Land banking in land consolidation processes in a regional context

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Abstract

Regional governments are responsible for nature development since 2007. Through differences between regional governments, the priority of land banking and land consolidation processes for nature development differs. As a consequence, this thesis researches the effectiveness of land consolidation for nature development in response to the share of parcels that a land bank of a regional government holds. Therefore, a model is built to simulate the effectiveness of land banking in land consolidation processes for nature development. The model shows a polynomial effectiveness where an increasing amount of land in the land bank extends the obtained amount of parcels in a planned enlargement zone of a nature area till an optimum. The research of modelling land banking in land consolidation processes concludes that a form of a land bank increases the land exchange for developing nature, certainly when nature organisations or other stakeholders play a role in the land exchange.

Keywords: land banking; land consolidation process; nature development; regional government; model

Summary

The demand for interconnected nature reserves in the Netherlands (Koomen, Kuhlman, Groen, & Bouwman, 2004), requires land consolidation in order to obtain large, contiguous areas of nature. Through differences in political and cultural backgrounds and budget constraints, the transfer of the land bank of BBL to the regional governments leads to a different extent to which regional policies prioritise land acquisition, land consolidation processes and nature development (Kuindersma et al., 2015; Van Straalen, Van den Brink, & Van Tatenhove, 2016). This distinction between regional governments implies different implementations of land banking and land consolidation in spatial policies, especially regarding nature development. Therefore this thesis researches the effectiveness of land consolidation for nature development in response to the share of parcels that a land bank of a regional government holds.

To test land banking in land consolidation processes a model is built with the general idea to enlarge a nature area within an agricultural area by exchanging parcels between a nature organisation and farmers, with a land bank of the regional government as an intermediate party. The effectiveness of land consolidation is measured by the eventual amount of parcels in possession of the nature organisation within a planned enlargement zone of a nature area relative to the total amount of parcels within the planned enlargement zone. The variables tested in the model are the amount of parcels in the land bank, the various degrees of dispersion of parcels of a farmer and the amount of farmers.

To answer the research questions how land banking affects the effectiveness of land consolidation, the total number of parcels in the land bank is compared to the percentage of the number of parcels in possession of the nature organisation in the planned enlargement zone of the existing nature area. Herein, the percentage of parcels in possession of the nature organisation in the planned enlargement zone is increasing with the increase of parcels in the land bank. The results show polynomial lines for all scenarios with the different amounts of farmers and various degrees of dispersion. These polynomial lines have an optimum. Besides, the model shows that when the degree of dispersion is high, the effectiveness of a land bank is higher, than when the fragmentation of agricultural parcels is low. Also, when the amount of farmers is smaller and thus the farm size is larger, the effectiveness of land banking on land consolidation is lower. The research of modelling land banking in land consolidation processes concludes that a form of a land bank increases the land exchange for developing nature, certainly when nature organisations or other stakeholders play a marginal role in the land exchange. However, a general conclusion regarding land banking in land consolidation processes cannot be made, because every area differs from each other due to the absolute and relative characteristics of a parcel, the different types of stakeholders and the economic mechanisms of the rural market which were simplified in the model. Therefore, tailored policies regarding land banking are needed to have a high effectiveness of land banking in land consolidation processes.

1. Introduction

1.1 Societal Relevance

The demand for interconnected nature reserves in the Netherlands (Koomen et al., 2004), requires land consolidation in order to obtain large, contiguous areas of nature. Land consolidation processes (Dutch: '*Ruilverkavelingsprocessen*') are reallocation procedures of parcels in order to improve the land division (Sonnenberg, 2002; Vitikainen, 2004). In the Netherlands, the Bureau Land Management (Dutch: '*Bureau Beheer Landbouwgronden* (BBL)'), was responsible for the buying, temporarily management and selling of land for nature development projects assessed by the government (Rijksoverheid, 2014). In the land consolidation processes, BBL actively acquired and exchanged land (i.e. land banking) to reach nature policy goals like the National Ecological Network, currently named as Nature Network Netherlands (NNN) (Kuindersma et al., 2015; Pleijte, Kuindersma, Hettinga, & Tepic, 2014; Westerink et al., 2010). Since 2007, the national government changed the direction and execution of land-oriented policies, whereby more responsibilities are handed over to the regional governments, i.e. the provinces (Boonstra, Bruil, Fontein, & De Haas, 2014; Kamphorst & Selnes, 2007; Slangen, Polman, & Jongeneel, 2008). Hereby, the regional governments took over the responsibility for nature developments including the tasks and the land bank of BBL (Kuindersma et al., 2015; Pleijte et al., 2014; Rouwenhorst, 2015).

Through differences in political and cultural backgrounds and budget constraints, the transfer of the land bank and tasks of BBL to the regional governments leads to a different extent to which regional policies prioritise land acquisition and nature development (Kuindersma et al., 2015; Van Straalen, Van den Brink, & Van Tatenhove, 2016). Therefore, the transfer of the parcels causes different approaches of land and nature policies by the regional governments (Kuindersma et al., 2015; Van Straalen et al., 2016). As a result, some regional governments choose to sell land while others choose to invest in land in order to reach nature policy goals (Kuindersma et al., 2015; Kuindersma et al., 2017). Some regional governments even started their own land development department, mostly in the form of a land bank (Van Straalen et al., 2016). This distinction between regional governments implies different implementations of land banking and land consolidation in spatial policies, especially regarding nature policies like the NNN. Therefore the question arises what amount of land a land bank of a regional government needs to hold to use land banking for nature development.

Besides the distinction between the regional governments, agricultural trends may lead to differences in the application of land banking to develop the NNN in the rural areas in the Netherlands. First, the decrease of farmers seems to lead to an increase in farm size and therefore in landownership change (CBS, 2017; Koomen, Kuhlman, Groen, & Bouwman, 2004). Second, when an optimum of the parcel distribution for a farmer has been reached by for instance land consolidation processes in the past or by the rural market, the exchange of parcels will be more difficult, though the farmer may not be willing to exchange his/her parcels. Thus, the parcel distribution can be described as an extent of dispersion of parcels around a farm. To conclude, the number of farmers and the existing degree of dispersion affect the effectiveness of land banking for nature development in land consolidation processes.

1.2 Scientific relevance

The research topic of land consolidation processes in the Netherlands has been part of many qualitative researches (Andela, 2000; Lambert, 1961; Van den Bergh, 2004; Van den Brink & Molema, 2008; Van den Noort, 1987; Vitikainen, 2004). However, most of these researches describe the history of land consolidation processes. Since the regional governments became responsible for nature development, land consolidation processes are hardly researched in the light of these developments. Besides, there is a decreasing interest in the use of land consolidation processes (Boonstra, Bruil, Fontein, & De Haas, 2014). Land banking as an instrument used within land consolidation processes or to reach public-oriented purposes like nature development in rural areas is hardly researched as well. When researched, it is researched qualitatively. (Damen, 2004; Hartvigsen, 2015; Spit, 2016; Van Dijk & Kopeva, 2006). However, a qualitative study does not provide answers to the problem statement. Although the interest in land banking is substantial considering a number of inventories and reports, the amount of scientific research is limited (Westerink et al., 2010).

Therefore, research needs to be done to have better insights in the use of land banking in land consolidation processes with the increased responsibilities of regional governments in spatial policies. One way to gain knowledge in land banking and land consolidation in cases where empirical observations are scarce is modelling. Modelling can increase the knowledge of land banking because several societal and physical aspects can be kept constant. Models have been used to simulate land exchange within land consolidation processes. Examples are the ATOR-model of Lemmen and Sonnenberg, the reallocation model of Ayranci and the RULEX-model of Bakker et al. (Ayranci, 2007; Bakker, Alam, Van Dijk, & Rounsevell, 2015; Lemmen & Sonnenberg, 1986). However, looking at the instrument of land banking, no quantitative researches are found to simulate land banking in land consolidation processes. Nevertheless, modelling seems to fit to research and experiment with the amount of land in a land bank of a regional government in land consolidation processes.

1.3 Objective and Research Question

1.3.1 Objective

The goal of this thesis is to research the effectiveness of land consolidation for nature development in response to the share of parcels that a land bank of a regional government holds. The effectiveness of land consolidation will be measured for various degrees of dispersion of parcels of a farmer and various amounts of farmers.

1.3.2 Research Question

Main research question:

"How does the amount of parcels in a land bank of a regional government affect the effectiveness of land consolidation?"

Sub-questions:

"How do various degrees of dispersion affect the effectiveness of land consolidation in relation to land banking?"

"How do various amounts of farmers affect the effectiveness of land consolidation in relation to land banking?"

1.4 Approach

To test land banking in land consolidation processes a model is built to get more insights. Modelling is a specific way of researching, but there are several reasons why using modelling. First, because of the complexity of land consolidation processes, a model is used to keep specific variables constant, so the results are relating to the tested variables. These parameters are needed because land consolidation processes are complex. Namely, besides the physical structure also the well-being of the entire community of the rural areas in the Netherlands was taken into account (Lambert, 1961). Second, it is impossible to do an empirical research, because the amount of farmers and the landownership of parcels cannot be varied in the field. Third, in this particular research, the model provides quantitative data on the topic of land banking, which will make a valuable contribution to the existing body of largely qualitative research-based literature.

2. Concepts

2.1 Land consolidation process

A land consolidation process means a comprehensive reallocation procedure to consolidate parcels in a rural area to improve the land division, where the exchange of the rights of ownership and the use of the land are the key driving forces behind land consolidation (Ayranci, 2007; Sonnenberg, 2002; Vitikainen, 2004). Specific characteristics of land consolidation are a limited area, i.e. the land consolidation space; a project-oriented structure and the fact that the benefits gained are considered larger than the costs of the implementation (Lemmen & Sonnenberg, 1986; Sonnenberg, 2002; Vitikainen, 2004). In reality, a commonly accepted definition does not exist (Hartvigsen, 2015). Through the years the meaning and even the term itself changed (Kamphorst & Selnes, 2007; Van den Bergh, 2004). In the 20th century, the meaning of land consolidation was to reunite scattered parcels of farmers to overcome structural problems such as fragmentation of parcels and holdings of farmers, accessibility and drainage problems (Ayranci, 2007; Lambert, 1961; Van den Noort, 1987). The fragmentation of parcels and holdings of farmers was one of the main drivers for land consolidation processes. 70 percent of the Dutch rural areas were occupied in land consolidation processes, where certain rural areas were part of several land consolidation processes (Van den Bergh, 2004).

Recently, land consolidation is used to reach nature policy goals such as the development of the Nature Network Netherlands or National Ecological Network (*Dutch: 'Natuurnetwerk Nederland (NNN)'* or 'Ecologische Hoofdstructuur (EHS)') (Kuindersma et al., 2015). Under the Dutch rural development act (Dutch: 'Wet Inrichting Landelijk Gebied (WILG)') that was applied in 2007, two instruments have its place considering land consolidation: legal land consolidation and land consolidation by agreement (Boonstra, Bruil, Fontein, & De Haas, 2014; Kamphorst & Selnes, 2007; Kool, 2013). Since the 'WILG', only eight legal land consolidation processes are started and 15 processes that were started under the land development act were classed under the 'WILG' (Boonstra et al., 2014). Thus, this implies a decline in the use of legal land consolidation. However, land consolidation by agreement has increased (Boonstra et al., 2014). Land consolidation by agreement or voluntary land exchange is an instrument where three or more stakeholders voluntary decide to consolidate parcels or holdings by the use of a notarial deed (Boonstra et al., 2014). Land consolidation by agreement should be simpler and faster than legal land consolidation (Rheinfeld, 2014). Regional governments prefer to use land consolidation by agreement above the use of legal land consolidation processes (Kuindersma et al., 2015). Therefore, in the here-developed model, land consolidation by agreement is the basis. This means that every actor is willing to exchange land, but considering the fact that the benefits need to be larger than the costs, land exchange will only take place when it is beneficial. Therefore, no actor loses land as a simplification in the model.

2.2 Land banking

When a government needs land for a certain development, land should be made available for this development, since the structure of ownership often does not match with the desired ownership structure (Van der Krabben & Jacobs, 2013). In this context, land banking as a way of land acquisition by the government is needed. Land banking is a process by which a government authority purchases land which results in a land bank (Carr & Smith, 1975). According to Spit and Hartvigsen, a land bank is an institution, either public, semi-public or privately owned, that purchases and sells real estate land in rural areas for reaching certain purposes (Hartvigsen, 2015; Spit, 2016). Because land banking for public-oriented purposes are mostly environmental or recreational developments (Spit, 2016), land banking in this thesis is focussed on nature development, because the regional government is responsible for nature development in the Netherlands. Within literature, the terms land fund or land assembly are synonyms for land banking (Hartvigsen, 2015; Van der Krabben & Jacobs, 2013; Van Dijk & Kopeva, 2006).

In Dutch cases, a land bank is often a governmental or public institution with the delegated mandate to purchase land in rural areas from private owners. In the Netherlands, BBL was active in land banking. The parcels in the land bank of BBL were brought into land consolidation processes to compensate the agricultural sector for taking land out of production for the implementation of nature restoration, landscape improvement or water management (Hartvigsen, 2015). The Council of Rural Areas (Dutch: '*Raad voor het Landelijk Gebied (RLG)')* in the Netherlands describes this kind of land bank as an exchange land bank. The meaning of an exchange land bank is to exchange parcels in order to consolidate parcels to favorable locations (Westerink et al., 2010). Nowadays, the tasks and the parcels of the land bank of BBL are taken over by the regional governments. In the here-developed model, the land bank consists of a certain amount of parcels or land scattered throughout the land consolidation space, owned by the regional government, and which functions as an exchange land bank for the interest of nature development.

2.3 Natuurpact

Besides the application of the WILG in 2007, the responsibilities of the regional governments in nature development and conservation were enlarged in 2013 due to a negotiation between the Dutch government and the regional governments, resulting in a treaty called the 'Natuurpact' (Folkert, Arnouts, Boonstra, Van Hinsberg, & Kuindersma, n.d.; Kuindersma et al., 2015; Rouwenhorst, 2015; Van Straalen et al., 2016). This treaty set ambitions and finances of nature policy in the Netherlands till 2027 (PBL & WUR, 2017). The ambition is to develop nature in the form of a robust network based on the ideas of the National Ecological Network (EHS), that is nowadays named as Nature Network Netherlands (Dutch: *'Natuurnetwerk Nederland (NNN)'*) (Kuindersma et al., 2015). The differences between Nature Network Netherlands and the EHS are a specific focus on the quality of nature; emphasis on enlarging nature areas and the realisation of connections to other nature areas (Rouwenhorst, 2015). To realise these enlargements and connections, the purchase of farmland that is directly adjacent to the existing nature areas is essential. Therefore, the here-developed model simulates a land consolidation process in order to become in possession of parcels of farmers adjacent to an existing nature area.

To enlarge nature areas or to construct nature connections, the Service for Land and Water Management (Dutch: '*Dienst Landelijk Gebied (DLG)*') was the main executor of the policies regarding the 'NNN' as an order of the national and regional governments (Pleijte et al., 2014). BBL was part of DLG and the main task of BBL was to buy land in rural areas on a voluntary basis; facilitate temporary land use; develop nature and sell and distribute land in order to serve the public (Damen, 2004; Rijksoverheid, 2014). After the development, the parcels were sold to nature organisations for nature management. The purchase was subsidized via a fund, the 'Particulier Natuurbeheer (PNB)' (Kuindersma et al., 2015). As a result of the WILG and Natuurpact, it was decided to abolish DLG in 2015 (Pleijte et al., 2014; Rijksoverheid, 2015). The tasks of DLG and the land in possession of BBL were taken over by the regional governments (Kuindersma et al., 2015; Pleijte et al., 2014; Rouwenhorst, 2015). The parcels of BBL give the regional governments more possibilities to be active in the land market to reach public-oriented objectives such as nature development (Kuindersma et al., 2015). The main functions of the regional governments in the context of nature development are land acquisition, the transformation of the destination of land, development, management and the connection within the Nature Network Netherlands and with its environment (Folkert et al., n.d.). However, every regional government has its own policy within the framework set by the national Dutch government. Some regional governments invest in land and in nature development, some regional governments delegate these tasks to other stakeholders and some regional governments sell land (Kuindersma et al., 2015, 2017). Besides, since the 'Natuurpact' other stakeholders have the possibility to be active in the land market as well to reach public-oriented purposes such as nature development (Kuindersma et al., 2015). Although these other stakeholders may be influencing nature development, in the here-developed model the focus lies with the regional government in land banking. However, the model does simulate the transfer of parcels from land bank to a nature organisation when they fall within the nature-designated zone.

2.4 Rural land market

Land consolidation and land banking are processes that interact with the rural land market. Rural land markets are, in turn, driven by demographics and land consolidation processes (Bakker et al. , 2017). The number of farmers is decreasing for years in the Netherlands because, for example, farmers cannot find a successor for their farm. The number of farms was decreasing from 410,000 in 1950 to 90,000 in 2000 (Koomen et al., 2004). However, the total area under cultivation decreased only with 16% in the same time. In the recent years between 2010 and 2016, the number of farmers decreased from 72,325 farms with 1,872,319 ha farmland to 55,680 farms with 1,796,261 ha farmland (CBS, 2017). This implies a farm size increase over time. When small farmers are quitting, the possible buyers are logically farmers in short distance of that particular farm (Cotteleer, Luijt, Kuhlman, & Gardebroek, 2007). The reason for this short distance transactions is that farms and parcels are fixed on a specific location (Bakker, 2017; Cotteleer et al., 2007). Because these small farms are not profitable, the farm will not be continued and the parcels are separately sold. So, other farms are growing. Therefore, the farm size increase may affect the effectiveness of land banking in land consolidation processes. Therefore, the model tests several amounts of farmers to research the effect of the amount of farmers on land banking in land consolidation processes.

In the buying and selling of parcels, characteristics of the parcels and the differences between parcels are important determining the value of these parcels. First, the transaction of parcels is mostly executed between farmers close to each other (Cotteleer et al., 2007). Therefore, the distance from parcel to farm and the distance between parcels are important for the value of a parcel. Several studies imply the importance of distance. For instance, Bakker (2017) and Tanaka (2008) state that a cost is associated with dispersed land, where the cost increases with the distance between parcels and the between parcel and farm. Therefore, it is logical that distance is also seen as one of the key elements taken into account in land consolidation for the optimisation of farms (Gniadek, Harasimowicz, Janus, & Pijanowski, 2013; Westerink et al., 2010). Second, the execution of land consolidation processes to counteract the fragmentation of agricultural holdings was mainly to increase the economic welfare of the farmers (Sonnenberg, 2002; Van den Noort, 1987). Therefore, the fragmentation of holdings and parcels determines a certain value of parcels. However, an optimum of parcel distributions will hardly be established. Reasons are the continuous historical fragmentation of an area; the environmental situation of the agricultural area and the many different landowners, not only farmers, who possess small parcels. Due to this reasons, every area differs from each other. Therefore, the degree of dispersion is a variable that may affect the effectiveness of land banking in land consolidation processes and is tested in the model. Third, the shape and size of the parcels are important for land consolidation and the value of a parcel (Gniadek, Harasimowicz, Janus, & Pijanowski, 2013). Fourth, the characteristics of land parcels contain a huge amount of variables that together influence the value of a parcel (Van den Bergh, 2004), such as soil type, water management, accessibility, parcel size or allotment, state of the buildings, land lease rights and property rights. In the rural land market, the WTP is the maximum price a buyer wants to spend for a parcel, whereas the WTA is the minimum amount of money a seller is willing to accept for a transaction of a parcel. Because distance is an important aspect of land consolidation processes the thesis will focus on the aspect of distance. Therefore, the characteristics of the parcels such as size and shape are kept equal, and WTP and WTA are only determined by the distance between parcel and (potential) owner.

3. Methodology

The methodology chapter consists of the conceptual model description, the technical model description, and the experimental design. First, in the conceptual model, an overview is given how the model simulates land consolidation in order to answer the research questions. Second, the technical model describes the mathematical rules in the model. Third, in the experimental design, the set up of the experiments to answer the research questions are described.

3.1 Conceptual Model

3.1.1 Model objective

In order to research the effectiveness of land banking by the regional government in land consolidation processes, a model is built with the general idea to enlarge a nature area within an agricultural area by exchanging parcels between a nature organisation and farmers, with a land bank of the regional government as an intermediate party. The *effectiveness of land consolidation* is measured by the eventual amount of parcels in possession of the nature organisation within a *planned enlargement zone* of a nature area relative to the total amount of parcels within the planned enlargement zone. The variables tested in the model are (i) the amount of parcels in the land bank, (ii) the various degrees of dispersion and (iii) the amount of farmers.

3.1.2 Simulated environment

The simulated environment in the model is a grid of parcels. This grid of parcels is *the land consolidation space*. The upper row of parcels in the land consolidation space is in possession of the nature organisation, representing the nature area that needs to be enlarged. Normally, nature areas are not divided into parcels; however, for the sake of the consistence of the grid in the model, this division was made. The other parcels in the land consolidation space are mostly owned by farmers, but some parcels are owned by the nature organisation or the regional government. The parcels in possession of the regional government are the parcels in the land bank. The farms are situated in the land consolidation space. The parcels below the upper row parcels are flagged as the parcels aspired for the enlargement of the existing nature area, called the planned enlargement zone, of which the majority is owned by farms. The purpose is that the nature organisation becomes the owner of all the parcels in the planned enlargement zone by means of *a land consolidation process*.

3.1.3 Land consolidation process

To describe the land consolidation of the parcels, this paragraph is described from the perspective of three types of owners in the land consolidation space. First, in the current legal situation, the regional government is responsible for the development of nature, like the NNN. Other governments or governmental institutes, such as municipalities or water boards, are not taken into account to simplify the model. Second, the group of organisations managing nature areas is represented by one nature organisation that follows the governmental nature policy and manages nature areas. The type of nature and way of managing is out of scope in this thesis. Third, because the nature development takes place in a rural area, the farmers are the last type of landowners in the land consolidation space.

The model will consist of time steps while the land consolidation takes place. Therefore, one time step will be described in the next paragraph to show how the model is carried out.

Every time step consists of several processes in which the landownership of parcels may change between the nature organisation, regional government and farmers. The basic principle of the model is that no stakeholder loses land. However, the goals of every stakeholder differ in the model. First, the farmers only exchange parcels when it is beneficial for their farms. Thus, in this model, the benefits are higher when the ‘new’ parcel is closer to the farm than the ‘old’ parcel. So, if the total distance of all the parcels from the centre of the parcel to the farm will be smaller in a future situation the farmer is prepared to exchange their parcels. Second, the nature organisation only wants to become in possession of the parcels situated in the planned enlargement zone. Hence, distributed parcels of the nature organisation in the agricultural area are exchanged against parcels from farmers and the regional government in the planned enlargement zone. Third, the regional government only facilitates the exchange by making use of their land bank to let the nature organisation become in possession of parcels in the planned enlargement zone and the farmers become in possession of parcels closer to their farms. Hence, the regional government's main purpose is to enlarge the nature area, however supporting farmers is a positive side-effect.

The goals of the stakeholders determine the processes taking place in the model. First, the nature organisation may exchange parcels directly with the farmers. Such an exchange only takes place when the parcel of the farmer lies in the planned enlargement zone and a parcel in possession of the nature organisation lies closer to that particular farm than the parcel of the farmer in the planned enlargement zone. Second, the regional government makes use of its land bank to exchange parcels of the farmers in the planned enlargement zone with parcels of the regional government in the land consolidation space. These exchanges only take place when the parcel of the land bank lies closer to the farm than the parcel of the farmer in the planned enlargement zone. The third land process taking place are parcel exchanges between the land bank of the regional government and the nature organisation. The parcels of the land bank situated in the planned enlargement zone are exchanged with parcels of the nature organisation in the land consolidation space. The landownership of the nature organisation of parcels in the planned enlargement zone is the end stadium in the model, whereby the amount of parcels owned by the nature organisation in the planned enlargement zone of the nature area determines the effectiveness of the land consolidation processes. At the end of a time step, a fourth kind of land consolidation process is executed. In this fourth process, the regional government exchanges parcels in the total land consolidation space with the farmers (this time not just the parcels situated in the planned enlargement zone). Nevertheless, the parcels are only exchanged when the distance from the farm to a land bank parcel is smaller than to the farmer's parcel. The parcels in the land bank can only exchange once in this fourth process. The goal is to create a new start position of the distribution of parcels in the land bank before starting the next time step. This simulates an active role of the regional government in land banking through time. After this land consolidation process, a new time step starts. After every time step, the amount of parcels in possession of the nature organisation within the planned enlargement zone is determined to answer the research questions.

On the next page, an impression is shown how one time step of the model is executed (figure 1). Thereafter, an explanation of the figure is given.

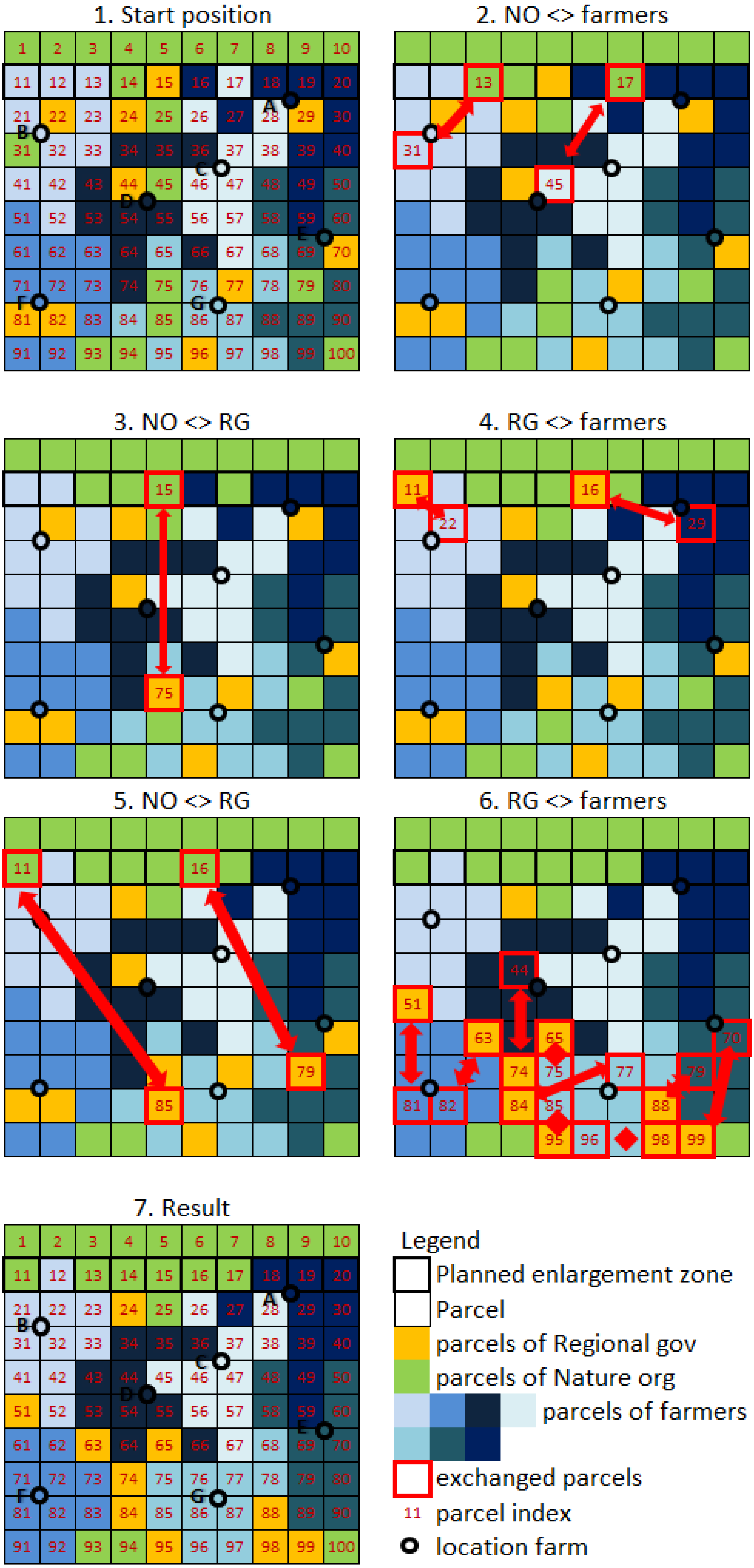

figure 1: land consolidation processes in one time step of the model

In figure 1, an impression of the model is shown. In seven pictures, the land consolidation processes are executed according to the order of the model script. In the first picture, the start position before the processes is given. Seven farms, named from A to G, are situated in the land consolidation space and the colour within the location symbol of the farm is also the colour of its parcels. The other parcels are distributed to the nature organisation and regional government. In the land consolidation space, every parcel is indexed from 1 to 100. These parcel and farm indices are also applicable to the other pictures, but not shown in every picture. In the second picture, the nature organisation directly exchanges parcels in the planned enlargement zone with the farmers based on distance. Parcel 31, in possession by the nature organisation, is situated adjacent to farm B. Parcels 11, 12 and 13 in the planned enlargement zone are all further away from the farm than parcel 31. However, parcel 13 has the highest distance between the parcel and the farm. Therefore, parcel 31 and 13 exchange landownership. This process is also applicable to parcel 17 in landownership of farmer C, i.e. parcel 45 of the nature organisation is closer to the farm than parcel 17. Thus, the landownership exchange. In the third picture, the parcels assigned to the regional government in the planned enlargement zone are exchanged with a random parcel of the nature organisation, i.e. the landownership of parcel 15 exchanges with the landownership of parcel 75.

The land bank of the regional government is willing to exchange parcels with the farmers in the planned enlargement zone in the fourth picture. Parcels 22 and 29 in possession of the regional government are situated closer to farms B and A than the parcels 11 and 16 of the farmers in the planned enlargement zone. Therefore, the landownership exchanges. Note that the distance of parcel 11 and 12 to farm B are exactly the same. However, in this case, the model exchange parcels with a lower index. In the fifth picture, the regional government exchanges the landownership of the obtained parcels with the nature organisation conform the arguments in the third picture. In the sixth picture the regional government exchanges parcels with the farmers in the total land consolidation space. Because the regional government does not possess parcels in the planned enlargement zone anymore, the planned enlargement zone is out of scope in this process. The result of all the processes can be seen in the seventh picture. In the next time step, all these processes described above are repeated. However, in this impression, it is impossible to exchange parcels in the planned enlargement zone in the next time step. But, the positions of the parcels of the regional government are changed. Hence, new possible exchanges between the farmers and the regional government in the land consolidation space in the new time steps may be executed according to the sixth picture. Thus, it may be possible in further time steps that the regional government possess some parcels in a position to exchange parcels in the planned enlargement zone again.

3.2 Technical model

The construction of the model consists of (a) the building of the grid with parcels (the land consolidation space), (b) the distribution of the farms over the land consolidation space, (c) the assignment of parcels to landowners, and (d) the mathematical script lines to execute the land consolidation processes. Steps a to c are described in the section 'Model initialisation'. The mathematical description for the simulation of land consolidation is described in the section 'Consolidation procedure'. In order to construct the model, two programs are used. First, to construct the grid, ArcGIS was used. The construction of the grid resulted in a shapefile. Second, the program R was used. Herein, the shapefile could be read as a start position for the model. In R a mathematical script was built to execute rules to simulate the land consolidation. The script is added as an appendix of this thesis.

3.2.1 Model initialisation

3.2.1.1 Construction of the land consolidation space and its parcels

The model contains a grid of c columns and r rows. The total amount of parcels in the grid N are determined by the columns and rows:

$$N = c * r$$

The boundaries of the model grid are also the boundaries of the land consolidation space as formulated as a characteristic by Vitikainen (Vitikainen, 2004). The parcels are of equal size and shape. Also, roads, ditches, and other buildings are not taken into account in the model. The width and length of the parcels are the same lengths in w meters. Hence, the formula for the size of a parcel (w_{parcel}) is:

$$w_{parcel} = w^2$$

The size of the land consolidation space (w_{total}) is based on the formula:

$$w_{total} = w_{parcel} * N$$

The parcels are denoted as P_i whereby i is the specific index of a parcel. The index of i contains the numbers 1 to N. Every parcel contains the following variables: landownership l, and coordinates x_i and y_i of the central point of the parcel. The landownership l can have three different types of values: the regional government (RG), the nature organisation (NO) or a specific farmer (f_j). To summarise, every parcel can be described as $P_i(x,y,l)$ whereby l is RG, NO or f_j. The upper row of parcels all have nature organisation (NO) as landownership, representing the nature area; the parcels in the row beneath are flagged as the planned enlargement zone.

3.2.1.2 Distribution of farms

A number of farms are randomly distributed over all the corners of the parcels. All the crossing borders of the parcels are possible locations for farms except the locations adjacent to the existing nature area. This choice was made, because demolishing, replacing or buying out of farms and farmers are out of scope in this thesis, while a farm in the midst of a nature area is not likely to be favorable for the farmer and the regional government. The possible locations are listed and from this list, a number of locations equal to the total amount of farmers M are randomly sampled.

Thereafter, every sampled location obtains a name of a specific farmer as f_j, whereby j the specific index of a farm is. The index of j contains the identifications 1 to M, where M is the total amount of farmers. The coordinates of a farm are described by x_j and y_j.

3.2.1.3 Landownership of parcels at the start position in the model

The parcels in the land consolidation space are distributed over the regional government *RG*, nature organisation *NO* and the farmers f_j. Thus, the landownership of the parcels *P* can be described as:

$$l = [RG, NO, f_1 \dots f_M]$$

The amount of parcels distributed to the regional government (RG) is similar to the land bank size is denoted as N_{RG} and can be described as:

$$N_{RG} = count\ [\ P_i(x_i,\ y_i,\ l = RG)\ ]$$

The parcels distributed to the nature organisation (NO) is denoted as:

$$N_{NO} = count\ [\ P_i(x_i,\ y_i,\ l = NO)\ ]$$

The parcels of the nature organisation can be divided into two components. The upper row in the model is already a nature area and is therefore in possession of the nature organisation. However, these parcels are not able to exchange in the model. Therefore the fixed parcels in the nature area are defined as $N_{NO\ (nature\ area)}$ and the other parcels of the nature organisation are defined as $N_{NO\ (other)}$. The total amount of parcels in landownership of the nature organisation can be denoted as:

$$N_{NO} = N_{NO\ (nature\ area)} + N_{NO\ (other)}$$

The remaining parcels in the land consolidation space are distributed to the farmers as N_f and can be denoted as:

$$N_f = count\ [\ P_i(x_i,\ y_i,\ l = f_1 \dots f_M)\ ]$$

The amount of parcels distributed to each farmer is defined as N_{fj}, where the index j matches the index of f_j.

$$N_{fj} = count\ [\ P_i(x_i,\ y_i,\ l = f_j)\ ]$$

The remaining parcels may not equally be dividable over the farmers. Therefore, a rule in the script is built to divide the N_{fj} amount of parcels per farmer as equal as possible. Thus, it may be possible that farmers have one parcel more or less in production. Therefore, before every model run, the N_{fj} amount of parcels per farm is determined by random sampling. To summarise the landownership of all parcels in the land consolidation space, the landownership can be summarised in the following formula:

$$N = N_{RG} + N_{NO} + N_f$$

The parcels belonging to the farmers are distributed in the model in three different ways, representing the various degrees of dispersion. The degree of dispersion is determined by the maximum distance *d* between parcels and owning farm. To distribute the parcels to the farmers, via the Pythagorean theorem (‘$a^2 + b^2 = c^2$’) the distance *e* of each farm to every central point of every parcel is calculated as:

$$e^2_{i,j} = (x_i - x_j)^2 + (y_i - y_j)^2$$

Where x_i and y_i are the coordinates of the centre of a parcel and x_j and y_j are the coordinates of a farm. The parcels that are situated within distance *d* are the parcels that may be distributed to the farmers. This is done according to the formula:

$$e_{i,j} \leq d$$

If a parcel lies within the maximum distance (*d)*, it could be distributed to the farm. However, the number of parcels situated within the maximum distance (*d)* is higher than the N_{fj} amount of parcels that should be distributed to a certain farm. Therefore, from the parcels situated within the maximum distance (*d)*, the N_{fj} amount of parcels is randomly sampled. Because the sampling is executed per farm, there is a chance that some parcels are sampled twice. To deal with the duplicate sampled parcels, the duplicates are deleted, the difference between the amount of parcels sampled and N_{fj} is calculated and a new round of sampling is executed. These samplings are executed in three rounds. For some farmers, it may be possible that after these rounds still some samples need to be taken to reach the amount of parcels N_{fj}, however, the parcels within maximum distance (*d)* are all sampled. Therefore, in the fourth and fifth round, the maximum distance *(d)* is enlarged to two times *(d)*. The remaining parcels after the distribution to the farmers are randomly distributed to the nature organisation and the regional government. In extreme cases, a farmer has not reached the total amount of N_{fj} and from the remaining parcels, farmers will also receive parcels to reach the amount of N_{fj}. The result of the model initialisation is a grid of parcels where the parcels P_i are distributed to a landowner *l*, what can have a nominal value of *RG*, *NO* or f_j.

3.2.2 Consolidation procedure

In this section, the rules behind the land consolidation of parcels are described. As described in the conceptual framework, the model consists of time steps where every time step exists of several processes. In the script, the processes are separately executed in a specific order. Therefore, the processes are divided into stages.

A time step consists of five stages (see table 1). In stage A, the farmers exchange their parcels in the planned enlargement zone directly with the nature organisation based on distance. In stage B, the randomly distributed parcels of the regional government, i.e. the land bank, in the planned enlargement zone are exchanged with parcels of the nature organisation. In stage C, the farmers are willing to exchange the parcels that were not exchanged in stage A with parcels of the land bank. In stage D, the mathematical rules of stage B are repeated. In stage E, the parcels in the land consolidation space are exchanged between the regional government and the farmers. These stages are also visualised in figure 1 in chapter 3.1.3. In the next paragraphs, the mathematical rules in the script behind these stages and processes are described.

table 1: the exchange between stakeholders in stages for time step t

Stage	Exchange between
A	Nature organisation <> farmers
B	Nature organisation <> regional government
C	Regional government <> farmers
D	Nature organisation <> regional government
E	Regional government <> farmers

The planned enlargement zone is the row beneath the upper row (which is already in possession of the nature organisation). The landownership of the parcels in the planned enlargement zone need to change to the nature organisation to develop a nature area. So, the general idea of all the stages in a time step is that all the parcels in the planned enlargement zone are transferred to the nature organisation. That means if $P_{i\,(PEZ)}\ (x_i,\ y_i,\ l = NO)$ the end stadium of the model is reached. In this notation, PEZ is the planned enlargement zone. When a parcel is already exchanged in the planned enlargement zone, it is in the same model run impossible to exchange again.

After the initial distribution (described in the previous paragraphs), stage A is executed for every parcel in the planned enlargement zone separately. When $P_i\,(x_i,\ y_i,\ l = NO)$, the parcel is already owned by the nature organisation and nothing happens. When $P_i\,(\ x_i,\ y_i,\ l = f_j)$, the parcel is owned by a farmer. Every parcel in the planned enlargement zone needs to be checked separately if the farmer wants to exchange a parcel with the nature organisation. The farmer is willing to change landownership when the distance of any parcel of the nature organisation outside the planned enlargement zone to the farm is smaller than the parcel of the farmer in the planned enlargement zone. Thus, a list is made of all the parcels when $P_i\,(\ x_i,\ y_i,\ l = f_j)$ in the planned enlargement zone. Then, the distance (*e*) between parcel and farm and the distance (*e*) between all $P_i\,(x_i,\ y_i,\ l = NO)$ in the land consolidation space and the same farms are linked in the list. The farmer whose farm is closest to the parcel of the nature organisation exchanges the parcel with the nature organisation. This can be described in the formula:

$$\min\,(e_{i(\,l\,=\,NO),j}) < \ (e_{i(PEZ,\ \ l\,=\,fj),j})$$

In the formula, *e* is the distance between the parcel and the farmer; *NO* is the nature organisation as landowner *l* and f_j is a specific farmer as landowner *l*. The formula describes that when the distance from a parcel owned by the nature organisation to the closest farm is smaller than a parcel of that particular farmer in the planned enlargement zone, an exchange is executed. The result of executing the formula is a table where all the parcels of the farmers in the planned enlargement zone of the grid are selected meeting the formula above. After that, the landownership are exchanged in the model.

In stage B, the parcels that were randomly distributed to the regional government in the planned enlargement zone are exchanged with parcels of the nature organisation outside the planned enlargement zone on a random basis. Thus, $P_{i\,(PEZ)}\,(x_i,\ y_i,\ l = RG) \Rightarrow P_{i\,(PEZ)}\,(x_i,\ y_i,\ l = NO)$ and a random draw out of parcels in the land consolidation area as $P_i\,(x_i,\ y_i,\ l = NO) \Rightarrow P_i\,(x_i,\ y_i,\ l = RG)$.

In stage C the farmers and the regional government exchange parcels using the land bank. When $P_i\,(x_i,\ y_i\,,\ l = NO)$ in the planned enlargement zone, the flagged parcel is already owned by the nature organisation and nothing happens. When $P_i (x_i, y_i, l = f_j)$, the flagged parcel is owned by a farmer. Every parcel in the planned enlargement zone needs to be checked separately again if the farmer wants to change landownership with a parcel of the land bank. The farmer whose farm is closest to the parcel of the land bank of the regional government exchanges the parcel. This can be described in the formula:

$$\min (e_{i(l = RG),j}) < (e_{i(PEZ,\ l = fj),j})$$

The formula is exactly the same as the formula used in stage A. The difference is that it contains an exchange of parcels between the regional government and a specific farmer. In stage D the obtained parcels by the regional government in the planned enlargement zone are exchanged with parcels of the nature organisation on a random basis conform the mathematical rules in stage B. Thus, $P_{i\,(PEZ)} (x_i, y_i, l = RG) \Rightarrow P_{i\,(PEZ)} (x_i, y_i, l = NO)$ and a random draw out of parcels in the land consolidation area as $P_i (x_i, y_i, l = NO) \Rightarrow P_i (x_i, y_i, l = RG)$.

Stage E consists of the exchange of parcels between the regional government and farmers in the land consolidation space. Whenever the distance of a land bank parcel to the farm is shorter than a parcel of the farmer, a voluntary exchange takes place. Thereby, the most beneficial land consolidation will take place. That means that the parcel will exchange to a farmer where the distance between parcel and farm is the shortest. This can be described in the formula:

$$\min (e_{i(l = RG),j}) < (e_{i(\ l = fj),j})$$

The formula describes that when the distance from a parcel owned by the regional government to the closest farm is smaller than the parcel of that particular farmer with the distance to the farm, an exchange is executed. Each parcel of the nature organisation and farmer only can exchange once per time step. After each time step, the amount of parcels in ownership of the nature organisation in the planned enlargement zone is calculated as t_n. These calculated amounts of parcels in ownership of the nature organisation is needed to answer the research question.

In the table below the variables named in this chapter are summarised (table 2).

table 2: constant variables in all the scenarios, model runs, and time steps

Name	Variable	Unit	Category	Constant or variable
P_i	Parcel in the land consolidation space	Amount	Ratio	Constant
N	Total number of parcels in the land consolidation space	Amount	Ratio	Constant
i	Index of parcels	i = 1 to N	Ratio	Variable per parcel
f_j	Farm in the land consolidation space	Amount	Ratio	Variable per model test
M	Total number of farmers	Amount	Ratio	Variable per model test
j	Index of farms	j = 1 to M	Ratio	Variable per farm
c	Columns of the grid	Amount	Ratio	Constant
r	Rows of the grid	Amount	Ratio	Constant
w	width/length parcel	m	Ratio	Constant
w_{parcel}	Parcel size	m^2	Ratio	Constant
w_{total}	Size land consolidation space	m^2	Ratio	Constant
x_i, y_i	Coordinates central point of parcels	m,m	Interval	Variable per parcel
d	Maximum distance of parcel to farm	m	Ratio	Variable per model test
l	Landownership of a parcel	NO, RG, f_j	Nominal	Variable
N_{RG}	Total number of parcels in land bank	Amount	Ratio	Variable per model test
N_{NO}	Total number of parcels of the nature organisation	Amount	Ratio	Constant
$N_{NO\ (nature\ area)}$	Total number of parcels of the nature organisation in nature area	Amount	Ratio	Constant
$N_{NO\ (other)}$	Total number of parcels of the nature organisation in land consolidation space	Amount	Ratio	Constant
x_j, y_j	Coordinates of farms	m,m	Interval	Variable per farm
N_{fj}	Total number of parcels per farmer	Amount	Ratio	Variable per farm
$e_{i,j}$	Distance of parcel to farm	m	Ratio	Variable per parcel and farm
t_n	Parcels in the planned enlargement zone in possession of the nature organisation per time step	Amount	Ratio	Variable

3.3 Experimental Design

3.3.1 Scenarios, model runs, and time steps

To answer the research questions, the effectiveness of the consolidation needs to be evaluated in response to three variables: the amount of parcels in the land bank, the number of farmers and the degree of dispersion. Hereto, the following experimental design was set up.

The N_{RG} amount of parcels in the land bank are first based on a rule of thumb of 5% described in the article of Damen (Damen, 2004). Therefore, the choice was made to choose proportionally 5 amounts of parcels in the land bank around this 5%. Therefore, the amount of land in the land bank in relation to the total amount of land in the land consolidation space 2%, 5%, 8%, 11% and 14% were chosen. In order to anticipate on the degree of dispersion, the model will test three various distributions of parcels around a farm. The amount of farms vary as well in the model. Two amounts of a total of farmers M in the land consolidation space were chosen to research the influence of the decline of farmers and the growth of the farm size. Summarising, the model tests five total amounts of parcels in the land bank, three different degrees of dispersion with maximum distance *(d)* and two amounts of farmers. Therefore, the amount of scenarios tested is 30.

Per scenario, 200 model runs are executed due to the random distribution of farms and parcels to farmers, nature organisation and regional government. This amount of model runs was limited by time constraints of model running. Per model run, the amount of time steps t is set on 10. This amount is chosen, to get a proper overview of the land exchange in the planned enlargement zone.

3.3.2 Other model parameterization

The model contains a grid of 20 rows r by 20 columns c. Thus, the amount of parcels in the land consolidation space *(N)* is 400. Every parcel has a width and length (*w)* of 200 meters. Because every parcel is equal, the exact size of the parcel is of minor importance. The size of the parcel w_{parcel} is determined as 200 by 200 as 40,000 m^2 (4 ha). The total size of the land consolidation space w_{total} is 40,000 times 400 parcels as 16,000,000 m^2 (1600 ha). The coordinates x and y of the left corner of the land consolidation space are set on 0 m by 0 m. Therefore, the coordinates x_i and y_i of the centre points of the parcels have all a positive value, where as an example the parcel in the left corner has coordinates of 100 m by 100 meters.

To construct the land consolidation space ArcGis was used to draw squares with a parcel size of 200 meters by 200 meters. In ArcGis the coordinates of the central point of the parcel were added as attributes of a parcel. The result was a shapefile that was exported into R via the package 'Rgdal'.

The parcel distribution is first based on the amount of parcels N_{RG} in the land bank. As mentioned, the amounts chosen were 2%, 5%, 8%, 11% and 14%. The amount of parcels N in the land consolidation space is 400; so conform the percentages the N_{RG} amount of land in the land bank is 8, 20, 32, 44 and 56 parcels. Second, the parcel distribution is influenced by the amount of farmers M in the land consolidation space. The choice was made to model an amount of M = 48 farmers and an amount of M = 36 farmers. This choice has been influenced by the limited amount of parcels that could be distributed to the farmers due to the maximum distance (*d)* for the various degrees of dispersion.

Third, the distribution of parcels has been influenced by the amount of parcels in possession of the nature organisation. This amount of parcels $N_{NO(other)}$ is constant in the model and is set on 24, besides the 20 parcels of the nature area as $N_{NO(nature\ area)}$. The planned enlargement zone consists of 20 parcels. In order to reach the maximum, a minimum of 20 parcels in possession of the nature organisation is needed to reach that maximum. Some extra parcels are added to the belongings $N_{NO(other)}$ of the nature organisation, to have some flexibility.

To conclude, the value of N_{RG} can be 8, 20, 32, 44 and 56 parcels. The value of $N_{NO(other)}$ is 24 and the N_{fj} amount of parcels per farmer is influenced by the value of N_{RG} and the M amount of farmers. The amount of parcels that need to be distributed over the three types of stakeholders are summarised in table 3.

table 3: Division of parcels per amount of parcels per land bank

	Amount parcels land bank size 2%	Amount parcels land bank size 5%	Amount parcels land bank size 8%	Amount parcels land bank size 11%	Amount parcels land bank size 14%
Parcels land bank (N_{RG})	8	20	32	44	56
Parcels nature area ($N_{NO(nature\ area)}$)	20	20	20	20	20
Parcels outside nature area of nature organisation ($N_{NO(other)}$)	24	24	24	24	24
Parcels farmers (N_f)	348	336	324	312	300
Parcels per farmer (N_{fj}) (M = 48)	36 farmers: 7 p 12 farmers: 8 p	48 farmers: 7 p	36 farmers: 7 p 12 farmers: 6 p	24 farmers: 7 p 24 farmers: 6 p	12 farmers: 7 p 36 farmers: 6 p
Parcels per farmer (N_{fj}) (M = 36)	24 farmers: 10 p 12 farmers: 9 p	12 farmers: 10 p 24 farmers: 9 p	36 farmers: 9 p	24 parcels: 9 p 12 parcels: 8 p	12 parcels: 9 p 24 parcels: 8 p

The distribution of parcels is based on the various degrees of dispersion with a maximum distance between parcel and farm d. The maximum distances (d) for the various distributions of parcels around farmers chosen to research are 600 m, 1200 m, and 1800 m. This means a maximum distance from the central point of a parcel to a farm according to d is 600, 1200 or 1800. The amount of parcels that may possibly be assigned to a farm according to the sizes of the land consolidation space are schematically sketched in figure 2.

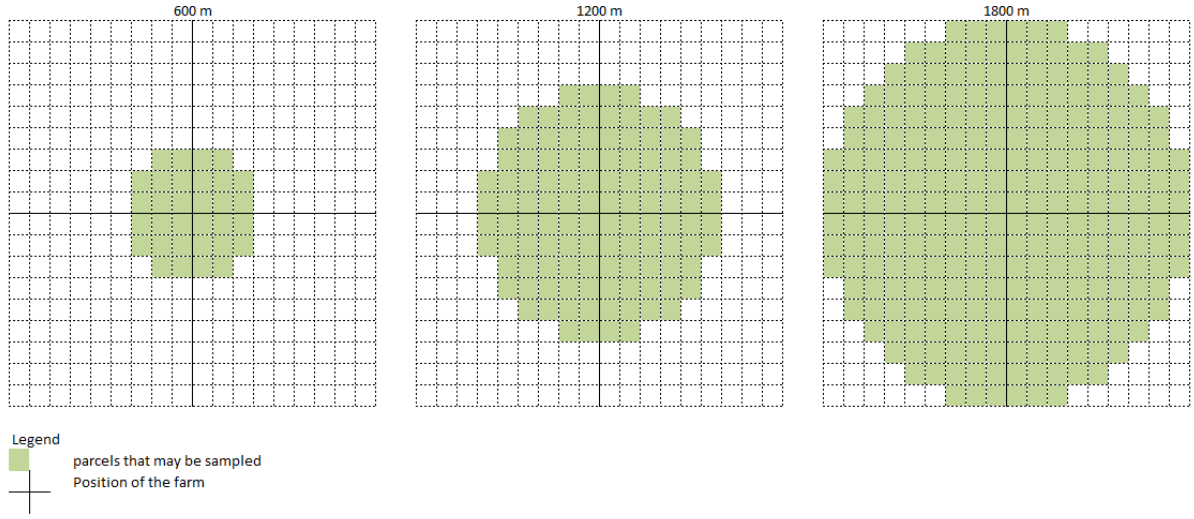

figure 2: parcels within a radius of 600, 1200 or 1800 meters as maximum distance *'d'*

If the farm is in the middle of the land consolidation space, the amount of possible distributed parcels are with degree 1 (600 meters) 32 parcels; with degree 2 (1200 meter) 108 parcels and with degree 3 (1800 meter) 256 parcels. However, when a farm is in the corner of the land consolidation space the options decrease to 8 (degree 1), 28 (degree 2) and 64 (degree 3) parcels. Besides, other farms may be situated on a location within the radius of the farm and an overlap arises. Therefore, the maximum distance (*d*) of the various degrees of dispersion needs to be not too high, but sufficient for the amount of parcels that need to be distributed to the farms.

To name the scenarios with the land bank sizes N_{RG}, farmers *M* and degrees of dispersion with maximum distance *d;* every scenario is marked with a label. These labels can be read in table 4.

table 4: Different model run categories based on the combination of the variables amount of parcels in the land bank, degrees of dispersion and amount of farmers

	d = 600 M = 48	d = 600 M = 36	d = 1200 M = 48	d = 1200 M = 36	d = 1800 M = 48	d = 1800 M = 36
Land bank 2% (N_{RG} = 8)	NRG8D1M48	NRG8D1M36	NRG8D2M48	NRG8D2M36	NRG8D3M48	NRG8D3M36
Land bank 5% (N_{RG} = 20)	NRG20D1M48	NRG20D1M36	NRG20D2M48	NRG20D2M36	NRG20D3M48	NRG20D3M36
Land bank 8% (N_{RG} = 32)	NRG32D1M48	NRG32D1M36	NRG32D2M48	NRG32D2M36	NRG32D3M48	NRG32D3M36
Land bank 11% (N_{RG} = 44)	NRG44D1M48	NRG44D1M36	NRG44D2M48	NRG44D2M36	NRG44D3M48	NRG44D3M36
Land bank 14% (N_{RG} = 56)	NRG56D1M48	NRG56D1M36	NRG56D2M48	NRG56D2M36	NRG56D3M48	NRG56D3M36

3.3.4 Determination of the effectiveness

To answer the research questions, the effectiveness of the land consolidation processes is measured by the fraction of exchanged parcels in the planned enlargement zone. This is done by looking at the amount of parcels in possession of the nature organisation as a response to the amount of land in the land bank at time step 5. Due to the 200 model runs per start position an average per series numbers is calculated. The differences between time steps are higher in the first time steps due to the maximum of 20 parcels in the planned enlargement zone. Therefore, the last time steps are flattening towards the 20. Thus, time step 5 is chosen to measure the effectiveness of the amount of parcels in a land bank of a regional government on the efficiency of land consolidation. The result is shown in a line graph.

4. Results

The results of each model run are shown in the appendix.

4.1 Land bank size 2%

The land bank size of 2% is similar to a land bank of 8 parcels (N_{RG}) in the model. In figure 3 on the next page, the results per scenario with a land bank size of 2% are shown. In the titles of these figures, the maximum distance *d* and the amount of farmers *M* are described. On the x-as, the time steps are shown, on the y-as the percentage of the parcels in the planned enlargement zone in possession of the nature organisation. The blue area is the percentage of parcels in the planned enlargement zone obtained by the nature organisation by the distribution of parcels before model running described as t_{start}. The red area is the percentage of parcels in the planned enlargement zone obtained by the exchange between the nature organisation and the farmers as t_A. The green area is the percentage of parcels in the planned enlargement zone obtained by exchanging parcels between the regional government and the nature organisation as t_B. These parcels are distributed to the regional government in the planned enlargement zone before modelling. The purple area is the percentage of parcels in the planned enlargement zone obtained by using the land bank in the different time steps as t_n.

To give an overview of the results, table 5 shows the contributions of t_{start}, t_A, t_B, the obtained parcels due to land banking in t_1, the obtained parcels at t_5, the obtained parcels in t_{10} and the cumulative percentage obtained by the nature organisation by t_1, t_5 and t_{10}. Note that the results of t_5 and t_{10} are the total amount of parcels exchanged by using land banking; so the data includes the obtained parcels in the previous time steps.

table 5: number of parcels in the planned enlargement zone at t_{start}, t_A, t_B, t_1, t_5, and t_{10}

N_{RG} 8	t_{start}	t_A	t_B	t_1	t_5	t_{10}	cumulative at t_1	cumulative at t_5	cumulative at t_{10}
d 600; M 48	3,06	4,61	1,07	0,66	2,23	3,00	*9,41*	*10,97*	*11,74*
d 600; M 36	3,01	4,06	1,00	0,58	2,03	2,73	*8,65*	*10,09*	*10,79*
d 1200; M 48	3,25	6,40	1,03	0,99	3,02	4,42	*11,66*	*13,69*	*15,09*
d 1200; M 36	3,35	5,68	1,07	0,90	3,20	4,51	*11,00*	*13,30*	*14,61*
d 1800; M 48	2,93	9,17	1,08	1,23	3,82	5,05	*14,41*	*17,00*	*18,23*
d 1800; M 36	2,85	8,54	1,01	1,44	4,21	5,48	*13,82*	*16,59*	*17,87*

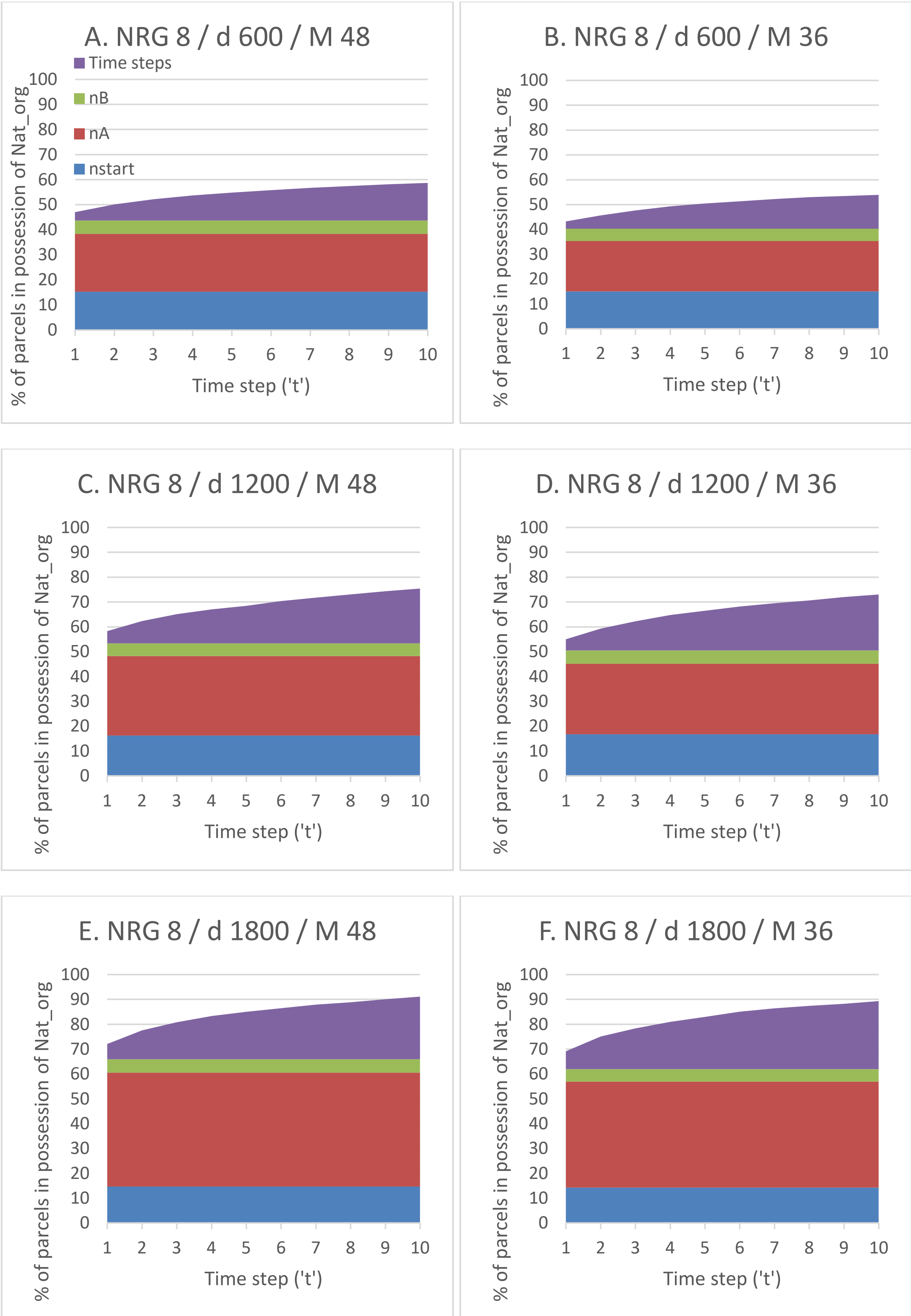

figure 3: percentage of parcels in possession of the nature organisation at the time steps with a land bank size of 8 parcels and different degrees of dispersion and different amount of farmers

4.2 Land bank size 5%

The land bank size of 5% is similar to a land bank of 20 parcels (N_{RG}) in the model. In figure 4 on the next page, the results per scenario with a land bank size of 5% are shown. The explanation of the axes and the coloured areas in the figures are the same as described in chapter 4.1.

To give an overview of the results, table 6 shows the contributions of t_{start}, t_A, t_B, the obtained parcels due to land banking in t_1, the obtained parcels at t_5, the obtained parcels in t_{10} and the cumulative percentage obtained by the nature organisation by t_1, t_5 and t_{10}. Note that the results of t_5 and t_{10} are the total amount of parcels exchanged by using land banking; so the data includes the obtained parcels in the previous time steps.

table 6: number of parcels in the planned enlargement zone at t_{start}, t_A, t_B, t_1, t_5, and t_{10}

N_{RG} 20	t_{start}	t_A	t_B	t_1	t_5	t_{10}	cumulative at t_1	cumulative at t_5	cumulative at t_{10}
d 600; M 48	3,03	3,74	2,44	0,99	3,16	3,90	*10,20*	*12,37*	*13,10*
d 600; M 36	2,80	3,67	2,59	1,07	3,02	3,59	*10,12*	*12,07*	*12,64*
d 1200; M 48	2,97	6,14	2,54	1,90	4,82	6,07	*13,54*	*16,46*	*17,71*
d 1200; M 36	3,01	5,98	2,50	1,78	4,70	5,99	*13,26*	*16,18*	*17,47*
d 1800; M 48	2,79	8,82	2,14	2,47	5,02	5,62	*16,21*	*18,77*	*19,37*
d 1800; M 36	2,74	7,98	2,14	2,50	5,54	6,28	*15,35*	*18,40*	*19,14*

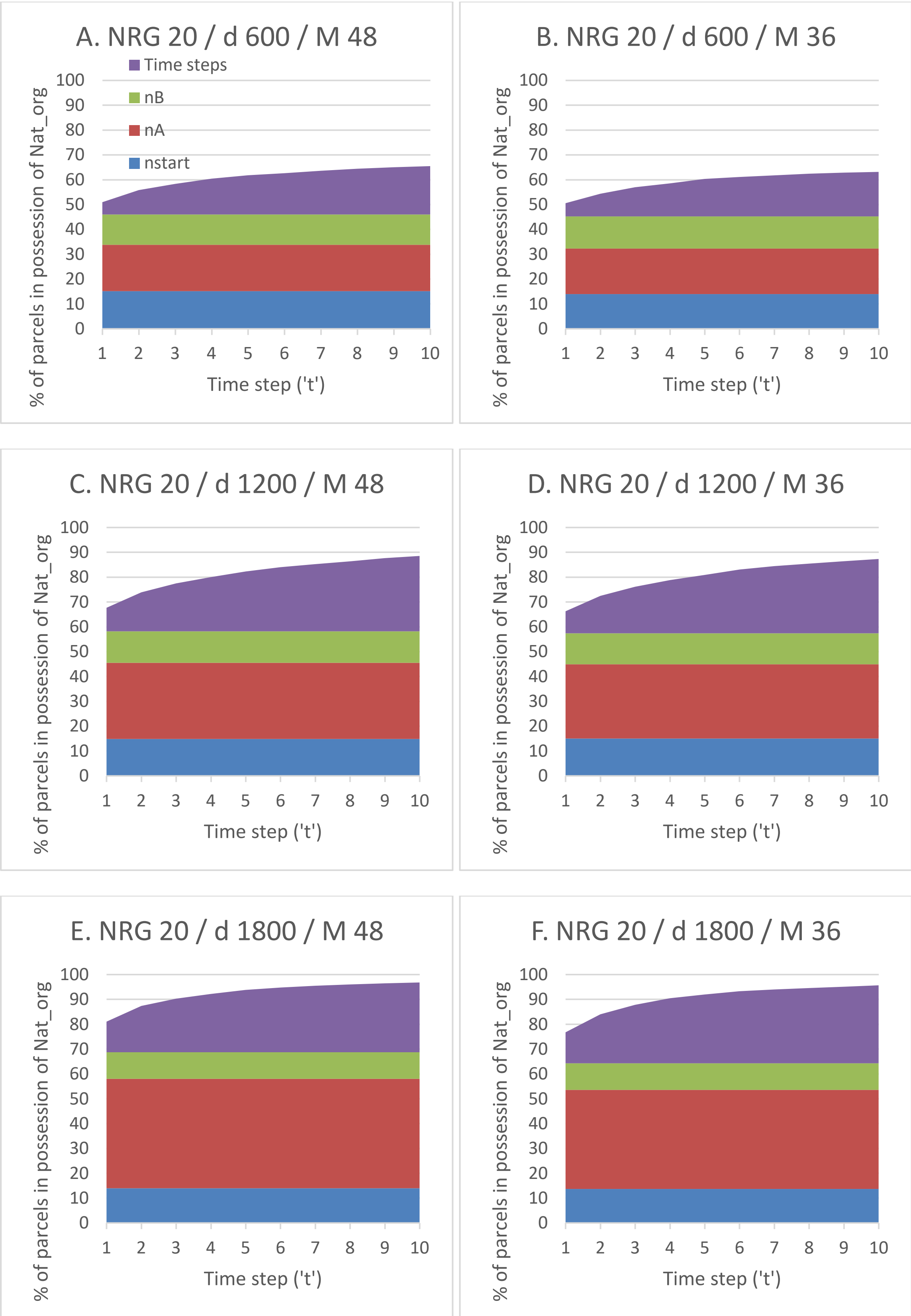

figure 4: percentage of parcels in possession of the nature organisation at the time steps with a land bank size of 20 parcels and different degrees of dispersion and different amount of farmers

4.3 Land bank size 8%

The land bank size of 8% is similar to a land bank of 32 parcels (*N_{RG})* in the model. In figure 5 on the next page, the results per scenario with a land bank size of 8% are shown. The explanation of the axes and the coloured areas in the figures are the same as described in chapter 4.1.

To give an overview of the results, table 7 shows the contributions of t_{start}, t_A, t_B, the obtained parcels due to land banking in t_1, the obtained parcels at t_5, the obtained parcels in t_{10} and the cumulative percentage obtained by the nature organisation by t_1, t_5 and t_{10}. Note that the results of t_5 and t_{10} are the total amount of parcels exchanged by using land banking; so the data includes the obtained parcels in the previous time steps.

table 7: number of parcels in the planned enlargement zone at t_{start}, t_A, t_B, t_1, t_5, and t_{10}

N_{RG} 32	t_{start}	t_A	t_B	t_1	t_5	t_{10}	cumulative at t_1	cumulative at t_5	cumulative at t_{10}
d 600; M 48	2,80	3,21	3,33	1,67	4,09	4,86	*11,00*	*13,42*	*14,19*
d 600; M 36	2,61	3,17	3,56	1,48	3,47	4,18	*10,81*	*12,81*	*13,52*
d 1200; M 48	2,75	6,06	4,00	2,59	5,36	6,06	*15,39*	*18,15*	*18,85*
d 1200; M 36	2,57	5,58	3,51	2,42	5,78	6,81	*14,07*	*17,42*	*18,46*
d 1800; M 48	2,67	8,55	3,57	2,63	4,59	4,90	*17,41*	*19,37*	*19,68*
d 1800; M 36	2,44	8,14	3,32	2,76	5,32	5,73	*16,64*	*19,21*	*19,62*

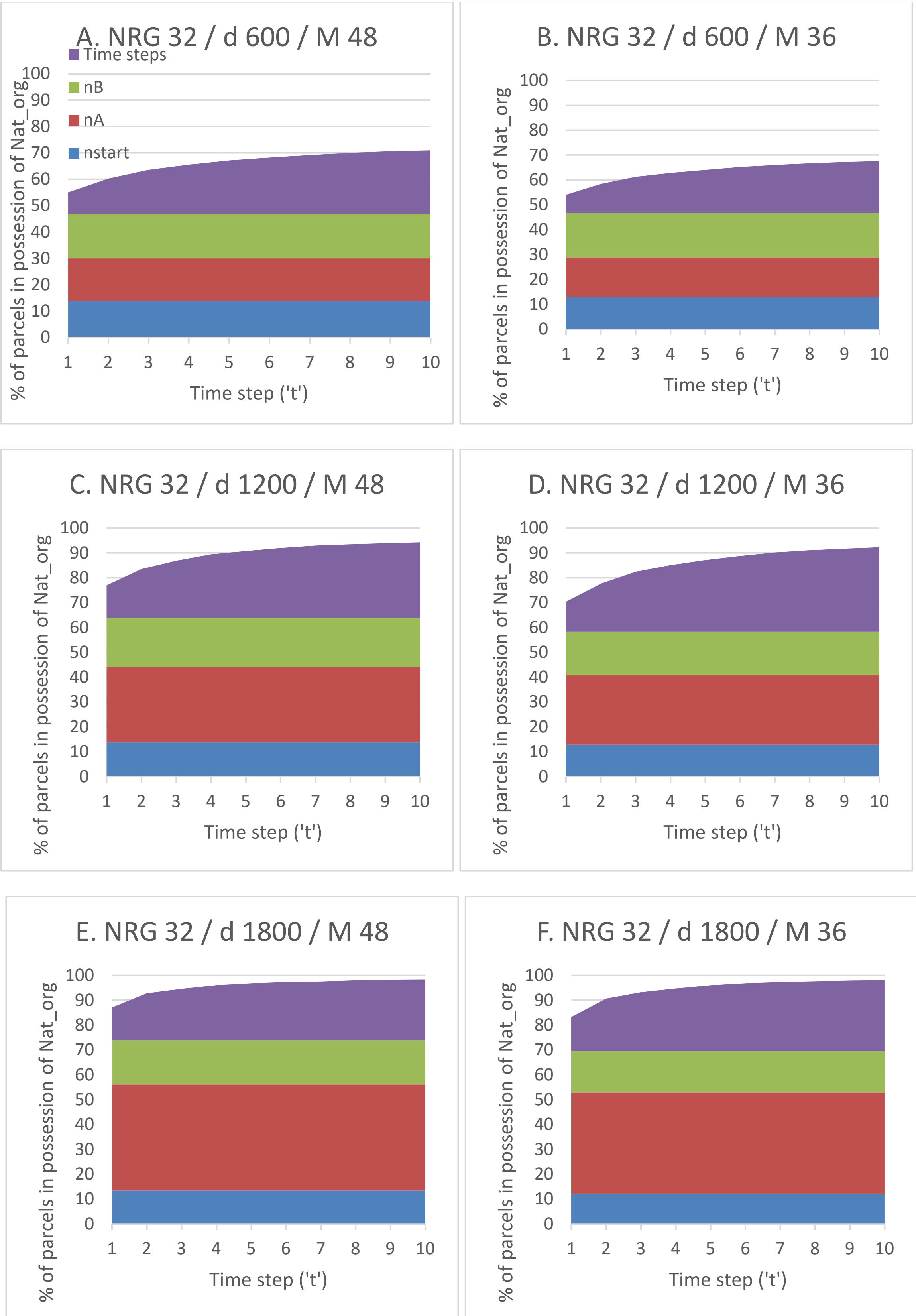

figure 5: percentage of parcels in possession of the nature organisation at the time steps with a land bank size of 32 parcels and different degrees of dispersion and different amount of farmers

4.4 Land bank size 11%

The land bank size of 11% is similar to a land bank of 44 parcels (N_{RG}) in the model. In figure 6 on the next page, the results per scenario with a land bank size of 11% are shown. The explanation of the axes and the coloured areas in the figures are the same as described in chapter 4.1.

To give an overview of the results, table 8 shows the contributions of t_{start}, t_A, t_B, the obtained parcels due to land banking in t_1, the obtained parcels at t_5, the obtained parcels in t_{10} and the cumulative percentage obtained by the nature organisation by t_1, t_5 and t_{10}. Note that the results of t_5 and t_{10} are the total amount of parcels exchanged by using land banking; so the data includes the obtained parcels in the previous time steps.

table 8: number of parcels in the planned enlargement zone at t_{start}, t_A, t_B, t_1, t_5, and t_{10}

N_{RG} 44	t_{start}	t_A	t_B	t_1	t_5	t_{10}	cumulative at t_1	cumulative at t_5	cumulative at t_{10}
d 600; M 48	2,63	3,28	4,56	1,82	4,42	4,97	*12,28*	*14,88*	*15,43*
d 600; M 36	2,54	2,84	4,75	1,66	3,98	4,42	*11,79*	*14,10*	*14,54*
d 1200; M 48	2,60	6,38	4,23	2,96	5,54	6,04	*16,17*	*18,75*	*19,25*
d 1200; M 36	2,41	5,47	4,50	2,83	5,84	6,44	*15,21*	*18,22*	*18,81*
d 1800; M 48	2,48	8,63	4,42	2,51	4,27	4,37	*18,03*	*19,78*	*19,89*
d 1800; M 36	2,34	8,30	4,22	2,97	4,83	4,99	*17,83*	*19,68*	*19,85*

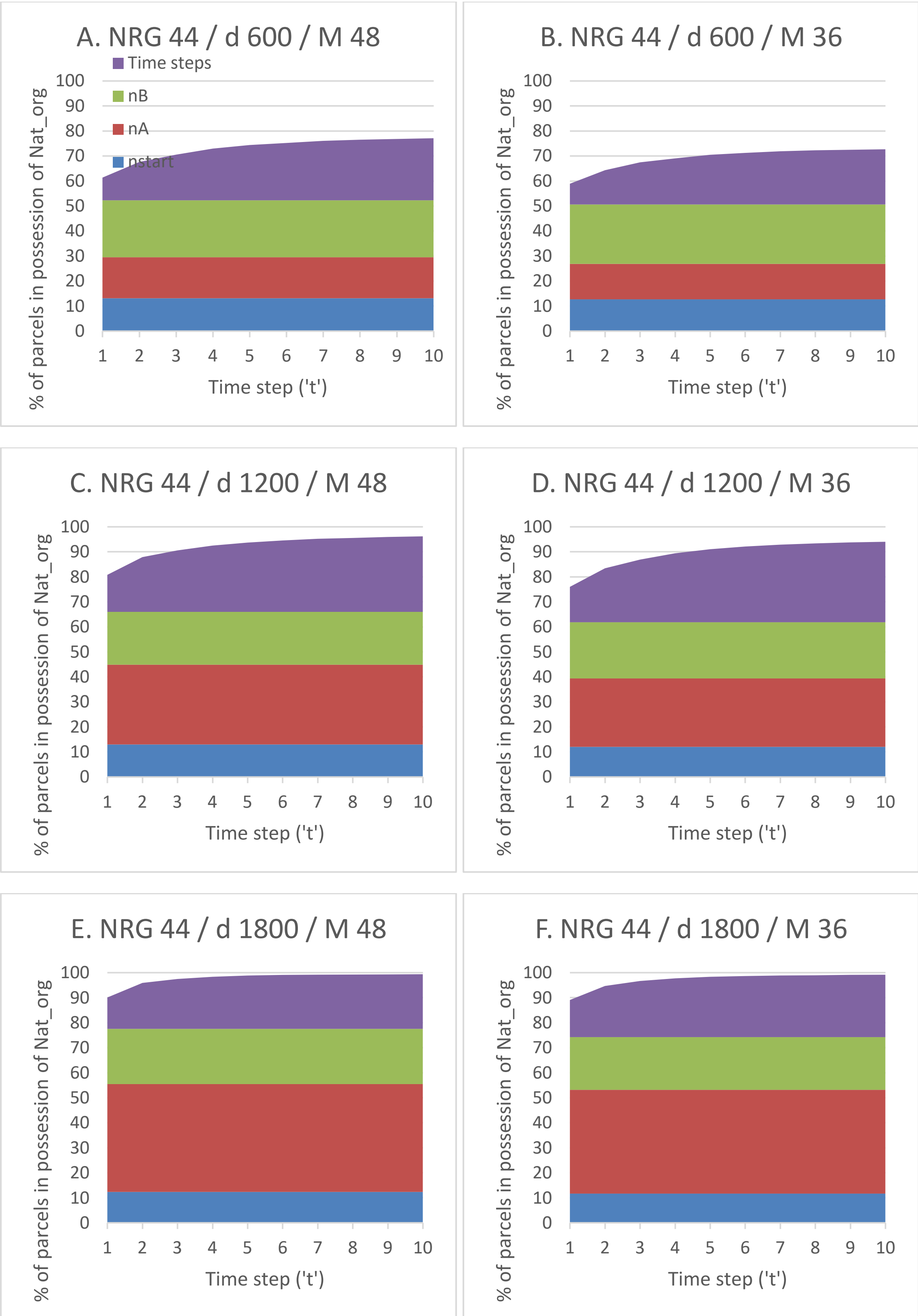

figure 6: percentage of parcels in possession of the nature organisation at the time steps with a land bank size of 44 parcels and different degrees of dispersion and different amount of farmers

4.5 Land bank size 14%

The land bank size of 14% is similar to a land bank of 44 parcels (N_{RG}) in the model. In figure 7 on the next page, the results per scenario with a land bank size of 14% are shown. The explanation of the axes and the coloured areas in the figures are the same as described in chapter 4.1.

To give an overview of the results, table 9 shows the contributions of t_{start}, t_A, t_B, the obtained parcels due to land banking in t_1, the obtained parcels at t_5, the obtained parcels in t_{10} and the cumulative percentage obtained by the nature organisation by t_1, t_5 and t_{10}. Note that the results of t_5 and t_{10} are the total amount of parcels exchanged by using land banking; so the data includes the obtained parcels in the previous time steps.

table 9: number of parcels in the planned enlargement zone at t_{start}, t_A, t_B, t_1, t_5, and t_{10}

N_{RG} 56	t_{start}	t_A	t_B	t_1	t_5	t_{10}	cumulative at t_1	cumulative at t_5	cumulative at t_{10}
d 600; M 48	2,39	3,00	5,72	2,08	4,58	5,06	*13,17*	*15,68*	*16,16*
d 600; M 36	2,43	2,72	5,94	1,89	4,16	4,58	*12,98*	*15,24*	*15,67*
d 1200; M 48	2,23	6,01	5,53	3,08	5,31	5,72	*16,85*	*19,08*	*19,49*
d 1200; M 36	2,52	5,64	5,96	2,74	4,87	5,26	*16,85*	*18,98*	*19,37*
d 1800; M 48	2,01	8,84	4,91	2,70	4,05	4,16	*18,46*	*19,81*	*19,92*
d 1800; M 36	2,18	7,80	5,26	2,82	4,42	4,61	*18,05*	*19,65*	*19,84*

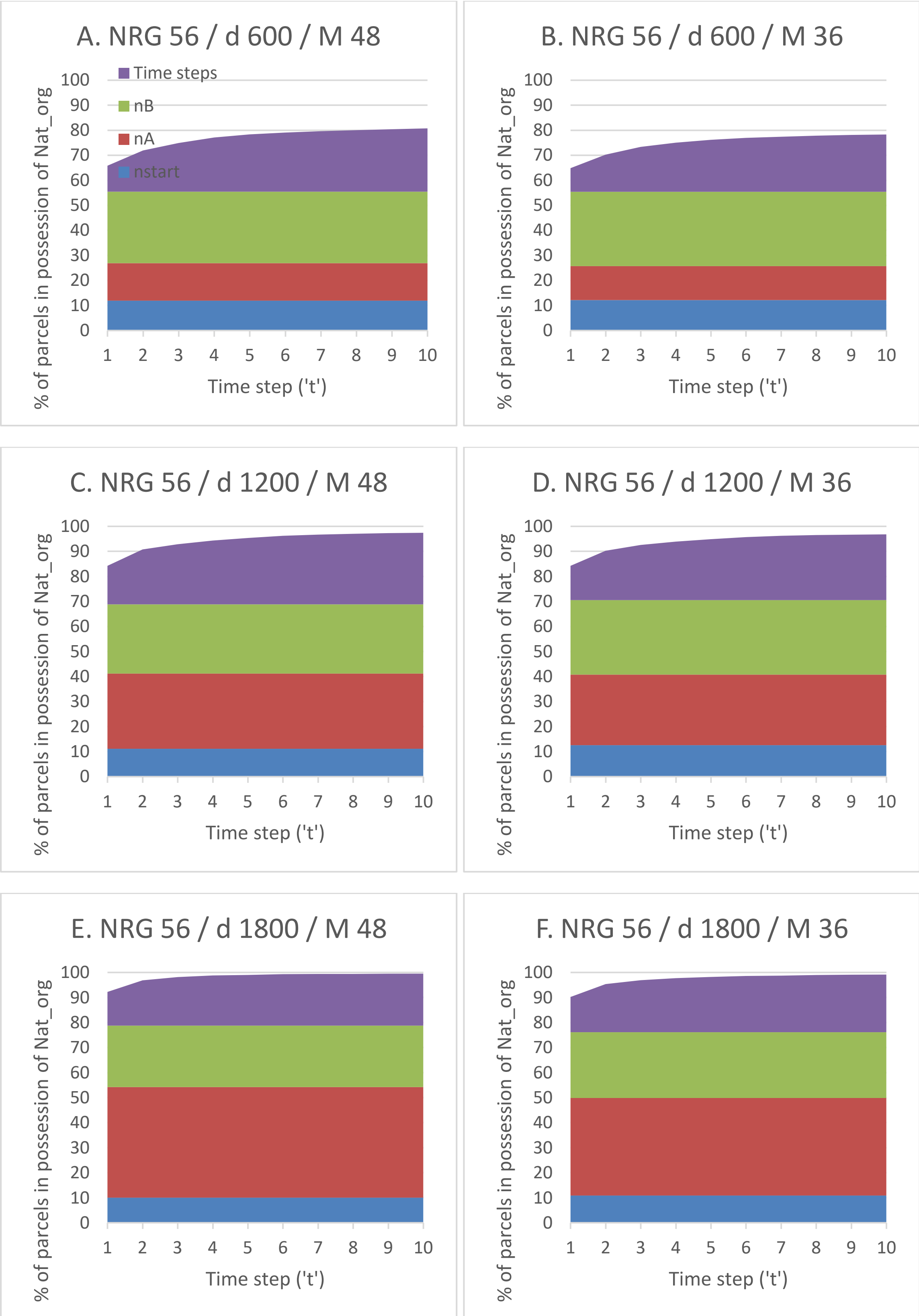

figure 7: percentage of parcels in possession of the nature organisation at the time steps with a land bank size of 56 parcels and different degrees of dispersion and different amount of farmers

4.6 Results of time step 5

To answer the research question of this research, the x-variable is the amount of land in the land bank for various degrees of dispersion in the form of scenarios and the amount of farmers. The responsive variable on the y-as is the amount of parcels in the possession of the nature organisation at time step 5. This result is shown in figure 8.

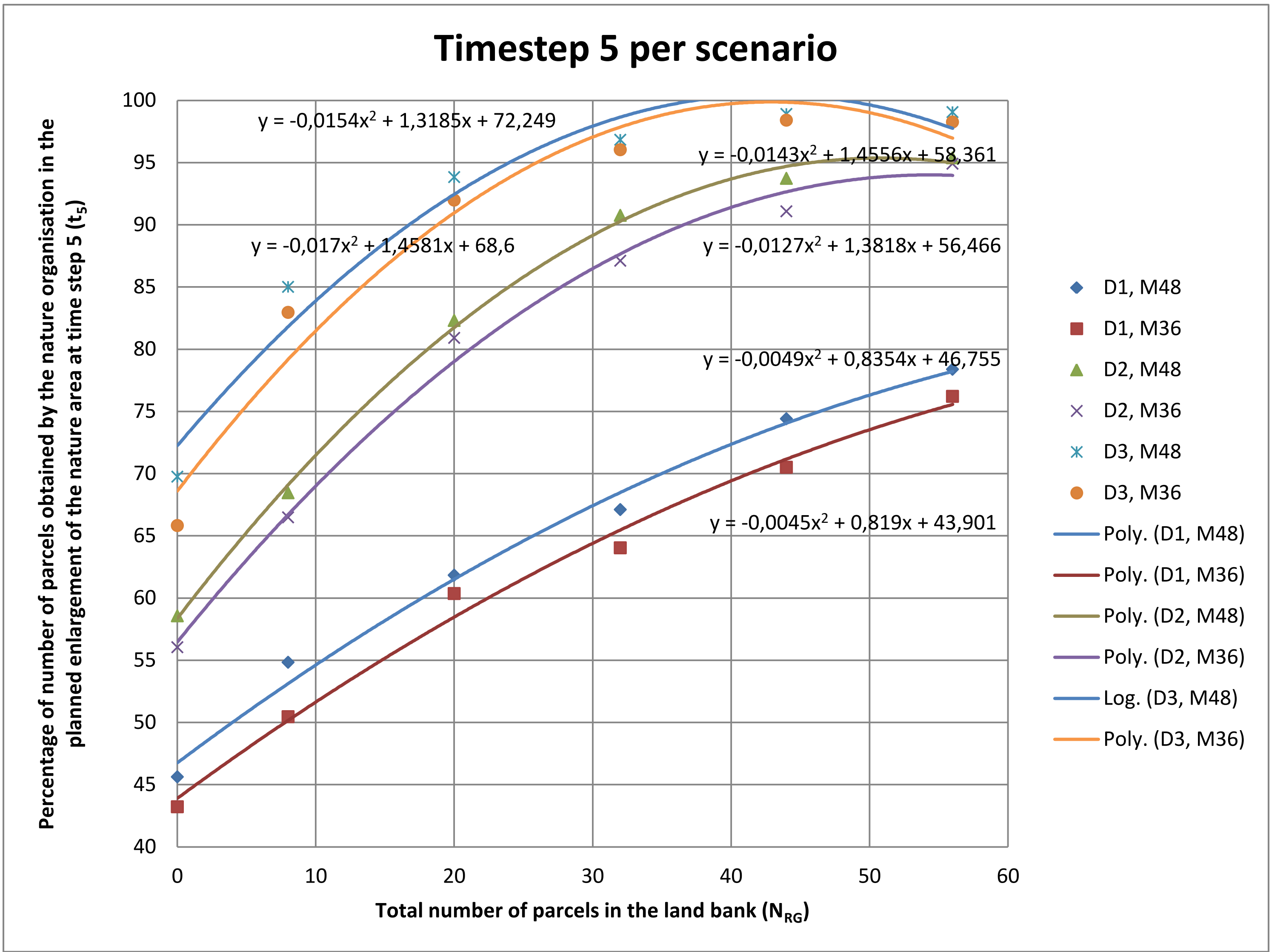

figure 8: number of parcels obtained by the nature organisation in the planned enlargement zone for the amount of parcels in the land bank, various degrees of dispersion and various amount of farmers

The lines in figure 8 are polynomials with an order of 2. To indicate data points when there are no parcels of the regional government in the land consolidation space, the average of the start position and the direct exchange between nature organisation and farmers for all the different amount of land banks are calculated. Looking at the graph, the lines with a d = 1200 m and d =1800 m show an optimum. The line with 48 farmers and a d = 1800 show an optimum above the 100%. Looking at the data, for the lines with d = 1800, an optimum is indeed reached.

5. Discussion

To answer the research questions how land banking affects the effectiveness of land consolidation, the total number of parcels in the land bank N_{RG} is compared to the percentage of the number of parcels in possession of the nature organisation in the planned enlargement zone after time step 5. In figure 8 the results are shown. Herein, the percentage of parcels in possession of the nature organisation in the planned enlargement zone is increasing with the increase of parcels in the land bank. The results show polynomial lines for all scenarios with the different amounts of farmers and various degrees of dispersion. These polynomial lines have an optimum. This optimum can already be seen when d = 1200 m or d = 1800 m. An explanation could be that too many parcels in the land bank decrease the exchange of parcels with other stakeholders. Van Dijk (2003) stated that applying land banking for public-oriented purposes is dependent on the degree of concentration of the land bank (Van Dijk, 2003; Van Dijk & Kopeva, 2006). In the model, mostly the degree of concentration of the land bank affects the effectiveness on land consolidation positively, while a land bank with too many parcels negatively affects the effectiveness of land banking in land consolidation processes.

The influence of the various degrees of dispersion on land banking in land consolidation processes is substantial. The various degrees chosen are quite coarse. However, when the fragmentation of agricultural parcels (d = 1800) is high, the effectiveness of a land bank is higher, than when the fragmentation of agricultural parcels is low. It means that when the optimum of distances of parcels to their farm is almost at the maximum, the effectiveness of land banking is lower. However, note that in a highly fragmented land consolidation space a substantial amount of parcels is already exchanged between the nature organisation and the farmers before the land bank becomes active. The calculated zero-point shows a higher starting point of the polynomial line when the *'d'* is increasing. So, the nature organisation plays a considerable role in every scenario. Besides the degree of dispersion, the model tested two amounts of farmers (M = 48 and M = 36). When the amount of farmers is smaller and thus the farm size is larger, the effectiveness of land banking on land consolidation is lower. Every scenario with M = 36 with a tested degree of dispersion has a lower effectiveness of land banking on land consolidation processes than the scenario with M = 48 with the same degree of dispersion. Note that the slope of the scenario with d = 1800 and M = 36 is steeper than the slope of the scenario with d = 1800 and M =48. An explanation for the differences between the amount of farmers is that with M = 36 the optimum of parcel distributions is reached faster in the time steps because the farmers have more parcels in their possession than when M =48. To conclude, the effectiveness of land banking in land consolidation for various amounts of farmers and various degrees of dispersion can be described as the slope of the polynomial lines, while the derivative of the functions is described in table 10 as the result of the effectiveness of land banking in land consolidation processes.

table 10: functions and derivatives of the results

Scenario	Function	Derivative
d = 600 (d1); M = 48	$y = -0.0049x^2 + 0.8354x + 46.755$	$y' = -0.0098x + 0.8354$
d = 600 (d1); M = 36	$y = -0.0045x^2 + 0.819x + 43.901$	$y' = -0.0090x + 0.819$
d = 1200 (d2); M = 48	$y = -0.0143x^2 + 1.4556x + 58.361$	$y' = -0.0286x + 1.4556$
d = 1200 (d2); M = 36	$y = -0.0127x^2 + 1.2818x + 56.466$	$y' = -0.0254x + 1.3818$
d = 1800 (d3); M = 48	$y = -0.0154x^2 + 1.3185x + 72.249$	$y' = -0.0308x + 1.3185$
d = 1800 (d3); M = 36	$y = -0.017x^2 + 1.4581x + 68.6$	$y' = -0.0340x + 1.4581$

The measured effectiveness needs to be reflected in a broader context. Therefore, this paragraph reflects on the results and the model. The measured effectiveness of land banking in land consolidation processes takes place in a land consolidation space with three types of stakeholders. Looking at the results, more stakeholders should lead to a higher effectiveness of land banking. This is only based on the differences between the two amounts of farmers tested. However, a higher variety of stakeholders and interests make land banking in land consolidation process more complex (Holtslag-Broekhof, Beunen, van Marwijk, & Wiskerke, 2014). Also, other types of stakeholders could make the process more complex, because these stakeholders could have different goals in the model. Hence, different types and different motives of stakeholders lead to a more uncertain context than simulated in the model. Thus, it is questionable if the land exchange by land banking increases with an increasing amount of stakeholders. The willingness of other stakeholders to exchange their parcels is also influenced by other factors. For instance, demographic change. The behavior of farmers is for instance intended to expand or shrink (M. Bakker et al., 2015). Therefore, with the types of stakeholders in the land consolidation space, the willingness to exchange parcels could have a large range of different motives. So, these motives could just increase the willingness of land exchange when a farmer wants to shrink, but also imply a decrease in the willingness to exchange when a farmer wants to expand.

Besides the stakeholders and their influence in land consolidation processes, the model is based on equal parcel characteristics. However, the production characteristics of land parcels contain a huge amount of variables that together determine the possibilities and weaknesses of agriculture (Van den Bergh, 2004), such as soil type, topsoil depth, erosivity, terrain, drainage, climate, temperature, sunshine, suitability of various crops, parcel size, parcel shape, micro-relief and the existing use (Gniadek et al., 2013; Koomen, Kuhlman, Groen, & Bouwman, 2004; Lambert, 1961; Palmquist, 1989). These parcel characteristics are different between parcels and based on the absolute location of a parcel. As well, the accessibility of the parcel is related to the absolute location (Alexander, 2014). Thereby, other relative factors of a parcel, such as the travel time from the farm to the parcel instead of measuring the direct distance between parcel and farm, the proximity of other land use of the same type and governmental policies have their influence on the differences between parcels (Ayranci, 2007; Gniadek et al., 2013; Koomen et al., 2004; Lambert, 1961).

All these kind of characteristics of parcels determine the value of a parcel (Woestenburg & Van der Krabben, 2013). So, besides the motives of the stakeholders, the value of the parcel makes the land exchange more complex due to the Willingness To Pay (WTP) or Willingness To Accept (WTA) of a parcel. And therefore, the economic mechanisms in the rural land market have its influence on land banking in land consolidation processes. First, the value of land is one of the shortcomings of land banking as a tool for public-oriented purposes, because the change of land use of rural areas into areas with a public-oriented purpose will decrease the value of the land (Spit, 2016). Therefore, purchasing land for public-oriented purposes will cause highly subsidized land. Second, land lease and property rights are not taken into account, even for the concept of systematic reduction, what is defined as the reduction of each property of landowners participating in a land consolidation process that has to be redistributed by a percentage in order to acquire land that can be used for other public-oriented purposes (Sonnenberg, 2002). Concluding, land and property are not normal market goods due to the variety of differentiating characteristics (Alexander, 2014). Thus, hedonic price analysis using the WTP and WTA could be included to give an economic value to parcels based on differentiating characteristics and economic mechanisms.

The inclusion of more types and motives of stakeholders, a monetary value to describe the parcel's absolute and relative characteristics would affect land banking in land consolidation processes, so the model. Besides, the model has technical simplifications. First, the simulated chronological order of land exchange. At a certain time step, only two types of stakeholders exchange parcels at once. Besides, the time steps were not defined in the model. The same processes are framed in one time step, however, in reality, it is a continuous process, where these processes interfere and influence each other. Therefore, the chronological order of the land consolidation processes in the model is a simplification of the model. Second, the land exchange in the model is only meant for nature development. Therefore, parcels between farmers are not exchanged, while it could increase the optimum of parcel distributions of farmers. However, this was not the aim of the model. Third, the nature organisation plays a substantial role in the land exchange to become in possession of the parcels in the planned enlargement zone. Since 2013, this land acquisition by other stakeholders like nature organisations is possible (Kuindersma et al., 2015), but it is unclear if nature organisations play a substantial role in the regional nature developments as sketched in this model. Also, it is questionable if these organisations have the power and knowledge to play a substantial role in land exchange. Fourth, the amount of farmers is not independent from the degree of dispersion. When the amount of farmers is smaller, the amount of parcels per farmer is increasing. When the degree of dispersion does not change, the chance that a parcel is sampled within the distance *'d'* is increasing as well. Therefore, there is a relation between the amount of farmers and the degree of dispersion. Fifth, the scenarios did not include scenarios with zero parcels in the land bank. Therefore, a zero-point was calculated by taking the averages of the distributed parcels to the nature organisation plus the direct exchange between nature organisation and farmers in the model tests with the same amount of farmers and the same degree of dispersion. Sixth, the farms are positioned at certain spots occupying no space. Besides, the position of the farm also influences the land exchange. When a farm is situated further away from the planned enlargement zone, a parcel in the planned enlargement zone is faster exchanged than when a farm is situated adjacent to the planned enlargement zone. Seventh, roads, ditches, buildings and other objects occupying space are not taken into account in the model. Roads have its influence on the accessibility of the parcels and also the distance between farm and parcel. Eights, the distributed parcels to a farm are not always situated within distance *d* due to the overlap of possible duplicated sampled parcels because the farms are situated close to each other. Therefore, it is highly possible that not every farm reaches an optimum of parcel distances to the farm. To conclude, although the model contains a substantial amount of simplifications and the model tests a limited amount of parcels and economic mechanisms in the rural market, the model can give insights into the relations between distance, amount of land in the land bank, degrees of dispersion and the amount of farmers.

6. Conclusion

6.1 Conclusion

The research was conducted, because the transfer of the parcels in the land bank to the regional governments lead to a different extent to which regional policies prioritize land acquisition and spatial development processes (Kuindersma et al., 2015; Van Straalen et al., 2016). These differences were caused by political and cultural backgrounds and budget constraints (Van Straalen et al., 2016). This distinction between regional governments implies different implementations of land banking and land consolidation in spatial policies, especially regarding nature policies like the NNN. The research of modelling land banking in land consolidation processes may conclude that a form of a land bank increases the land exchange in order to reach nature policy goals, like nature development for the NNN, certainly when nature organisations or other stakeholders play a marginal role in land exchange. However, a general conclusion regarding land banking in land consolidation processes cannot be made, because every area differs from each other due to the absolute and relative characteristics of a parcel, the different types of stakeholders and the economic mechanisms of the rural market. Therefore, tailored policies regarding land banking are needed to have a high effectiveness of land banking in land consolidation processes. In case of starting land banking in regions, the model predicts a higher effectiveness in land consolidation spaces where a certain extent of fragmentation, i.e. degree of dispersion and the amount of small farmers are high. Besides, when farmers are located further away from a planned enlargement of a nature area, the chance of exchanging parcels will become higher. Note that the degree of concentration of the land bank can negatively affect the effectiveness of land banking in land consolidation processes (Van Dijk, 2003; Van Dijk & Kopeva, 2006). Thus, land banking can have an added value to reach nature policy goals, however, the extent of the effectiveness is dependent on an excessive amount of factors.

6.2 Recommendations

The simplifications in the model ask for further research. First, the fact that the absolute and relative parcel characteristics were not taken into account, may improve the model. Besides, introducing different motives and different types of stakeholders reflecting reality could improve the model. Therefore, introducing the concepts WTP and WTA in the model make the model more realistic. Improving the model by using WTP and WTA is a recommendation to make the model more applicable to a real-life situation. However, the current model can already be applicable to a land consolidation space in the Netherlands. This application is possible because the script is based on a shapefile, while the '*Basis Registratie Percelen*', containing all parcels in the rural areas, is also a shapefile. Adapting the script to a different shapefile can be easy. Therefore, further research can be done on the application of the model. Second, extra steps can be taken to make the model more reliable. For instance, it is possible to enlarge the land consolidation space to simulate the differences between the scales of land consolidation processes. Third, an interesting aspect of this model is the fact that an optimum of land banking is shown in the results. The degree of concentration of the land bank determines the application of land banking in land consolidation (Van Dijk, 2003; Van Dijk & Kopeva, 2006). Therefore, a quantitative research can be done to investigate this optimum of land banking.

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Appendix

Because the thesis is a model built digitally, a CD-ROM is added as an appendix. The data of the thesis are stored on this CD-ROM. In this appendix, the description is given which data are stored and how it is labelled.

Appendix 1. The model script with description

Appendix 1 contains the script used for this thesis. The script is divided into chapters. In green fond, an extra explanation is given what the script lines are used for in R. Sometimes the names of variables within the script lines are not in line with the names of the variables in the thesis. When this is the case, an explanation in green fond will explain the differences with the thesis text.

Appendix 2. R-script files

Appendix 2 exists of two files. Appendix 2a is the total R-script inclusive the installation of packages and the determination of the results. However, the script line of modelling 200 times the model needed a link to a different R-script file. This is Appendix 2b. It contains exactly the same script only without the installation of packages and determination of the results. When copying the R-script files to a computer, do not forget to change the directory in the R-script lines. Otherwise, the model cannot read the shapefile (appendix 4).

Appendix 3. Data of the model tests

Appendix 3 consists of the results of the model tests. For every scenario, see labels in table 4, the 200 model runs give the amount of parcels in ownership of the nature organisation in the planned enlargement zone at a certain time step. Also, the mean, the standard deviation, the variance and the 95% upper and lower interval are calculated.

Appendix 4. Shapefile

Appendix 4 are the files containing the grid. The shapefile was used as a layer of the model.