are also juridical barriers: Struvite and compost have been or are still underprivileged compared to mineral fertilisers. Until the end of 2013, struvite was not allowed to be sold as an agricultural fertiliser due to hygienic reasons (struvite is recovered from wastewater) (Roekel 2013). In contrast, compost still

48 Being a regiegemeente means that the municipality tries to outsource as many tasks (such as waste collection) as possible to other parties.
49 Although the topic has received a strong boost and political attention in the past years both on the national and on the European level (setup of Dutch Nutrient Platform, European Sustainable Phosphorus Platform, first European Sustainable Phosphorus Conference in 2013, etc.). Likewise, there have been a number of large-scale projects recently, with Waternet having completed the construction of Europe’s so far largest phosphorus recovery installation at the WWTP in Amsterdam West in December 2013. Also, the Water Board Vallei en Veluwe is reconstructing the WWTP in Amersfoort into a ‘resource factory’ that will recover phosphorus and thereby produce approx. 900 tonnes of struvite per year.
comes under the Dutch Fertiliser Act, since it contains nitrogen and phosphorus. According to INT. TWE (2013), this should actually not be the case, because the Fertiliser Act essentially aims to avoid leakage of nutrients. Compost as a soil conditioner with organic content just avoids this leakage. Since it comes under the Fertiliser Act, it can however hardly compete with mineral fertiliser. Moreover, as has been explained in section 6.1, at the WWTP Renkum, phosphorus is not recovered from the effluent since it is allowed to be discharged in the Rhine. As long as the standards for effluent discharged are not changed by Rijkswaterstaat, there will be no incentive for the Water Board Vallei en Veluwe to invest in a reconstruction of the WWTP so as to remove P from the effluent. These are only some of the factors that operate on other scales and that explain why there is still a relatively low political, economic and societal pressure to foster P recycling and reuse in the Netherlands. This pressure is particularly low for municipal governments, since the issue is first and foremost considered to require national and European legislation.

The findings suggest that the municipal government is currently rather lagging behind than leading in the process towards more P recycling and reuse. Instead, it is actors such as the water board and private companies who take the initiative and have started to build networks trying to influence the governance process. This is in line with the experiences from studies in the field of network governance and urban low carbon transitions, which show that municipalities are at best only one of many actors in implementation or innovation, and are normally not the main driver (Khan 2013). Partly due to the trend towards ‘regiegemeentes’, municipal governments increasingly lack full implementation capacities and therefore need to find new ways to implement policy measures. This requires institutional innovations where forms of network governance can be an instrumental (Bulkeley and Kern 2006).

Analysing the multi-level governance of climate change, Bulkeley (2005) describes how particularly transnational municipal networks (TNMs) such as the Cities for Climate Protection (CCP) seek to foster a discursive shift of rescaling climate change as an issue with local causes and consequences, while simultaneously reframing issues which are institutionalised and ‘made’ at local level (e.g. traffic congestion or green space) as having global dimension. “This discursive rescaling elevates local institutions and practices as an arena of influence and reduces the roles of international and national scales of governance” (ibid.: 893). In the field of phosphorus recycling and reuse, this discursive shift has not taken place so far, with most of the attention and hope for a regulative framework still directed towards national, supranational or even international scales of governance (Scholz et al. 2013, SEI 2012, Ulrich 2011). However, the symposium on local phosphorus cycling in Berlin in January 2014 might be a first sign for such a shift towards the local scale – it will be interesting to observe how the role of urban areas will evolve in the debate on governance for sustainable phosphorus management.

What about solid waste?
Finally, I want to mention some general observations regarding the role I made during this research. The discussion has so far mainly touched upon potential ways and stakeholders to effectively address P recycling from wastewater. In her analysis of the phosphorus flows through the food system of Wageningen, Jenkins (2014) however shows that solid waste flows are also important with regard to
Discussion

recycling and reuse of phosphorus.\(^{50}\) Just as with wastewater, large parts of the P contained in the solid waste streams get lost. Although both the household and non-household sectors contribute to the reuse of phosphorus in the form of compost, this amount is minimal compared to the amount of P incinerated and ending up in road works and other infrastructure (ibid.).

Having said that, it is interesting to note that the individuals working in the field of solid waste collection and processing (TWE1, ACV1, VGW1, MUN\(^{51}\)) are astonishingly poorly connected to others in the network, occupying very peripheral positions. There is no real sub-network on P recycling from solid waste in the investigated network as it is clearly the case for wastewater (sub-group 2). This is not to say that there are no activities going on in Wageningen that aim to increase the amount of solid organic waste being recycled – the municipality has ambitious plans with regard to that (Gemeente Wageningen 2012, Jenkins 2014). What it does suggest is that the focus on phosphorus as a single nutrient is apparently not that strong in the solid waste recycling community as it is in the wastewater community. This makes sense if one keeps in mind that, phosphorus does not have to be separately removed from organic waste – which is the case for wastewater in order to avoid discharge of P into water bodies and thus eutrophication. During this study, Jenkins and I however got the impression that solid organic waste might be an underestimated stream of P in the phosphorus recycling and reuse community.\(^{52}\) For instance, potential approaches to recycle the P fraction contained in solid organic waste (such as food waste) were not at all discussed at the symposium on “Phosphorus in a local circular economy” that took place in Berlin in January 2014. Only two out of more than 35 participants partly covered that topic; as opposed to a much larger number of participants who professionally deal with P recovery from wastewater. Accordingly, the discussions were quite biased towards solutions in that field. Our observation is also in line with the findings of Kalmykova et al. (2012: 1): In a study on the urban P flows through the City of Gothenburg in Sweden and relevant policies, she found that “solid waste incineration residues represent a large underestimated sink of phosphorus. Focusing on wastewater as the sole source of recovered phosphorus is not sufficient. […] The role of solid waste in nutrient management should be reconsidered and more whole system-oriented routes for sustainable disposal of biowaste assessed.”

The bias towards wastewater is most likely a reason why only one individual contacted during the snowball sampling referred to one other individual working in the field of solid waste collection and processing. The others that were included in the analysis, I researched myself. This, in turn, contributed to those network members that work in the field of solid waste being so poorly connected to the rest of the network.

If Platform Water Vallei en Eem may be a suitable actor to facilitate P recycling and reuse from wastewater of Wageningen, who could fulfil such a role for more P reuse from solid waste of Wageningen then? The results of the SNA do not allow to make any substantial propositions for this ques-

\(^{50}\) However, (Jenkins 2014) stresses that there is a high uncertainty in the solid waste flows originating from the non-household sector, both in terms of quantity and destination. Accordingly, the actual amount of P from solid waste streams could vary greatly.

\(^{51}\) As policy officer for environment and sustainability Wageningen Municipality, MUN1 has been involved in the development of the waste policy plan.

\(^{52}\) Although, Twence and Van Gansewinkel are part of the Dutch Nutrient Platform.
Jenkins (2014) however formulates strategies for more P reuse from solid organic waste. An actor who supports and consults municipalities on how to implement strategies to increase the amount of solid organic waste being recycled is the Vereniging Afvalbedrijven, a business association of waste management companies. Another potentially interesting stakeholder in this context is the Royal Dutch NRWV, the largest national waste management association in the Netherlands. It unites municipalities and the municipal waste management companies. In this platform, municipalities share best practices and exchange strategies with each other on how to effectively boost waste separation. Further investigation into their capacities, interests and objectives of this would be interesting, but was not conducted in this study due to time constraints.

6.2 Critical reflection of the research design

Timing for conduction of interviews

In chapter 3 I presented my research design based on the categorisation of Morgan (1998 in Bryman (n.d.)). The research design I employed in this study comes closest to the first type outlined by Morgan (Qual. → Quant.), which means that I first conducted the qualitative study (i.e. in-depth interviews), which was followed by the principal method of the study, namely the quantitative SNA. The purpose of the interviews was twofold: First, they were meant to help me (and my thesis colleague Jenkins (2014)) gain a first overview and background on the topic of phosphorus recovery and reuse, with a special emphasis on the situation in the Netherlands. Moreover, they were aimed at revealing the specific perspectives, drivers, motivations and interests of the various stakeholders as well as if and how they see a role for urban areas in this field. Second, the interviews were, at least in my case, part of the snowball sampling. The interviews proved to be very helpful to these ends – and in that sense it paid off to conduct them before conducting the SNA. Another advantage was that they increased the willingness of interviewees to respond to the network survey (response rate among interviewees was 100%). Furthermore, since the research was carried out in collaboration with a thesis colleague (Jenkins 2014), we intended to conduct interviews jointly so as to keep the efforts for interviewees as low as possible (otherwise, two interviews would have had to be conducted).

Nevertheless, a downside of conducting the interviews before the SNA was that I did not know beforehand which stakeholders would take which position in the network. Interviewing them after the network analysis and evaluating what they think about their network position as done by Prell et al. (2008) would certainly have delivered interesting results. I could have asked more specific and targeted questions about the potential implications of the results. Particularly, I did not know before which stakeholders would appear to take key positions in the network. Interviewing those key stakeholders about their potential role would have enabled me to find out if and how these stakeholders would like to use their position and what their specific visions regarding P recycling and reuse are.

This makes clear that the timing of the qualitative interviews depends on what is supposed to be achieved by them: In case one sets priority on (1) getting a first broad and general overview of the social system under scrutiny and the perspectives and interests of its relevant stakeholders and (2) ensuring a

53 Vereniging Afvalbedrijven was not included in the SNA since I decided to not include any business associations in the analysis.
high response rate for the network survey, the interviews should be conducted before the quantitative SNA. In case one prioritises the opportunity to deepen the investigation of key stakeholders and empirically explore their opinion regarding the outcomes of the SNA and their potential future role and capacities, then the interviews should obviously be conducted afterwards. In conclusion, I found it more useful to conduct the interviews before the SNA, because this enabled me to get information and hints to other relevant stakeholder that would otherwise have missed out of the analysis (such as the two members of the PWVE) and since it enabled me to get a very high response rate, which is a pre-requisite for a Social Network Analysis. More in-depth analysis of the identified key stakeholders can build on this foundation.

**Network survey**
As mentioned in chapter 3.1.2, the survey apparently allowed respondents to differently interpret the questions concerning information exchange. Some respondents also considered indirect communication (via reports) as information exchange. I however only considered direct communication (via email, meeting each other on networking events, etc.) as information exchange. This mistake could have been avoided by describing more precisely what is meant by information exchange in the first place, i.e. that direct contact is decisive.

**Network boundaries**
A major point of discussion concerns the definition of the network boundaries. For this study, I chose an approach that combines a top-down (list of potential stakeholder plus criteria for selection) and a bottom-up approach (snowball sampling) (see chapter 3.1.1). Although the criteria for selection in the network are clear and leave little room for interpretation, the network boundaries remain contestable and artificial. After all, the question of where one should set limits when collecting data on social relations that, in reality, may have no obvious limits (Barnes 1979 in Knoke and Yang 2008) cannot be objectively answered. It utterly depends on the specific research question and is prone to produce distortions of the resulting picture of social structure (Bodin and Prell 2011a). This study accordingly also carries the risk that the criteria were too strict so that stakeholders important for the network under study were left out of the analysis. Generally, Diani (1995 in Steinberg 2009) stresses that “it is advisable to err on the liberal rather than conservative side in setting boundaries”. Since the first two criteria defined in chapter 3 are quite strict, I might have rather erred on the conservative side. However, by defining the criteria that allowed the inclusion of individuals who are named at least three times by other network members, I offset this potential limitation and added a liberal component to the boundary.

On the other hand, the selection process might have been too liberal and led to the inclusion of individuals who actually might be irrelevant for recycling and reuse of urban P flows of Wageningen. For instance, one may raise the question why individuals from organisation such as Alterra, PRI, Soil Quality were included in the network analysis although they primarily deal with P from an agricultural perspective (given that this study is interested in urban P recycling). Again however, it is important to note that the boundaries are not clear-cut and it is difficult to judge the (potential) involvement of every single individual in issues relevant to urban P cycling. Although a person’s focus may lie on P cycling in an agricultural context, he or she might be a person that has the capacity to initiate a process towards more P recycling and reuse from urban P sources. This is for instance the case for nodes ALT4 and ALT7, who
acquired the urban P project in Amsterdam – they could potentially co-initiate such a project in Wageningen and/or the region as well.

By choosing the integrative approach (bottom up plus top down), I was able to account better for the fact that there is no formal network in the case of phosphorus recycling and recovery in Wageningen, but where particularly members of an informal network needed to be identified (Sandström 2011). First, the initial list of stakeholders ensured that for instance persons representing the solid waste management or animal feed production sector were included in the analysis. As discussed in section 6.1, this was not a given and those stakeholders could have easily been missed out since they are poorly or not connected to the rest of the network. By including them, the analysis gives a more complete picture and highlights the potential need and ways to involve those stakeholders in the network. Second, the snowball sampling method allowed me to uncover a number of interesting links of stakeholders with phosphorus recycling and reuse issues which were not apparent before. For instance, the primary expertise of ALT4 does not seem to lie in the field of P; in his publications, this topic does not explicitly appear. After I acquired the name through the snowball sampling, I did therefore not expect the person to occupy such a central position in the network. The person did, as mentioned above, acquire the Amsterdam project and has been described as a generalist, who displays typical attitudes of a broker with a broad network much more than other persons in the network (INT. SQ, 2013). In that sense, it fits that the person scores high in terms of Betweenness Centrality.

In contrast to other studies (e.g. Heinrup 2012), I decided to also include individuals in the network who were named only once during the snowball sampling. Although some of these individuals may not focus on or deal with phosphorus recycling as much as others, such peripheral and weakly connected stakeholders can be very important in terms of feeding in innovative ideas and unconventional perspectives. This is what Granovetter (1973) describes as the ‘strength of weak ties’. They can avoid the effect of social closure and group thinking that often hinder actors from reflecting on goals, norms, and rules (Newig et al. 2010).

**Individuals vs. organisations**

Another point worth discussing is the relation between individuals and organisations. Some studies in the field of natural resource governance and social network analysis choose entire organisations as the smallest social unit in their network analyses (e.g. Ernstson et al. 2010, Luthe et al. 2012, Ricke 2009, Vignola et al. 2013), while others investigated the relations between individuals (e.g. Heinrup 2012, Prell et al. 2011). For this study, I considered only the latter approach as useful. Especially in a large institution like Wageningen UR, where each scientist has worked in different projects and thus has his/her own network, it would have led to a high data inaccuracy if only relations between organisations would have been chosen. Often, not even close colleagues can give an accurate picture of the contacts of a person within an institution like WUR. In organisations such as the municipality, where relationships are more formalised due to a high degree of institutionalisation, it is much more likely that colleagues can report the network contacts of a colleague.

As mentioned in chapter 3.1.1, I therefore used the words ‘individuals’ and stakeholder exchangeably throughout this study. It is however important to realise that the degree to which individuals are free to
Discussion

choose P recycling and reuse as a topic varies greatly between the organisations that are represented in this network analysis. While researchers of Wageningen UR have a great deal of freedom in which topic(s) they specialise and deal with in their daily work, employees of organisations such as the water board and the municipality that hold certain responsibilities relevant to P recycling are much more restricted. That, in turn, means that also the representativeness of the individuals varies – if an employee of the municipality is weakly connected to the rest of the network, this is much more likely to be representative for the whole organisation than it is in the case of a WUR researcher and WUR. This needs to be borne in mind when using the findings of this study.

Benefits of the quantitative network analysis

The principle method applied in this study has been quantitative Social Network Analysis. I argue this method have had three main benefits and contributions:

First, the quantitative network analysis has been capable of grasping the structural communication and collaboration patterns of stakeholders relevant for P recycling and reuse in Wageningen. It could thereby go beyond formal institutional settings (cf. Lienert et al. 2013), which is especially relevant in the field of P recycling and reuse that is not only characterised by top-down centralised governance and implementation structures, but at this stage primarily by informal networks based on personal relations between individuals from public and private organisations. It thereby sheds light on some interesting and unexpected opportunities for how certain individuals can act as brokers between action and knowledge communities and different sub-groups within the network. These opportunities would, I argue, not have been identified by means of a simple stakeholder analysis that would primarily look at the attributes, interests and influences of stakeholders instead of their mutual relations.

Second, and related to that, SNA particularly acknowledges the role communication networks play in categorising and understanding stakeholder relationships and thereby addresses limitations of current methods for classical stakeholder analysis (Prell et al. 2009). Compared to current methods for stakeholder analysis, it does so on the basis of a fairly standardised and rigorously data collection procedure and set of analytical measures and is thus less prone to biases in the subjective assessment of stakeholders’ relative power and influence. I found it especially valuable to compare some of the initial findings and patterns from the in-depth interviews with the actual communication patterns revealed by the SNA and thereby to test some hypotheses based on the in-depth interviews.

Third, the network analysis further allowed me to identify the decentralised structure and fragmentation of the network into different sub-groups. These results give an indication of how capable the network is to coordinate joint action and how different stakeholders behave and communicate in the governance process towards more P recycling and reuse (cf. Bodin and Crona 2009). While some stakeholders seek to cross boundaries and connect with various actors of different kinds, others largely remain within their own community and show a great deal of homophily (the latter especially applies for the scientists of sub-group 3). The SNA was useful to highlight patterns of interaction that prevent communication. In doing this, the network members are advised on the strategic links they may need to make so as to overcome the isolation (Holman 2008).
Limitations

Besides the outlined benefits, I can highlight a number of important limitations of this study that point to recommendations for further research on network governance for local phosphorus recycling and reuse that will be outlined in chapter 7.

Considering the time that was available to conduct this study, coupled with the conduction of interviews, network survey design, and analysis this study is limited in its accuracy and scope. The findings therefore provide a general picture or impression of the communication and collaboration network of stakeholders relevant for phosphorus recycling and reuse in Wageningen.

Missing data was a limitation in this study, particularly regarding the questions for perceived influence and expertise of stakeholders and the future collaborations they are interested in. Many respondents did understandably not make a judgement about the perceived influence or expertise of persons they are not in contact with. Accordingly, people who are weakly connected within the network therefore tended to receive only few judgements. Some respondents also skipped the last question concerning future collaborations. Due to the missing data, the results on relational ties should be handled with care in terms of arguing from connections between individuals to connections between organisations. In about 30 cases, respondents stated to have a connection with another person, which was however not confirmed by that other person. It is, for instance, striking and surprising that node MUN1, the municipality’s policy officer who has been involved in the development of the waste policy plan is ACV groep’s contact person in the municipality, stated to not have a connection with the network member of ACV groep (ACV1), while ACV1 did state to have a tie with MUN1. MUN1, however, most probably does have another contact at ACV. This points to the possibility that the network survey question concerning linkages was differently interpreted by respondents – while some rather regarded themselves as representatives of their organisation and accordingly stated the linkages their organisations has with other organisations (like ACV1 apparently did in this case), others really only looked at the individual and stated whether they have contact with this special person or not. It is unfortunate that MUN1 in this case did not make use of the survey’s name generator to provide the name of his/her contact person at ACV groep.

Another limitation concerns the type of relationships investigated in this network study. In social networks, many different types of tangible (e.g. physical and financial flows) and intangible (e.g. trust and moral support) resources are exchanged (Hanneman and Riddle 2005), with the latter often being crucial but underestimated in collaborative processes for natural resource management. In this study, I did however not specifically differentiate between these different resources. I instead just investigated ties based on information exchange and collaboration, which usually contain both intangible (information) and tangible resources (funds). Considering and separately investigating (some of) these different resources in the network analysis would have provided a more detailed and thorough picture of the mutual dependencies among the network members and their potential for joint collaborative processes.

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54 ACV groep is the company that collects waste of households in Wageningen.
Conclusions and recommendations for further research

7. Conclusions and recommendations for further research

7.1 Conclusions

This thesis set out to investigate limitations and opportunities to advance recycling and reuse of phosphorus flows of Wageningen, the Netherlands, from a social network perspective. For this purpose, six sub-research questions were formulated, which will be answered in the following. First the members of the relevant governance network were identified. Subsequently, the structure of this network was analysed in order to assess its overall capacity to facilitate joint action, its sub-structuredness as well as the structural network position of individual network members. Furthermore, the study aimed to investigate the interests and capacities of the municipality to facilitate more P recycling and reuse.

Sub-research question 1 asked: Which stakeholders are part of the governance network relevant for recycling and reuse of phosphorus flows of Wageningen?

Conclusion #1: The governance network analysed for this study consists of 40 individuals from various organisations covering different sectors relevant in the field of phosphorus recycling and reuse, including the regional water board, the municipal and national government, various research & knowledge institutions, sewage sludge processors, waste collectors and waste management companies, animal feed processors and others. More than half of the individuals are scientists working for various research & knowledge institutions.

Sub-research question 2 asked what the status of key indicators is characterising the structure of the governance network. This structure was analysed on three levels: (a) a “global” level that focuses on the network population as a whole by the patterns of relations; (b) a “local” level that pays particular attention to the division of the network into sub-groups; and (c) a “individual” level that emphasises structural network features of individual stakeholders and identifies those with key positions in the network. Related to the latter, sub-research question 3 asked how the network members are perceived in terms of their influence and expertise regarding recycling and reuse of phosphorus flows of Wageningen.

Looking at the global level of the network structure, it has been shown that a strength of the network is its fairly high overall density with many both strong and weak ties between its members. Especially the core of the network displays a dense web of short channels for communication, which means that information can be transmitted very easily and quickly within this core. The core however mainly consists of scientists and lacks members of non-research institutions (i.e. action community), which limits its capacity to initiate and coordinate collaborative processes outside the scientific community. Although the network graph has a small-world character, which means that most of its members are able to connect with a small number of steps to the entire network, the results show that some of the stakeholders are structurally far away from each other. A structural weakness of the network is its relatively low centralisation – this compromises capacity to coordinate collective action. Given that the process of phosphorus governance in Wageningen has not really started, a higher centralisation with a central body that coordinates communication and collaboration between the various stakeholders would however be beneficial at this stage.
Conclusions and recommendations for further research

**Conclusion #2a:** The network displays multiple channels for communication and close collaboration between a large part of the stakeholders; its capacity for coordinating joint action is however limited.

Regarding the local level, the network appears to be fragmented into three sub-groups. The first sub-group is formed by employees of the municipality and a representative of the company that provides waste management services to the municipality. The two other sub-groups form thematic communities: One of them consists of individuals who deal with the recovery of phosphorus from wastewater, while the majority of the members of the other sub-group deal with phosphorus in an agricultural and soil management research context. While the latter two sub-groups are connected to each other via multiple strong linkages, the first (municipality and waste management) and the third (mainly scientists of WUR) are very weakly connected to each other; the municipality is connected to the second sub-group primarily via employees of the water board. Generally, the municipality appears to have very few and weak links with scientists regarding P recycling and reuse in the network. However, especially two individuals (an employee of the water board and a WUR scientist) appear to be bridging actors between these three sub-groups and could therefore help the different stakeholders initiate and support collaborative processes.

**Conclusion #2b:** The network is fragmented into three sub-groups and two isolates, with the municipality occupying a peripheral position and having only few links to the scientific community. However, communication between these sub-groups could be facilitated by two key individuals with broker positions.

Looking at the individual level, it becomes clear that a number of individuals affiliated to the Water Board Vallei en Veluwe and Wageningen UR occupy central positions in the network, by having either many linkages with other stakeholders, being a broker between peripheral and central network members individuals or possessing many ties to either action or knowledge communities. Additionally, some are rewarded high perceived influence and/or expertise with regard to recycling and reuse of phosphorus flows of Wageningen. The different key positions come along with different degrees and types of influence within the network. Not all network members who possess a central position in the network are awarded a high perceived influence by other network. Also, they do not necessarily have actual influence in decision-making processes (formal authority). Hence, I argue there are several dimensions of influence in the social network, which can derive from or relate to a person’s structural network position, reputation or formal authority. These different forms of power need to be taken into consideration in the further institutionalisation towards more P recycling and reuse in Wageningen, since they mutually rely on each other for the successful achievement of more P recycling and reuse.

**Conclusion #2c and 3:** The key individuals in the network possess different types of influence within the governance network and the decision-making process, which can derive from their structural network position, reputation or formal authority. These different forms of power need to be taken into consideration in the further institutionalisation towards more P recycling and reuse in Wageningen.

**Research question 4** asked: What are the interests and capacities of the Municipality of Wageningen with regard to advancing recycling and reuse of phosphorus?
The results also show that formal authority does not necessarily lead to a central network position. For instance, the employees of the municipality are very weakly connected to other network members regarding the P recycling and reuse. Although the municipality has formal competencies relevant to P recycling and reuse (i.e. building and maintaining the sewer system as well as collection of household waste), the topic is currently no real issue for the municipality and its capacities to facilitate it are limited. The interviews conducted for this study indicate that this applies to many other municipalities as well. Civil servants are commonly occupied with practical and operational tasks in a clearly defined range of duties, which leaves little time and space to freely pick up something exotic like phosphorus recycling. Moreover, municipalities lack direct influence over new housing developments (where new sanitary systems could potentially be installed), the processing of solid waste from private companies and due to the outsourcing of tasks like waste collection from households. Additionally, there are currently no financial incentives for municipalities to stimulate P recycling and reuse from wastewater. Nevertheless, the municipality is open for low-threshold solutions such as collecting urine at large events (Liberation Day) and promotes innovative sanitary technologies, for instance by installing vacuum toilets in the new town hall.

**Conclusion #4:** The municipality has currently low interests, incentives and capacities to initiate, facilitate and coordinate collaborative action of various stakeholders towards more P recycling and reuse; the topic plays only a minor role in municipal policies and administration.

Apart from describing the status quo, this study also explored the potential future role of other promising actors and municipalities to advance recycling and reuse of phosphorus flows. **Sub-research question 5** asked which stakeholders are potentially capable of facilitating more phosphorus recycling and reuse in Wageningen.

An organisation that lies at a strategically interesting position within the investigated governance network is the Platform Water Vallei en Eem (PWVE), a network organisation in which the Water Board Vallei en Veluwe and other municipalities from the region (including Wageningen) collaborate to improve the functioning and coordination of the (waste) water chain. The Platform has recently developed new strategic objectives, in which phosphorus recycling is explicitly mentioned. In this context, it strives to be trend-setting by implementing pilot projects as well as stimulating, facilitating and coordinating by connecting municipalities, water boards and other relevant actors such as business organisations. On this basis, I argue that the PWVE is a promising stakeholder that could take up the role of a bridging organisation, which strengthens and extends the governance network and links actors across various scales. In this function, it could for instance coordinate projects like purchasing a urine tank that is jointly used by the member municipalities to store urine collected at large events (Liberation Day in Wageningen, “Veluwse Dagen” in Barneveld, etc.) and subsequently used for struvite production.

**Conclusion #5a:** The Platform Water Vallei en Eem is suited to take up the role of a bridging organisation that facilitates and coordinates collaborative action towards P recycling and reuse from wastewater of Wageningen and other municipalities in the region.
Members of the governance network who work in the field of solid waste collection and processing are astonishingly poorly connected to others and occupy very peripheral positions in the network. They are also not connected among each other, which is why there is no sub-group on P recycling and reuse from solid organic waste (as it is the case for wastewater). The results suggest that the focus on phosphorus as a single nutrient is apparently not that strong in the solid waste recycling community as it is in the wastewater community. Business associations like the “Vereniging Afvalbedrijven” and the Royal Dutch NRWV, who collaborate with and unite various municipalities to enhance separated collection and processing of solid organic waste, might be stakeholders who could assist the municipality of Wageningen to increase the amount of phosphorus recycled from solid organic waste.

**Conclusion #5b:** The focus on phosphorus as a single nutrient is not as strong in the solid waste recycling community as it is in the wastewater community. Potentially promising organisations that could collaborate with the municipality of Wageningen are the Royal Dutch NRWV and the Vereniging Afvalbedrijven.

Based on the findings, I conclude that there are four ways for municipalities to foster P recycling and reuse. They can play a

- **Facilitative role:** Municipalities with sufficient capacities (usually large cities such as Amsterdam and Rotterdam) can facilitate and coordinate joint action for P recycling and reuse by initiating pilot projects and bringing various actors together, as has been done by the Municipality of Amsterdam (Reinhard et al. 2013, Thoden van Velzen et al. 2013).

- **Regulative role:** For instance by obligating project developers to setup a sewer system that separates grey from black water and thereby enables the installation of ‘new sanitation’ technologies. Municipalities can also condition the delivery of permits for large events such as festivals to separate urine collection and development of a centralised infrastructure to store the urine (urine tank) and recover struvite. This is planned by the Municipality of Amsterdam in collaboration with the brewery Heineken. Another important opportunity for municipalities is to formulate stricter guidelines for the selection of waste management companies so as to choose those ones who recycle solid organic waste and produce compost from it. This is already done by the Municipality of Wageningen. Furthermore, from 1 January 2014 onwards, livestock farmers are obliged to partly process manure on their farm. Especially smaller municipalities who have livestock farms within their borders (this however also applies to some larger cities such as Almere) can support P recycling from animal manure by granting the necessary environmental permission (‘milieuvergunning’) to local farmers. This also applies to other innovative business cases, which require special permissions.

- **Executive role:** In case Platform Water Vallei en Eem would coordinate a project like the “urine tank”, municipalities would still need to take over the actual execution of the necessary practical tasks. This role is especially relevant in the case of municipalities who do not have the capacity to develop the required expertise and coordinate such projects themselves.

- **Educative role:** All the above examples also have an educational aspect. By collecting urine on large festivals and produce struvite from it, municipalities can raise awareness for topics like nutrient scarcity. They can also implement innovative sanitary technologies within public buildings (as it is planned for the new town hall in Wageningen) and thereby set a good example.
**Conclusion #6:** In order to foster P recycling and reuse, municipal governments can play a facilitative, regulative, executive as well as educative role.

This study provides a revealing snapshot and thus basic understanding of how the governance network relevant for recycling and reuse of phosphorus flows of Wageningen looks like. By systematically analysing the relational patterns of the network members, the study gives valuable insights into opportunities and limitations that derive from the associated network structure. Moreover, it shows which stakeholders should take part in the further process in order to strengthen communication within the network and extend the network outwards as efficiently as possible. The findings complement the material flow model and strategies developed by Jenkins (2014) and thereby provide a more realistic and complete assessment of the potential and feasibility of ways to foster P recycling and reuse in Wageningen. Hence, the study highlights the social conditions that need to be met when technological options are to be realised.

### 7.2 Recommendations for further research

However, further research is needed in order to investigate the qualitative characteristics of the network linkages. For instance, this study did not look into the content of the communication between the stakeholders. That is, what exactly do the network members exchange? Similarly, it would be extremely useful to know why people (intend to) communicate with each other so as to understand the reasons for the network structure in greater depth. A qualitative approach should also explore power in the network more thoroughly and cross-check whether the quantitative indicators of influence and power used in this study – central network positions based on Degree and Betweenness Centrality – provide a realistic picture. Furthermore, a qualitative stakeholder analysis could investigate in more detail to what extent the identified key stakeholders are willing and able to more systematically facilitate and coordinate P recycling and reuse and what their strategies are to do so.

As outlined in the discussion, communication and collaboration patterns among individuals and organisations are not static, but change over time. Another promising line of research would therefore be to capture these dynamics and to investigate how the governance network emerges over time. Do the emerging network structures might coincide with behavioural changes of the individuals? Do certain stakeholders or sub-groups become particularly active in communicating with each other at different moments or in response to certain events/developments? Does the content of what is communicated through the linkages change over time? Does the Platform Water Vallei en Eem succeed with its strategic plans and evolves into a bridging organisation, stimulating the strengthening and extension of the regional network? Have the stakeholders established the connections they indicated to be interested in in the network survey? Such longitudinal studies have been conducted by e.g. Hermans et al. (2013).

Finally, it would be of high practical value to extend the analysis towards other relevant but so far mainly neglected sectors such as supermarkets, housing cooperations/project developers and educational institutions in order to explore what their potential role could be to contribute to P (or more general nutrient) recycling and reuse and how they could be involved in relevant network activities.
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Interviews


Appendices

Appendix 1: Phosphorus issues in the Netherlands

The national P balance
Like the majority of European countries, the Netherlands does not have any economically viable phosphate resources, which is why the country is entirely dependent on the import of mined phosphorus (P) from abroad (Van Enk et al. 2012). For 2005, the phosphorus balance for various subsystems in the Netherlands was calculated by means of a material flow analysis (MFA) (Smit et al. 2010). The subsystems included agriculture (arable farming, grazing animals and intensive animal husbandry), industry (feed, food and non-food products), households and waste disposal. According to this systematic assessment, the total import of phosphorus accounted for some 108 Mkg P, which includes both organic sources of phosphorus such as food and animal feed as well as inorganic phosphorus sources (e.g. mineral fertilisers and feed additives). This number increased to 115 Mkg P in 2008. Approximately 45% of the phosphorus imported into the Netherlands was again exported in the form of food for human consumption, as manure, and to a lesser extent as non-food products and waste. As a result, the national balance surplus amounted to some 60 and 51 Mkg P in 2005 and 2008, respectively. Table 10 gives a more detailed overview of the national phosphorus balance for the years 2005 and 2008.

Table 10: National phosphate budget in 2005 and 2008 in the Netherlands (Mkg P/a) (Smit et al. 2010).

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Products</th>
<th>2005</th>
<th>2008</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Import</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>Fertiliser</td>
<td>21.0</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td>Living animals</td>
<td>0.21</td>
<td>0.22</td>
</tr>
<tr>
<td>Industry</td>
<td>Feed</td>
<td>50.4</td>
<td>60.1</td>
</tr>
<tr>
<td></td>
<td>Food</td>
<td>28.0</td>
<td>31.1</td>
</tr>
<tr>
<td></td>
<td>Non-food</td>
<td>1.4</td>
<td>3.3</td>
</tr>
<tr>
<td></td>
<td>Feed additives</td>
<td>7.2</td>
<td>8.1</td>
</tr>
<tr>
<td><strong>Total import</strong></td>
<td></td>
<td><strong>108.2</strong></td>
<td><strong>114.8</strong></td>
</tr>
<tr>
<td><strong>Export</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>Manure</td>
<td>7.0</td>
<td>12.8</td>
</tr>
<tr>
<td>Industry</td>
<td>Food</td>
<td>37.5</td>
<td>47.6</td>
</tr>
<tr>
<td></td>
<td>Non-Food</td>
<td>1.3</td>
<td>1.2</td>
</tr>
<tr>
<td>Waste</td>
<td>Waste</td>
<td>2.7</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>Total export</strong></td>
<td></td>
<td><strong>48.5</strong></td>
<td><strong>63.6</strong></td>
</tr>
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<td><strong>Balance surplus</strong></td>
<td></td>
<td><strong>59.7</strong></td>
<td><strong>51.2</strong></td>
</tr>
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</table>

55 According to De Buck et al. (2012), the reduction of the phosphorus surplus was a result of the decreased use of mineral fertilisers and the increased export of manure, combined with the increased net import of the industry.
In other words, around half of the total amount of imported phosphorus remains in the country in one form or another. What are the reasons for that and where does this remainder end up?

**Livestock farming and P-saturated soils**

The bulk of the national phosphorus surplus can be attributed to the large amounts of imported animal feed into the agricultural sector, which is typical for those countries, including the Netherlands, Belgium and Denmark, that produce vast quantities of meat, poultry and dairy products (relatively to the amount of agricultural land available) and who depend on the import of animal feed to feed their livestock and poultry (Van Enk et al. 2012). Due to intensive livestock farming, the production of manure in the Netherlands accounted to some 58 Mkg of P in 2010, of which slightly more than half was used as fertiliser at the farms where it was produced. The other half was sold to the agricultural sector via the manure market (40%), exported abroad (30%) or processed (incinerated or taken up by other sectors in the Netherlands) (approx. 20%); 10% were taken up outside the agricultural sector (De Koeijer, Hoogeveen and Luesink 2011). For 2 to 3.5 Mkg of P, there were no purchasers found. In general, such a surplus would then come on the manure market in the following year, increasing the pressure on the manure market and thereby resulting in relatively high charges for manure removal.

The highest amount of phosphorus “production” from animal manure occurs in areas with high concentrations of livestock farming: the eastern part of Noord-Brabant and the Western Veluwe (CBS, PBL and WageningenUR 2013b). Since farmers have to pay for manure removal via the manure market, they will instead apply the maximum amount of manure that is permitted by law onto their own land. Besides manure, Dutch farmers apply another 12 Mkg of phosphorus in the form of mineral fertilizer (Vergouwen 2010). Consequently, and taking account of other flows as well, half of the national phosphorus surplus accumulates in agricultural soils as less available forms of phosphorus (Smit et al. 2010). Soil analyses conducted in the 1990’s show that 56% of the arable land in the Netherlands is therefore saturated with phosphorus (see Figure 11). According to calculations by Van Enk et al. (2012), the accumulated amount of phosphorus in the topsoil layer is equal to about 40 years of the current consumption of inorganic phosphorus fertilisers. It is estimated that fertilisation with phosphorus would actually not be required at all on 35% of the agricultural land in the Netherlands.

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56 The maximum amount of manure that is permitted to be applied on land is regulated in the “Usage norm for manure” (“gebruiksnorm voor dierlijke mest”). In general, this norm prescribes that no more than 170 kilo of nitrogen per hectare may be applied to agricultural soils (derogation companies may use 250 kilo of nitrogen per hectare). Next to this usage norm, there are the nitrogen usage norm and the phosphate usage norm, which prescribe different amounts depending on the type of land that is to be fertilised. For more information, see: http://www.drloket.nl/onderwerpen/mest/dossiers/dossier/gebruiksruimte-en-gebruiksnormen/gebruiksruimte-dierlijke-mest-en-derogatie/berekening-gebruiksruimte-dierlijke-mest

57 Phosphate tends to co-precipitate with various minerals that naturally occur in the topsoil layer and to adsorb on their surfaces. The primary phosphate mineral, apatite, is slowly broken down by weathering and subsequently transformed into a fixed and occluded phosphate pool, which is hardly available for plants. The longer phosphate remains in the topsoil, the more of it co-precipitates and adsorbs and the less will therefore be available for uptake by plants. According to Van Enk et al. (2012), this process is the reason why only 60% of the agricultural phosphorus consumption in the Netherlands is effectively used for the production of crops, animal products and animal feed.
Eutrophication of water bodies
While one half of the national phosphorus surplus accumulates in agricultural soils and contributes poorly to crop food supplies, the other half accumulates in water bodies (groundwater, rivers, lakes, etc.) and is sequestered. As mentioned above, excess phosphorus in surface water, which in the Netherlands originates equally\(^58\) from the leaching and runoff from agricultural land and from the effluent of wastewater treatment plants\(^59\) (Smit et al. 2010), contributes to eutrophication of water ecosystems and can have detrimental effects on the quality of drinking water reserves. Large parts of the surface water in the Netherlands do not comply with desired the European Water Framework Directive (2000/60/EC), among others due to their high amount of nitrogen and phosphorus\(^60\) (CBS, PBL and WageningenUR 2012b). Relatively high concentrations of phosphorus in surface water, originating from agricultural land, occur not only in clay- and peatlands (Western and Northern parts of the country with soils that are by nature richer in nutrients), but also in sandy areas. Especially the sandy areas in Noord-Brabant and the Veluwe area are saturated, as mentioned earlier, yet simultaneously hold important drinking

\(^{58}\) In 2005, the total emission of phosphorus to surface water amounted to some 7 Mkg P. Approximately 47% (3.3 Mkg P) of this could be attributed to leaching from agricultural land, while the remainder originated from non-intercepted phosphorus from communal and industrial wastewater treatment plants (Smit et al. 2010).

\(^{59}\) About 75% of the residential wastewater is treated, while the remaining quarter drains into surface water.

\(^{60}\) Regarding the standardisation of nutrients in surface waters, critical concentrations (maximum acceptable concentrations – MAC values) for standing waters (primarily lakes and ponds) have been defined, since they are most sensitive to eutrophication. Summer averages must not exceed 0.15 mg/l total-phosphorus. These values can differ for water types less sensitive to eutrophication, such as small water bodies and large rivers that are located further upstream. Further, the European Water Framework Directive differentiates between natural bodies of surface waters and heavily modified or artificial bodies of water, for which it defines a “good ecological status” (GES) and a “good ecological potential” (GEP), respectively. Next to the MAC values, there are thus also GES and GEP values for the different water types. For a detailed list of the values, see Schoumans, Willems and Van Duinhoven (2008).
water reserves (CBS, PBL and WageningenUR 2013a). The accumulation of phosphorus in the sandy areas has reached a critical level where it is leached into groundwater and thereby affecting drinking water quality (Vergouwen 2010).

**Accumulation of toxic metals**
As outlined above, most mineral phosphorus fertilisers contain rather high concentrations of toxic heavy metals such as cadmium. This issue is increasingly becoming relevant in the Netherlands: Since these toxic metals also tend accumulate in the topsoil layer, a considerable amount of agricultural soils in the Netherlands is significantly enriched with cadmium and zinc and thus pose a risk to food safety. Especially in the central and northern parts of the Netherlands (sandy soils), this is mainly related to agricultural practices (Van der Vee 2006).

![Figure 12: Density corrected absolute enrichment of Cd and Zn (mg/kg) in the Netherlands (Van der Vee 2006).](image)

**Other P losses**
Next to the described losses of phosphorus (leaching and runoff, accumulation), Smit et al. (2010) point out that there are so-called ‘missed opportunities’: potentially recoverable P-flows, which are however not returned to agricultural land. One example is sewage sludge that is currently mainly incinerated\(^6\), among others due to concerns of contamination with heavy metals. Also, the performance of water treatment plants is only benchmarked in terms of the effluent quality (not in terms of how much phosphorus they recover), which is why they primarily aim to generate an effluent that contains as little phosphorus as possible in order to minimise the pollution of surface waters with nutrient. In Dutch wastewater treatment plants, some 14 Mkg of phosphorus are annually removed from residential and

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\(^6\) In the Netherlands, about 60% of the sewage sludge is incinerated (Kalmykova et al. 2012). The incinerated ash is subsequently used in the cement industry, road construction, and the brick industry (Van Enk et al. 2012).
industrial wastewater.\(^{62}\) Having in mind the amount of imported phosphorus that is utilised as mineral fertiliser (12 Mkg P in 2008), it becomes apparent that phosphorus recovery from wastewater could significantly contribute to closing the P loop (Vergouwen 2010). Another major loss of phosphorus in the Netherlands is through the destruction of dead animals and slaughter waste, particularly the bones that are rich in phosphorus. Due to hygiene regulations (in relation to BSE ‘mad cow’ disease), almost half of the P in bones is incinerated. Moreover, the practice of incinerating and landfilling of P containing residues from the food and feed industry as well as from households (such as food or garden waste\(^ {63}\)\(^ {64}\)), are other factors that explain the low efficiency of phosphorus use in the chain from mine to fork.

In the light of the large quantities of phosphorus that are either lost or not recovered, it becomes apparent that phosphorus is not yet treated as a valuable and finite resource in the Netherlands. Smit et al. (2010) point out that although “it appears as if the Netherlands is less dependent on mineral P-fertiliser (because of its surplus) it must be realised that most of the P-rich feed that is imported from other countries (e.g. Brazil), could only be produced with the input of fertiliser itself. Therefore, Dutch agricultural activities are equally dependent on the use of mineral P-fertiliser.”

**Possibilities for more sustainable phosphorus use**

In spite of the aforementioned issues, there have been positive developments with regard to phosphorus in the past decades, too. In an attempt to respond to the large phosphorus surplus and to reach a balance between input and output of P, the Dutch government in 1984 and 1987 introduced regulations\(^ {65}\) that were, among others, dedicated to reduce the amount of phosphate from animal manure. This led to a gradual decrease of the phosphorus surplus on agricultural land (52% between 1986 and 2011; see Figure 13) (CBS et al. 2008). The reduction was further accelerated by a decreasing consumption of inorganic sources of phosphorus such as feed additives\(^ {66}\) and detergents as well as mineral P-fertiliser. Furthermore, the standards for phosphorus of livestock were lowered. Another reason for the decreased consumption of inorganic P sources was the reduction of phosphorus in detergents so as to prevent eutrophication of surface waters. All in all, 75-89% of the lowered P input in freshwater streams since 1986 can be attributed to efforts from industry and communities (including process improvements in wastewater treatment plants), and only 12% to measures undertaken in agriculture. In 2006, the Dutch government replaced the existing regulations through a new legislative framework (Fertiliser Act), which requires farmers to further reduce their application of major nutrients such as phosphorus (Van

\(^ {62}\) About 80% originates from human faeces and urine (Vergouwen 2010).

\(^ {63}\) In Dutch GFT-afval (groenten-, fruit- en tuinafval)

\(^ {64}\) According to Smit et al. (2010), some 10.4 tonnes and 7.5 tonnes of P are incinerated and landfilled, respectively, on an annual basis in the Netherlands.

\(^ {65}\) “Beschikking Superheffing” (from 1984) and “Mestwetgeving” (from 1987)

\(^ {66}\) The decreased need for feed additives was a result of the introduction of phytase in feed for pigs and chickens. Phytase is an enzyme that increases the uptake of phosphorus from feed, so that 25% less phosphorus has to be added to the feed (Schoumans et al. 2008).
Enk et al. 2012). To enable this, there are numerous actions currently carried out, which are however focused on agriculture and thus less relevant for the scope of thesis.  

Figure 13: Uptake of phosphorus on agricultural soils and groundwater, historical development during the last three decades (CBS, PBL and WageningenUR 2012a).

All these measures make clear that government policy has so far mainly focused on balancing the use of phosphorus by making its use more efficient, but were not directed toward recycling of available phosphorus sources as such. However, this is what a more sustainable use of phosphorus requires as well. So far, most of the recycled phosphorus in the Netherlands originates from animal manure, by-products from food production as well as plant and animal by-products. Other potential sources for the recovery of phosphorus include human urine and wastewater. Phosphorus from human urine can be precipitated by evaporation or after precipitation into struvite. This however requires a modified sanitation system that separates urine and faeces. Several projects to this end are currently in place on a local scale. A major hindrance to this practise is that struvite, although the technology is fully available, is still not permitted as an agricultural fertiliser in the Netherlands, while it is already widely used in Japan. Studies have shown that struvite has better fertilising qualities than conventional commercial fertilisers (Van Enk et al. 2012).

As explained in 1.2.6., phosphorus from wastewater is usually recovered after precipitation into struvite or calcium phosphate. In the Netherlands, there is currently only one plant that produces calcium phosphate pellets from sewage influent (Geesmerambacht sewage works). Until 2012, the phosphate recovered from these pallets used to be added to the phosphate rock feed at the Thermphos furnace operation in Vlissingen (ibid.), the main production site of Thermphos International. The company produced different phosphorus containing products such as phosphorus derivatives, phosphoric acid, phosphates

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67 They include: reduced phosphate content in feed concentrates; reduced import of dietary phosphates; reduced use of phosphate from mineral fertilisers; treatment of manure and other biosolids; phosphorus recovery (for a more detailed overview, see Van Enk et al. (2012)).

68 An overview of projects on ‘New Sanitation’ systems in the Netherlands supported and carried out by STOWA (Foundation for Applied Research on Water Management) is given here: http://nieuwesanitatie.stowa.nl/Projecten/index.aspx?pld=1340
and phosphonates and had the ambition to completely use waste streams (such as sewage sludge and bone meal) in the production process by 2020. However, Thermphos was declared bankrupt in 2012 (Thermphos-International 2012).

If the recycling rate of phosphorus is to be increased in the Netherlands, current regulation both at the national and EU level, for instance regarding the use of struvite in agriculture, needs to be reviewed. Smit et al. (2010) underline that the recycling of phosphorus will have consequences for agriculture. In the short term, the national P surplus will be higher for agriculture. This will require adaptations in one way or another, such as more export of manure or recycled phosphorus, less livestock, less fertiliser use, or less imported animal feed.
Appendix 2: Network survey

Fosfaatrecycling en -terugwinning - Master thesis onderzoek

1. Introductie

Geachte heer, mevrouw,

In het kader van mijn afstudeeronderzoek werd u aanbevolen te behoren tot een netwerk van individuen die relevant zijn voor de fosfaatrecycling en -terugwinning in Wageningen. Ik wil u hierom verzoeken om deze online enquête in te vullen, wat niet meer dan 10 minuten van uw kostbare tijd in beslag zal nemen.

Doel

Het overkoepelende doel van mijn Master thesis is het identificeren van mogelijkheden om een duurzamer gebruik van fosfaat vanuit een gedichtelijk perspectief te faciliteren. Wageningen is hierbij mijn case study. Hierdoor voer ik een sociale netwerkstudie uit. Ik wil hiermee het communicatienetwerk van individuen in kaart brengen welke invloed (indirect of direct) hebben op fosfaatrecycling en -terugwinning in Wageningen. Sociale netwerk analyse (SNA) biedt zowel een visuele en wiskundige analyse van menselijke relaties.

Anonimitiet, gebruik van resultaten, feedback

- Om in kaart te brengen wie met wie praat, heb ik uw naam nodig, de enquête zal dus NIET anoniem zijn. Ik garandeer u echter dat er geen namen van individuen in de uiteindelijke versie zullen worden genoemd.
- De data die met behulp van deze enquête wordt verzameld zal uitsluitend voor mijn afstudeerscriptie gebruikt worden. Deze zal digitaal in de bibliotheek van de Wageningen Universiteit beschikbaar zijn. Er worden geen beleidsgerelateerde documenten of rapporten op basis van de uitkomsten van deze enquête geschreven.
- Indien u graag individuele feedback over uw positie in het netwerk wilt krijgen, kunt u dit aanvinken aan het einde van de enquête.

Voor vragen over de enquête kunt u contact met mij opnemen via e-mail op timo.eckhardt@wur.nl of telefonisch op nummer 06 855 498 19.

Zodra de data is verzameld zal ik de sociale netwerk kaarten als volgt construeren:
Appendices

**Fosfaatrecycling en -terugwinning - Master thesis onderzoek**

### 3. Informatie-uitwisseling

3.1 Kruis het juiste vakje aan bij de stakeholders van wie u INFORMATIE ONTVANGT welke relevant is op het gebied van fosfaatrecycling en -terugwinning.

3.2 Kruis het juiste vakje aan bij de stakeholders aan wie u INFORMATIE VERSTREKT welke relevant is op het gebied van fosfaatrecycling en -terugwinning.

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Rol</th>
<th>1: Ik ontvang informatie van</th>
<th>2: Ik verstrekt informatie aan</th>
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<tbody>
<tr>
<td>Henk de Vries, Organisatie X, Manager</td>
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<tr>
<td>Jan Janssen, Organisatie Y, Medewerker</td>
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<tr>
<td>Ella Molenveld, Organisatie Z, Bestuursvoorzitter</td>
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</table>

Zijn er nog andere stakeholders met wie u informatie uitwisselt die relevant zijn m.b.t. fosfaatrecycling en -terugwinning in Wageningen? Voeg deze aantekening toe hoe vaak en toon aan of uw informatie ontvangen of verstrekt (nee=0 en ja=1). *** Voorbeeld: Ik ontvang informatie, maar verstrekt zelf geen informatie. "Henk de Vries, Organisatie X (1,0)"

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### 4. Invloed

Op een schaal van één tot vier, beoordeel de INVLOED van elk van de stakeholders op het gebied van fosfaatrecycling en -terugwinning.

>>> één staat voor een erg hoge invalvoed en vier voor een erg hoge invalvoed

>>> Invloed betekent: Uw mening over het vermogen van de andere organisaties om het gedrag van uw organisatie te beïnvloeden.

>>> Voorbeelden hiervan zijn: vermogen om overkoepelende beslissingen te nemen/voorzien, belangrijke speler in uw sector, verspreiding van informatie/kennis.

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<thead>
<tr>
<th>Stakeholder</th>
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Zijn er nog andere stakeholders die volgens u relevant zijn m.b.t. fosfaatrecycling en -terugwinning in Wageningen? Voeg deze aantekening toe (ideaal met contactpersoon) en beoordeel hun invloed. *** Voorbeeld: Stakeholder X heeft relatief weinig invloed t.a.v. fosfaatrecycling en -terugwinning. "Stakeholder X (2)"
Appendices

Fosfaatrekcyling en -terugwinning - Master thesis onderzoek

5. Deskundigheid

Op een schaal van één tot vier, beoordeel Hoe Deskundig elk van de stakeholders naar uw inschatting is op het gebied van fosfaatrekcyling en -terugwinning.

>>> één staat voor erg weinig deskundig en vier voor zeer deskundig

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Zijn er nog andere stakeholders die volgens u relevant zijn m.b.t. fosfaatrekcyling en -terugwinning in Wageningen? Voeg deze afstublief hier toe (ideaaliter met contactpersoon) en beoordeel hoe deskundig zij zijn. *** Voorbeeld: Stakeholder X is zeer deskundig op het gebied van fosfaatrekcyling en -recycling. ”Stakeholder X (4)”

Fosfaatrekcyling en -terugwinning - Master thesis onderzoek

6. Toekomstige samenwerking

Kruis het juiste vakje aan bij de stakeholders met wie u in de TOEKOMST graag wilt SAMENWERKEN en informatie uitwisselen op het gebied van fosfaatrekcyling en -terugwinning.

>>> Alleen als u tijd en middelen in deze informatie-uitwisseling en samenwerking wilt investeren!

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<thead>
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<th>Name</th>
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<tbody>
<tr>
<td>Henk de Vries, Organisatie X, Manager</td>
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<tr>
<td>Ella Molenveld, Organisatie Z, Bestuursvoorzitter</td>
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</table>

Zijn er nog andere stakeholders die volgens u relevant zijn m.b.t. fosfaatrekcyling en -terugwinning in Wageningen en met wie u in de toekomst informatie uitwisselen of samenwerken? Voeg deze dan afstublief hier toe (”Stakeholder X, naam indien bekend”)
Appendix 3: Exemplary topic list for interviews

- Rol van steden bij nutrientenbeheer
  o Solid waste
    ▪ Bijdrage
    ▪ Wat zou hier verbeterd kunnen worden?
  o Afvalwater
    ▪ Struviet
  o Gemeente invloed
    ▪ Kleine gemeenten / grote gemeenten
  o Drivers cities for action
- Match supply and demand
  o Welk schaalniveau?
- Actoren
  o Samenwerking tussen verschillende actoren lokaal / regionaal niveau
  o Concrete namen
  o Key actors op regionaal niveau
- Nexus: food, water en energy
  o Conflictende doelen?