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RESEARCH ARTICLE

The feasibility of implementing an ecological network in The Netherlands under conditions of global change

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Abstract
Context Both global change and policy reform will affect the implementation of the National Ecological Network (NEN) in the Netherlands. Global change refers to a combination of changing groundwater tables arising from climate change and improved economic prospects for farming. Policy reform refers to the abolition of an intermediary organization that organizes land trades with the support of a national land bank.

Objective In this paper we evaluate the effects of these factors on future land acquisition for the NEN.

Methods We applied an agent-based model of the land market based on sales and purchases between farmers and nature-conservation organizations (establishing the NEN) within a case study area.

Results Our results demonstrate that future land acquisitions for the NEN are constrained by strong competition for land from farmers due to improved economic prospects for farming. Effects of climate change are that fewer parcels will be sold from farmers to nature-conservation organizations in a dry scenario as compared to a wet scenario. An important constraint for land acquisitions is the low willingness to pay (WTP) for land by nature-conservation organizations. We demonstrate that higher WTP increases land purchases considerably. However, the spatial pattern of land acquisition is fragmented, which may undermine its effectiveness from a restoration perspective.

Conclusions The combination of these processes leads to land acquisitions for the NEN that do not meet the initially-stated policy objectives by far. In addition, the abolition of a land-trade organization supported by a land bank leads to more fragmented pattern of nature reserves.

Keywords Ecosystem restoration · Agent-based model · Climate change · Land use change · Land market · Land use planning

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Introduction

In order to safeguard and promote biodiversity, several European governments have committed themselves to the implementation of a national ecological network (Jongman et al. 2011). Being strongly based on the principles of island biogeography (MacArthur and Wilson 1967) and meta-population theory (Hanski 1998), such networks envision enlarging existing nature areas in order to decrease extinction risk and connecting areas to increase resilience by facilitating dispersal and genetic exchange. The creation of a coherent network of nature areas is important for facilitating the northward migration of species in response to climate change (Vos et al. 2008).

In the Netherlands, the National Ecological Network (NEN) was, as in most other countries, designed in the 1990s (Horlings and Gersie 1995). At that time, ambitions were high because of strong public and political support for nature restoration and the appealing concept of a national ecological network (Turnhout 2009; Buijs et al. 2014); the economic outlook for farming was not good and many farmers were willing to sell land; and the Netherlands had one of the most efficient planning systems in Europe (Van Der Valk 2002). The original ambition was to implement a network of 728,500 ha by 2018. In the meantime, the economic situation has deteriorated and public support for nature restoration has waned; the economic outlook for farming, on the other hand, has improved, and farms are on average more prosperous and competitive than those in the 1990s. Moreover, land-use planning responsibilities have gradually been transferred from the national to the provincial level, which has generally led to a loss in efficiency (Roodbol-Mekkes et al. 2012; Van Straalen et al. 2014). Together, these factors have decreased ambition for NEN implementation, both in terms of the targeted area and the timing.

The most recent development within the process of decentralization is the planned abolition of the governmental body that has been largely responsible for implementing the NEN. Responsibilities are being transferred to provincial governments, and it is expected that this reform will have an impact on land acquisitions for the NEN. The role of this national governmental body (i.e. the Government Service for Land and Water Management) was, until 2007 and to a lesser degree until today, the following. It bought agricultural parcels that were placed on the market within or close to the NEN-zone, and acted as a land bank. Few parcels were directly transferred to one of the nature-conservation organizations (NCOs) (very few parcels were sold directly from a farmer to an NCO), but most parcels were used as trading material: they were offered to specific farmers in return for parcels that were of particular interest for the NCOs. Sometimes entire farms were moved, often to one of the Dutch polders. Because most farmers could be offered an attractive alternative parcel, the organization has facilitated the acquisition of parcels adjacent to existing nature areas, which, in turn, facilitated efficient management, e.g. raising ground water tables (required for specific wet habitat restoration) and grazing by large herbivores.

Now that the national government has withdrawn, provinces are left to decide how best to meet the NEN targets, to which they still adhere. They may take over the function of the land bank (including those parcels still remaining), but the extent to which they can do so depends on their financial situation. Clearly, their total stock of trading parcels will always be smaller than that of the national land bank, and so will their capacity to negotiate with farmers (Provincie Gelderland 2013). As an alternative, provinces have the legal right to expropriate farmland for public purposes (also known as compulsory purchase), but this instrument is unpopular and has resulted in tension and wariness among farmers in the past. Several provinces want to intervene as little as possible, and prefer to leave the land acquisitions for the NEN to the NCOs, providing them with subsidies to do so (Provincie Gelderland 2012).

The province of Gelderland—the largest province of the Netherlands, containing the largest terrestrial nature reserves in the country—is one of these provinces. Given the problems the province experienced with land acquisition at designated locations in the past, and the abolition of the national land bank, there is great uncertainty as to whether the implementation of a pre-planned NEN will still be feasible. Our aim in this paper is to simulate land transaction dynamics between NCOs and farmers, in order to test whether pre-defined spatial planning targets can be achieved through bottom-up, free land-market dynamics. To achieve this aim, we developed an agent-based model to simulate land-use change by land transactions in a case study area in the province of Gelderland. The Rural Land Exchange

model (RULEX, Bakker et al. (2014)) is used to (i) simulate the amount and spatial pattern of land acquisitions for the NEN assuming that NCOs operate in a free land market while maintaining their current willingness to pay for land; (ii) explore realistic acquisition targets by taking account of the degree to which farmers are willing to sell land; and (iii) explore how land acquisitions by NCOs can increase if they display a higher willingness to pay. The simulations are undertaken for two contrasting scenarios of global change, in order to account for changes in the economic perspectives of farmers and the potential effects of climate change on land suitability for agriculture and nature management.

The scientific challenge of this exercise is in the diversity of drivers that influence the land market, as well as the diversity of actors active within it. Both farmers and NCOs are influenced by policy, markets, and biophysical conditions although their responses differ. Furthermore, both actor types have different goals and motives, and they differ considerably in the structure of their population (many individuals versus a few organizations). The rural land market is a typical social-ecological system, which—by its very nature—responds to a wide range of drivers that often interact. For understanding the response of such systems to change, different actors and drivers should be studied simultaneously. This requires combining different scientific disciplines, but attempts to do so often strand in practical problems of combining scientific paradigms. Agent-based modelling is an instrument that potentially overcomes these problems, as its loose equation- or rule-based structure allows combining different types of data and information. Agent-based models of land-use change are not new (Matthews et al. 2007; Valbuena et al. 2010; Schouten et al. 2013), but no such model has simulated the interaction between such different agent types, responding to such a wide range of driving factors. Here, we demonstrate how land transactions between agent types can be simulated, and we use this model to explore the dynamics in the spatial extent of ecological networks under conditions of global change.

In the next section we introduce the case study area, followed by an overview of the two global change scenarios that are implemented in RULEX. We then present an overview of the RULEX model, with an emphasis on the model mechanisms that control acquisitions for the NEN. Next, we present the experimental setup and simulation results, followed by recommendations for policy.

Case study area

The case study area is a region of about 300 km^2 in the East of the Netherlands (Fig. 1), and is referred to as the *Baakse Beek* area after the brook that runs through it (*beek* is Dutch for brook). According to the Dutch Agricultural Census and the Dutch Parcel Registration Database of 2009, the area comprised—at that time—959 farms and 8,930 agricultural parcels. Most farmers are dairy farmers, but arable farmers, pig breeders, and market gardeners are also present. In spite of the intensive agriculture the area is still considered to be a visually attractive, small-scale landscape. The many hedgerows and the presence of estates and nature reserves contribute to this image (Bakker et al. 2014). The NEN covers about 13 % of the area (about 3,804 ha) of which 2,769 ha has currently been established. The NCOs managing the realized NEN are The Dutch Society for Nature Conservation (Natuurmonumenten; a private society for nature conservation), Staatsbosbeheer (a state agency for forestry and nature management), Geldersch Landschap & Kasteelen (a private foundation for the conservation of natural and cultural heritage), and 87 private estates (Bakker et al. 2014).

The province provides subsidies for land acquisition for NEN-implementation to any party (individuals and organizations) that agrees to comply with a set of conditions, including a function change to nature and a management regime aimed at developing specific nature-conservation targets. In the past, the three NCOs active in the Baakse Beek area received 100 % of the purchase price, but this percentage has recently been reduced to 85 %. Because of their 'green' character, private estates are generally considered to be an important part of the green infrastructure in the area and in many cases are considered to be part of the NEN. However, due to the strict regulations accompanying provincial remuneration of land purchases for NEN implementation, private estates are generally much less inclined to use NEN-subsidies (Vader et al. 2012). In this paper, we therefore consider the estate owners as autonomous parties whose acquisitions are not influenced by the governmental budgets allocated for land acquisition, in

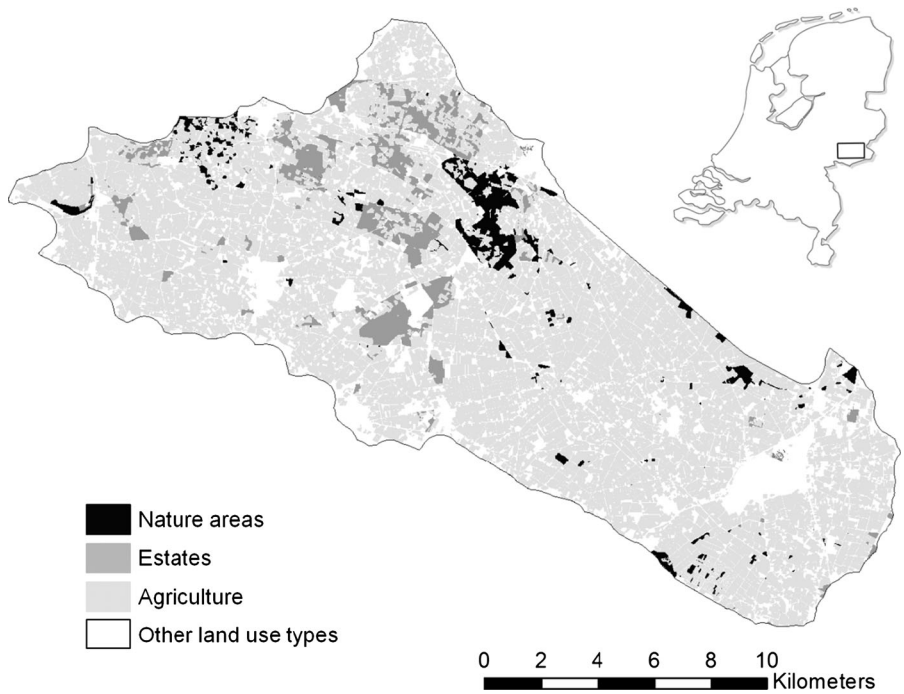

Fig. 1 Study area with the three major land use types indicated in *different shades*. Estates are distinguished as a separate land use type because they have a multifunctional land use that is considered to contribute to the natural infrastructure of the area. Other land use types comprise mainly of urban areas, farmsteads, and production forest but also include infrastructure and waterways

contrast to the NCOs, who depend strongly on these budgets.

Global change scenarios: socioeconomic and climate change

Two global change scenarios were explored: one reflects a so-called *Global Economy* world (GE); the other reflects a *Regional Communities* world (RC). Both scenarios are derived from the SRES storylines (Arnell et al. 2004; Westhoek et al. 2006). We collected trends in relevant variables from various sources that also used these storylines (Table 1). In the GE world, most farmers experience considerable increases in gross margins, in particular arable farmers and market gardeners. In the RC world, changes in the economic prospects of farmers are less strong, but also here arable farmers and market gardeners experience a stronger growth than dairy farmers and pig breeders. Two corresponding climate change scenarios from the Royal Dutch Meteorological Institute (KNMI) were used. Following Riedijk et al. (2007) the GE scenario was combined with a climate scenario showing a strong increase in temperature in combination with circulation change, while the RC scenario was combined with a climate scenario with a moderate rise in temperature and no circulation change. In the case study area, the climate scenario accompanying the GE storyline shows a decrease in the number of parcels that are waterlogged during spring, while the scenario accompanying the RC storyline shows a small increase. Both scenarios also show more dry spells in spring and summer. Trends in spatially-explicit soil suitability, affected by ground water levels and expressed as percentages of the potential yield that can be obtained on the land, were computed for a mix of agricultural crops representative for the area. Hereby we assumed that farmers irrigate whenever necessary, as this is currently the general practice and the province is not considering a restriction on irrigation permissions. Quantitative trends in the two scenarios are given in Table 1.

Materials and methods

The RULEX model

The RULEX model simulates rural land transactions among farmers and between farmers, estate owners, and NCOs. It is strongly empirically-grounded and has been calibrated on observations from the study area for

Table 1 Global change for two contrasting scenarios

Variable	Annual change in GE scenario (%)	Annual change in RC scenario (%)	Source
Gross margins arable farming	3.14	1.94	Kanellopoulos et al. (2014) with adapted price scenarios based on De Vries et al. (2013)
Gross margins dairying	2.57	0.41	Paas (2013)
Gross margins horticulture	4.34	2.39	Correction factor compared to arable farming, based on yield changes (Wolf et al. 2011) and price changes (De Vries et al. 2013)
Gross margins pig breeding	2.57	0.54	Correction factor compared to dairy farming, based on yield changes (FAOSTAT) and price changes (De Vries et al. 2013)
Spring groundwater level (median for all parcels)	0.014	0.008	Van Ek et al. (2012)
Soil suitability for agriculture (median for all parcels)	2.60	−0.19	Applying HELP tables (Van Bakel et al. 2005) on Van Ek et al. (2012)

GE global economy, *RC* regional communities

the period 2001–2009 so that it generates realistic transaction frequencies and land-use change. The model underwent a performance verification that showed satisfactory results. These results, together with details about the model, are described in Bakker et al. (2014). Here we give a brief overview.

The existing population of farmers, estate owners, and NCOs is taken as the starting point. For the farmer population census data indicate farmer age, economic farm size, farm area, and farming type. ArcGIS shapefiles delineate parcel boundaries and contain the ID of the farmer that owns or leases the parcel. This shapefile was complemented with the property ownership of estate owners and NCOs. In each model timestep (representing 1 year in reality), RULEX assigns buying and selling behaviour to individual farmer-agents based on an empirically-derived probability distribution that is conditional on age, economic farm size, farm area, and farming type (this is a stochastic process). Estate-owner agents and NCO agents are considered not to sell land, which is in accordance with their stated strategies (Bakker et al. 2014). Selling farmer-agents select their least favourite parcels and place them on the market. Favourability is based on biophysical parcel properties, but also on the distance from the farmstead; more detail is provided below. Buying agents (estate owners and NCOs, but also other farmers) bid for these parcels. All have different criteria for evaluating for-sale parcels (see below). The agent with the highest bid purchases the parcel, provided that the bid exceeds the seller's willingness to accept (WTA). Not all for-sale parcels are sold, and not all buying agents succeed in buying land. After a cycle (one time step), all agent-properties and land-ownership links are updated, and another cycle takes place. A model run refers to a simulation of 15 time steps and represents land exchange from 2010 to 2025, which is the period over which the Province of Gelderland wants to implement their part of the NEN (Provincie Gelderland 2014).

In addition to the land-exchange mechanisms, RULEX simulates ageing, succession, and the death of farmer agents. Economic development, which differs between the two contrasting global change scenarios, is implemented in the model as exogenous trends in gross margins per farming type (Table 1). These are incorporated as changes in the economic farm size of farmer agents, which together with their age, farm area, and farming type affect their decisions to buy or sell land. Local climate change is introduced into the model simulations as trends in parcel hydrological properties, affecting the favourability of land from the perspective of both farmer and NCO agents.

The degree to which NCO agents in RULEX succeed in buying land is affected by a number of mechanisms. First, their *willingness to pay* (WTP) for

land that becomes available for sale in the simulated market. A survey was held among representatives of NCOs from which we obtained the relative importance assigned to a set of parcel properties, using a combination of conjoint analysis and regression analysis. Then, using data of past land acquisitions by these organizations, we scaled the obtained function so that it returns land prices in euro per hectare (Bakker et al. 2014). This resulted in the following empirical equation for the WTP of NCOs (WTP_N):

$$WTP_N = 11,000 - 7.9 \times Distance + 9214 \times Seepage - 320 \times GVG\left(€\,\mathrm{ha}^{-1}\right) \quad (1)$$

where *Distance* is the distance to existing nature reserves in metres, *Seepage* is a dummy variable that indicates the presence of exfiltrating groundwater (coded as presence = 2; absence = 1), and *GVG* is the spring groundwater level in cm from the surface.

This equation implies that NCO agents are willing to pay more for parcels that are close to existing nature reserves (for every 100 m further away the WTP_N drops by $790 € \mathrm{ha}^{-1}$). Given that NCOs are particularly interested in restoring historic marshland ecosystems (which contain high numbers of rare species), the presence of exfiltrating groundwater on a parcel increases the WTP_N by $9,214 € \mathrm{ha}^{-1}$, and every 10 cm increase in groundwater level increases the WTP_N by $3,200 € \mathrm{ha}^{-1}$.

In interviews, private estate owners indicated a particular interest in expanding their existing properties and were generally not interested in land acquisition for nature restoration. Hence, in RULEX, estate-owner agents place a bid whenever adjacent agricultural land becomes available:

$$WTP_E = 35,000 € \mathrm{ha}^{-1} \quad \textit{if parcel borders existing property} \quad (2)$$

$$WTP_E = 0 € \mathrm{ha}^{-1} \quad \textit{for any other parcel}$$

The competition with farmers is a factor that constrains the rate of land acquisition for the NEN. Hence, the competitive ability of farmer agents, expressed as their willingness to pay (WTP_F) is an important variable. Based on a combination of hedonic price analysis and econometric parameter fitting on past transaction data (Bakker et al. 2014), the following equation was obtained:

$$WTP_F = (4.16E-05 - 1.89E-07 \times SoilSuit - 1.62E-03 \times (1/(DistTown + 100))) + 5.26E-04 \times (1/(DistNEN + 100))^{-1} - 16.85 \times (DistFarmstead - 250) \quad (€\mathrm{ha}^{-1}) \quad (3)$$

where *DistFarmstead* is the distance between the parcel and the farmstead (m), *SoilSuit* is an indicator for the percentage of the potential yield that can be obtained on the land (affected by ground water levels), *DistTown* is the distance from the parcel to the nearest town (m), and *DistNEN* is the distance between the parcel and the NEN zone (m). In RULEX, the same equation (Eq. 3) is used by the selling farmer agents to determine which parcels to put onto the market and hence interpreted as the willingness to accept (WTA_F) for the sellers.

Equation 3 implies that farmer agents, NCO agents, and estate-owner agents do not necessarily compete for the same parcels. By contrast, parcels with high groundwater tables are generally valuable from the perspective of NCO agents (*GVG* in Eq. 1) while they result in lower soil suitability (*SoilSuit* in Eq. 3) and hence a low appreciation from a farmer agent's perspective. However, distance to farmstead is an important factor, and since many farms are still located within the NEN zone, this can result in competition for land in which farmer agents may out-compete NCO and estate-owner agents.

Transaction prices were taken to be the average of the WTA of the seller and the WTP of the buyer; a model assumption implying no particular market power of either sellers or buyers. In order to be able to link acquisition rates to budgets constraints for NCOs, cumulative budget spent on land acquisitions by NCO agents were recorded during a simulation run for the 15 year period. Cumulative budgets and purchased area (in hectares), in addition to the spatial patterns of land acquisitions, are the two model outputs reported in this paper.

Methods: experimental setup

Farmer, NCO, and estate-owner agents were initialized using the census and ownership data for the year 2009. Model experiments were designed to answer the following questions: (1) How will land acquisitions for

the NEN proceed in the 15-year period following the initial year, for two contrasting global change scenarios; and how will this relate to the official targets and available budgets? (2) What is the total amount of land placed on the market by farmers within the NEN zone during this period for the two global change scenarios? This gives us the theoretical upper limit of possible purchases for the NEN zone. (3) What will be the effect of land purchases and expenditures if NCO agents increase their willingness to pay? This allows us to identify realistic targets and budgets for nature acquisitions for the remainder of the period during which the NEN aims to be implemented.

In order to answer these questions, RULEX was run several times with varying settings, to explore different outputs. Because the assignment of buying and selling behaviour of farmer agents involves a stochastic component, each model run produces slightly different results. For this reason, RULEX was run ten times with the same initial settings with the average of these ten runs, and the smallest and largest numbers, being presented as results. When presenting maps, the *most representative* run was selected. This was done by first computing the mode of land use in 2025 for each parcel, computing the difference between each individual run and the mode as a percentage of matches, and then selecting the run with the highest match.

To answer question 1, RULEX was run for the period 2010–2025 for the two scenarios as outlined in Table 1. This generated land transactions between farmers, estate owners, and NCOs under the conditions of a free land market, while agricultural markets and climate conditions change. In order to see how these acquisitions relate to the official targets we compared the total acquired area to the NEN area that is still to be implemented (1,035 ha). In order to see how expenditures relate to available budgets, we compared total budgets spent on NEN-acquisitions by the NCO agents to realistic budgets allocated by the government to the three large NCOs for nature acquisition. These realistic budgets were estimated from past annual expenditure at the national level, in which we distinguished two periods: the period 2007–2010 when the economic crisis had not yet affected budgets for nature so that these were still relatively high; and the period 2011–2012, when the government made severe budgets cuts. We used both budgets as a reference with which to compare simulated expenditure. National annual budgets were downscaled to the Baakse Beek area, which resulted in an expenditure level of €391,687 per year for the large-budget option and €88,977 per year for the small-budget option. For the period 2010–2025 these budgets accumulate to €6,266,995 and €1,423,635 respectively. Adding a required own contribution of 15 % from the NCOs amounts to €7,207,044 and €1,637,180, respectively.

To answer question 2, (What is the theoretical upper limit of possible purchases for the NEN zone?) we used the same RULEX runs as those described above, but explored a different output: the total amount of land placed on the market by farmer agents. This is land that could theoretically be purchased by the NCO or estate-owner agents. Setting targets that exceed this area may be futile, as farmers are not forced or otherwise stimulated to sell. To explore this constraint, we plotted the total amount of land placed on the market by farmer agents within the NEN zone against time, for the two scenarios.

From observed land acquisitions by NCOs in the previous decade, we know that the willingness to pay by NCOs was generally low, and that consequent acquisition rates were also low (Bakker et al. 2014). Since RULEX was calibrated on these observations (for the period 2001–2009), we anticipate low acquisition rates for the future as well. Behavioural change in the future is nevertheless a possibility that is worth exploring, and in response to the withdrawal of the Government Service for Land and Water Management (i.e. the national land bank) as an intermediate party, NCOs may become more assertive in bidding for land (i.e. displaying a higher willingness to pay). Therefore, to answer question 3 (What will be the effect of land purchases and expenditures if NCOs increase their willingness to pay for parcels?) we explored different levels of WTP_N to investigate how the total amount of purchased land can be increased when NCOs are willing to pay more. Thus, we increased the WTP_N by 10, 20, 30, 40, and 50 % respectively (we multiplied the parcel-specific outcomes of Eq. 1 by 1.1, 1.2, 1.3, 1.4, and 1.5), and let RULEX run with these increased levels of WTP_N. The WTP by estate-owner agents (WTP_E) remained unchanged for two reasons: first, land acquisition by estate owners is already expected to take place at satisfactory rates; and secondly estate owners are rather autonomous and their acquisition activities are unlikely to be influenced by the province.

Results

Simulated land acquisitions by NCO and estate-owner agents within the NEN zone between 2010 and 2025 are shown in Fig. 2, for the GE and RC scenarios. It can be seen that in the RC scenario, NCO and estate-owner agents together acquire on average 135 ha, while in the GE scenario they acquire on average 99 ha. In the RC scenario, estate-owner agents are responsible for 49 % of all acquisitions, in the GE scenario for 53 % (not shown in Fig. 2). The budget spent by the three NCOs (Fig. 3) is on average €1,281,963 in the RC scenario and €861,011 in the GE scenario. Expenditure in the RC scenario is close to the small budget, while expenditure in the GE scenario is well below. Expenditure in both scenarios is far below the large budget.

Figure 4 shows the spatial pattern of the simulated purchased parcels for the GE and RC scenarios in 2025. Apart from the difference between the scenarios in the total area that was acquired by NCOs and estate owners (as also shown in Fig. 2), both scenarios show a highly fragmented pattern when it comes to the location of newly purchased nature parcels, rather than large contiguous areas or parcels that together serve as a corridor connecting two larger areas.

The total area placed on the market by farmer agents within the NEN zone during the period 2010–2025 for the two scenarios is shown in Fig. 5. These trends may be considered to be the upper limits of land that could theoretically be purchased for NEN implementation, under the condition of a free land market. It can be seen that in the RC scenario, on average 655 ha of the land was placed on the market, while in the GE scenario 529 ha was placed on the market. This suggests that only 50–60 % of the remaining 1035 ha within the NEN zone can theoretically be achieved. However, combining the information from Figs. 2 and 5 shows that only about 20 % of all land that becomes available is bought by the NCO or estate-owner agents, which reduces the overall expected achievements to 10 % of the official targets.

This 50–60 % figure reflects the constraint of the lack of farmers that are willing to sell, and the generally slow rate at which shrinking farms sell their land (as also observed by Geerling Eiff and Van der Meulen (2008)). However, the fact that only 20 % of the land that is placed on the market ends up being bought by NCO or estate-owner agents is due to a combination of their low willingness to pay (in particular, that of the NCO agents) and the relatively high willingness to pay by the farmer agents. Clearly, when NCO agents are willing to pay more, this increases their chances of buying more land by winning more bids over farmer agent than in the default case. This was explored by running RULEX with higher levels of WPT_N, for which the results are shown in Figs. 6 and 7.

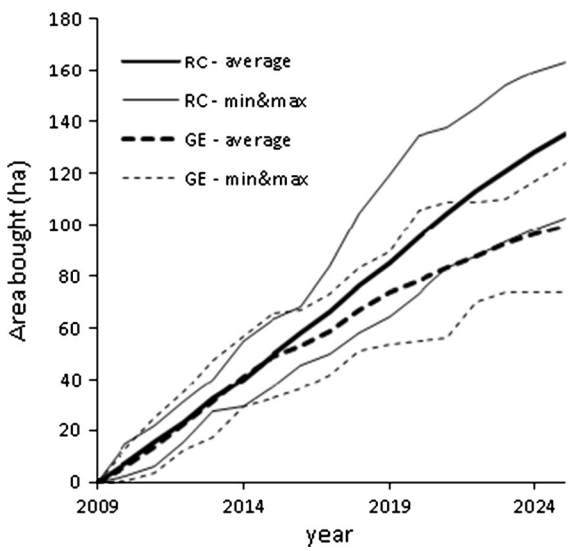

Fig. 2 Cumulative area bought by NCO agents and estate-owner agents over a 15 year period (2010–2025) for the regional communities (RC) and global economy (GE) scenarios

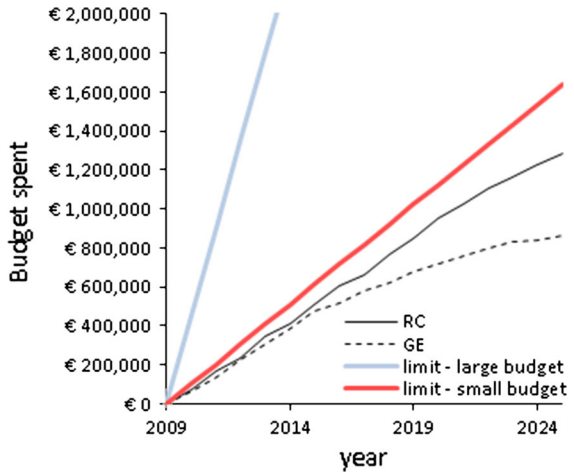

Fig. 3 Average cumulative budget spent by NCO agents for NEN acquisitions over a 15 year period (2010–2025) for the regional communities (RC) and global economy (GE) scenarios

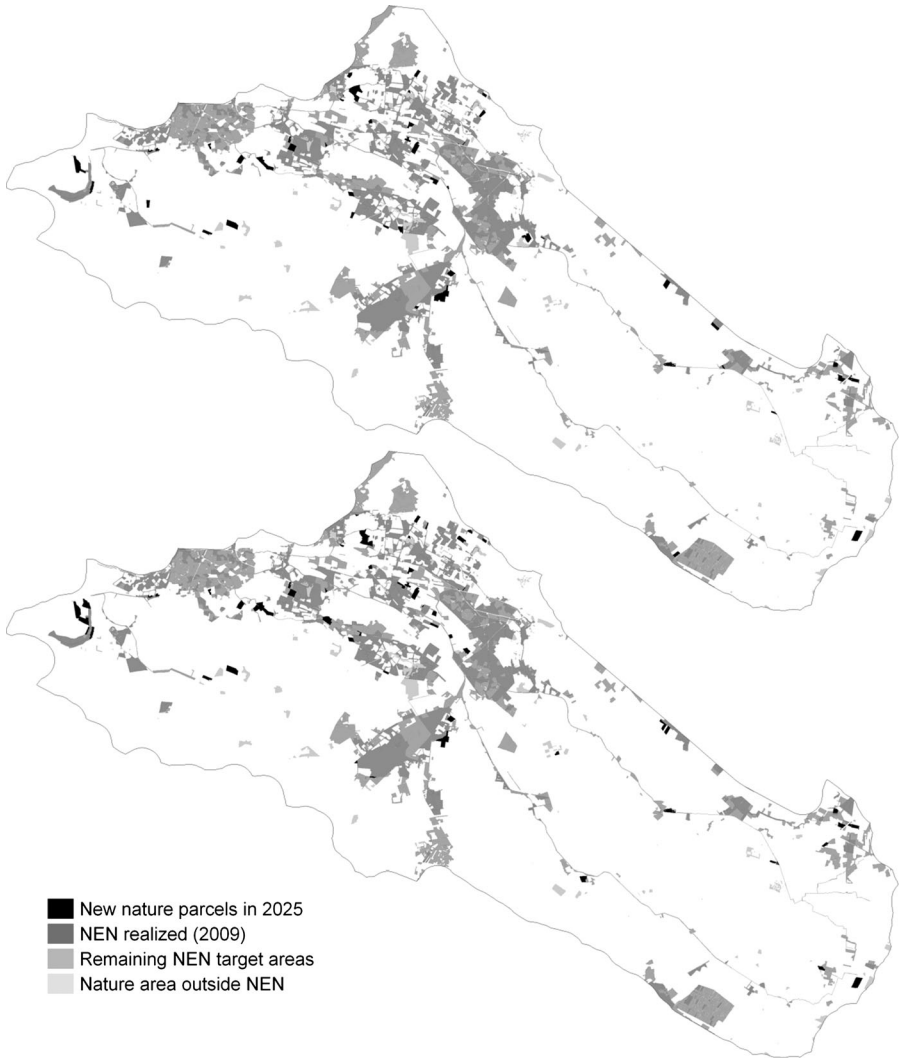

Fig. 4 New nature parcels in 2025 in the GE (top) and RC (bottom) scenario. All other land use types are left blank in these maps

Both acquired areas and spent budgets increase considerably with higher levels of WTP_N. However, not all increments have the same effect. Figure 6 demonstrates that, for both scenarios, increases of 10 and 20 % are rewarding in terms of land acquisitions, while a further increase to 30 % makes much less difference. A further increase of 40 and 50 % is again rewarding. It appears that there are relatively few for-sale parcels in the price segment of 1.2 × WTP_N and 1.3 × WTP_N and/or the WTP by farmers is relatively high in this price segment.

In terms of budget, Fig. 7 shows that the small budget is a constraint for increasing the WTP_N. Only in the GE scenario is some room for increasing the willingness to pay, but by a maximum of 10 %. The large budget, on the other hand, does not limit increases in WTP_N up to 50 % in any of the scenarios. The results also show that budgets may be exceeded in the first years; while in 2025 total expenditure is well within the budget. This is because land acquisitions progress relatively quickly in the early years, when there are still sufficient farmers that are willing to sell land.

Despite the larger amount of new nature parcels that are purchased when the WTP_N is increased by 50 %, the spatial pattern of the purchases remains fragmented in both scenarios (Fig. 8). Large contiguous purchases and sets of parcel with a connecting function are still largely absent.

Figure 9 shows the response of transaction prices of NEN acquisitions to varying levels of WTP_N. This

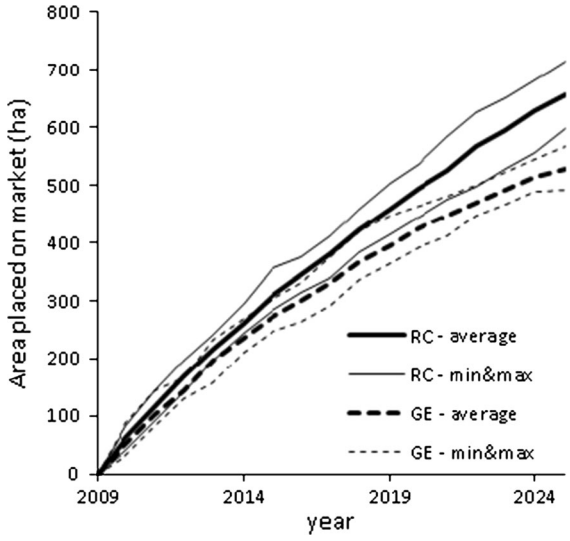

Fig. 5 Cumulative area placed on the market within the NEN zone over a 15 year period (2010–2025) for the regional communities (RC) and global economy (GE) scenarios

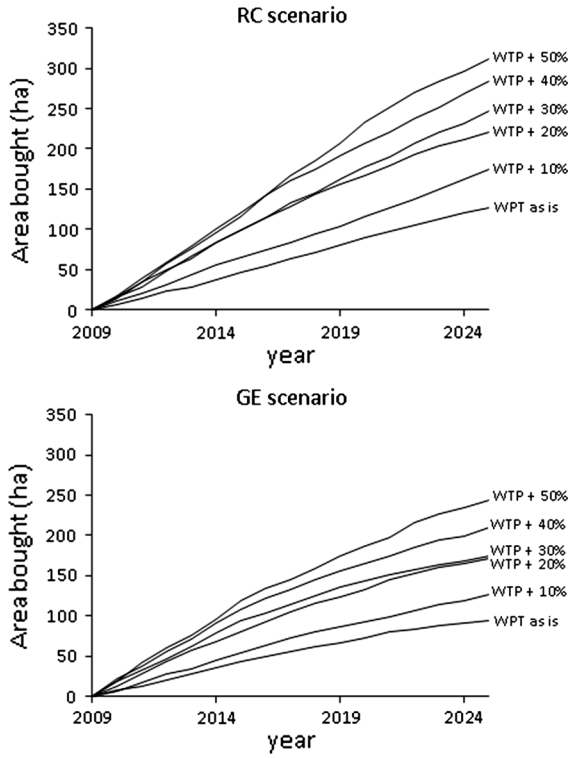

Fig. 6 Cumulative areas bought by NCO agents and estate-owner agents over a 15 year period (2010–2025) for different levels of willingness to pay (WTP_N), for the RC scenario (*top*) and GE scenario (*bottom*)

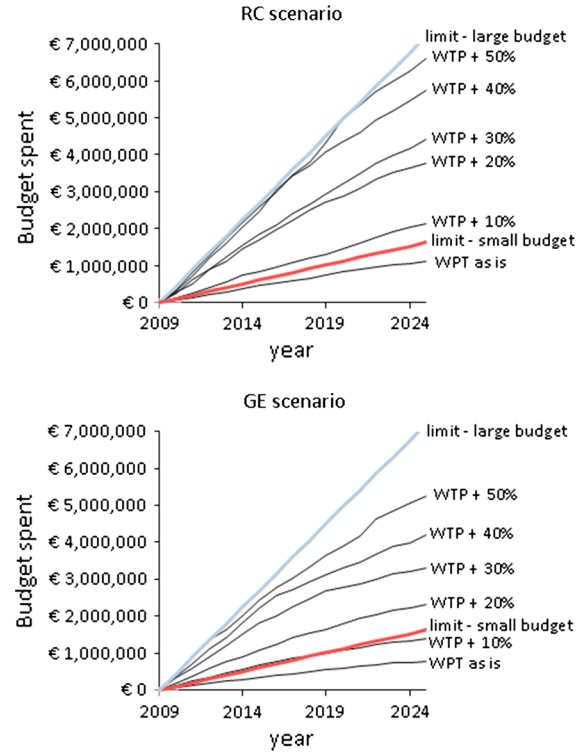

Fig. 7 Cumulative budget spent by NCO agents on NEN acquisitions over a 15 year period (2010–2025) for different levels of willingness to pay (WTP_N), for the RC scenario (*top*) and GE scenario (*bottom*)

demonstrates that the initial increments lead to an increase in transaction prices, which levels off beyond a 30 % increase in WTP_N. The non-linearity in this response curve can be attributed to the number of transactions, which varies with each WTP_N level. Considering average transaction prices between farmers, which have a median of €36, 220 in the area (extracted from DLG (2012)), the prices paid under the higher WTP_N options seem to conform better to the market.

Discussion

The results demonstrate that at best only a fraction of the NEN area that is still to be implemented can actually be implemented in the period 2010–2025. Although low rates of land acquisition (also those in the past) have often been attributed to budget limitations, our results demonstrate that the low willingness

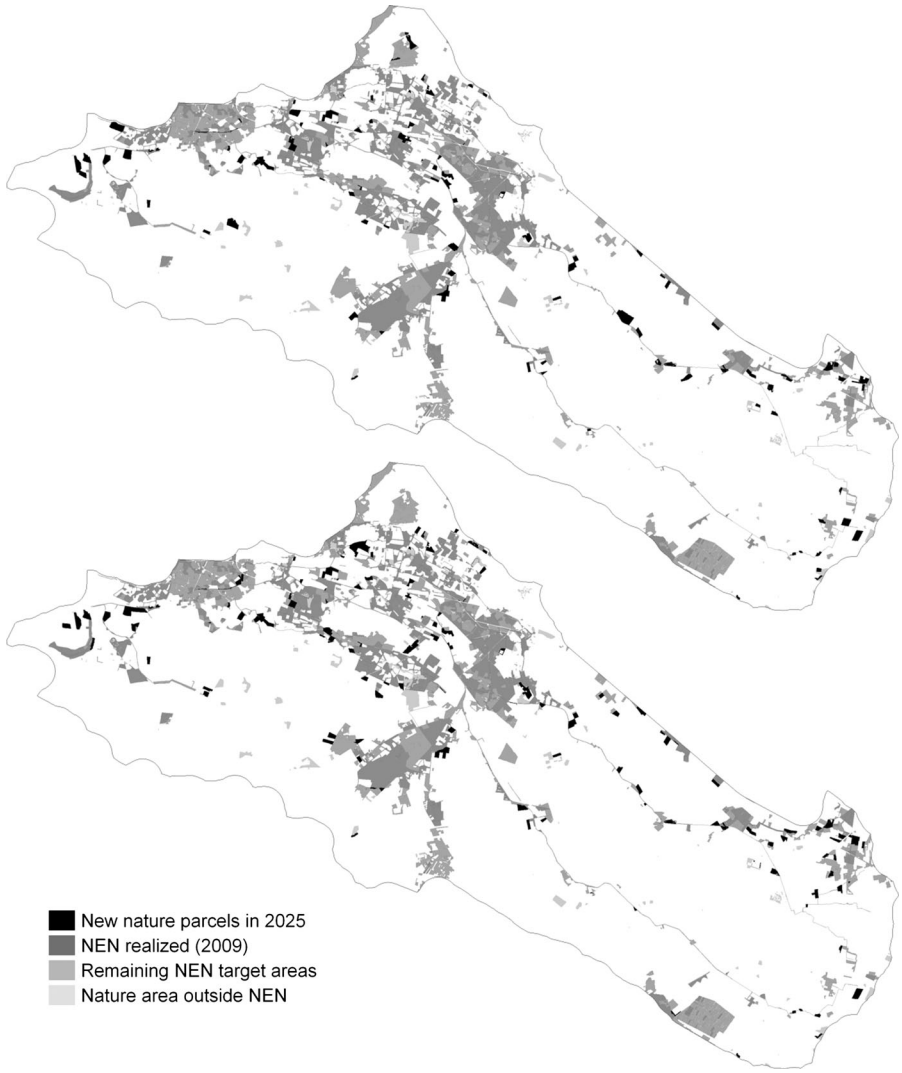

Fig. 8 New nature parcels in 2025 in the GE (*top*) and RC (*bottom*) scenario with a 50 % increase in WTP_N. All other land use types are left *blank* in these maps

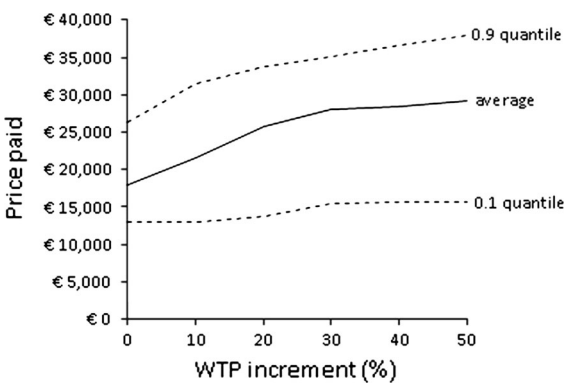

Fig. 9 Transaction prices for NEN-acquisitions in response to WTP_N averaged for the two scenarios

to pay for land by NCOs (WTP_N) and the limited availability of for-sale land are equally—if not more—important. Theoretically, assuming an average transaction price of €$25,000$ ha^{-1} (supported by Fig. 9), the low budget allows 65 ha to be purchased while the high budget allows 288 ha. However, our results suggest that—after subtracting the shares bought by estate-owner agents—only 47 and 69 ha are bought by NCO agents in the GE and RC scenarios, respectively. This suggests that only a combination of a small budget with a GE scenario constrains land acquisitions, but that once this budget is enlarged or a scenario unfolds with less good prospects for farmers, other constraining mechanisms become important.

What is simulated, and what was also observed in the past, is that NCOs buy less land than they can afford. One reason for this is their low willingness to pay. A major reason for this is that the condition of former agricultural land is generally far from ideal when it comes to the potential to restore valuable nature types (Van Teeffelen et al. 2015). Specifically residual soil fertility, acidification, and low groundwater levels significantly constrain the possibilities for ecosystem restoration without expensive restoration measures (Van Dijk et al. 2007; Witte et al. 2015). Extra budget allocated for land acquisitions, which is currently being considered by the province, will only result in more acquisitions when NCOs translate this extra budget into higher bids. We demonstrate that increasing the willingness to pay results in more land being acquired, although this is a non-linear response. Higher bids help in buying more land, but this does not guarantee a sale of any particular parcel desired by an NCO. First, not all parcels are owned by farmers who are willing to sell land; secondly, some for-sale parcels are of interest to other farmers who are willing and able to bid far higher prices than the NCOs. Even when we assume a 50 % increase in WTP_N, land acquisitions are not likely to exceed 50 % of the land that is potentially available, which suggests a strong competition from expanding farmers. Although physical parcel characteristics are generally favourable to either NCOs or farmers, there are still many parcels that are attractive for both parties, which can be attributed to the vicinity of existing properties (either farmsteads or nature reserves). As long as farmers have farmsteads within the NEN, they are willing to pay high prices for parcels in close proximity (i.e. within the NEN). Moving farms to other regions, as happened in the past (Van den Brink 1991), would be required to overcome this problem, but with the abolition of the national land bank, this is difficult to achieve.

Despite a preference of NCOs for parcels in close proximity of existing nature areas, new land acquisitions for ecosystem restoration show a fragmented pattern (Fig. 4). This fragmented pattern emerges even when NCOs would have a higher willingness to pay, which resulted in a larger amount of land acquisition (Fig. 8). Since the pattern of land acquisition by NCOs not only depends on their willingness to pay, but also on sufficient land becoming available at the right locations, our results suggest that without an intermediate party that negotiates between farmers and NCOs, supported by a sufficiently large stock of parcels to offer in exchange, it will be difficult to realize a well-connected network of nature areas. Whether the simulated fragmented pattern of acquired restoration areas is detrimental to the functioning of the NEN in terms of habitat provision and dispersal routes for species is difficult to say: one would need to couple the spatial layout of new and existing nature parcels with models of species' population dynamics (e.g. Van Teeffelen et al. 2015)) for more meaningful conclusions. The fragmented nature pattern will nevertheless be less efficient in terms of managing the land, as (i) raising groundwater levels in isolated nature parcels will not be possible without impinging surrounding farmers, (ii) the parcels cannot serve as habitats for species with larger area requirements, and (iii) eutrophication from nearby agricultural land will hinder the establishment of particular ecosystems (Kros et al. 2014).

Differences in outcomes between the two global-change scenarios result from two mechanisms. One is the strong economic growth of the agricultural sector in the global economy (GE) scenario. This results in more farmer agents being willing to buy land, and less willing to sell. Another effect is climate change. In the regional communities (RC) scenario, more parcels become prone to waterlogging. From the perspective of farmers, these parcels become less valuable, while from the perspective of NCOs, interested in creating wet habitats, these parcels become more valuable. Therefore, in the RC scenario more parcels exist of which the WTP_N exceeds the WTA_F of the selling farmer, and the WTP_F of possible competing farmers, resulting in more farmer-nature transactions. In the global economies (GE) scenario, the opposite happens, as less parcels become prone to waterlogging. The first mechanism (fewer parcels put on sale) results in 19 % less land being available for sale in the GE scenario (Fig. 2, computation not shown); the two mechanisms together result in 26 % less land being purchased by NCO agents in the GE scenario (Fig. 5, computation not shown).

Apart from an increase in buying farmers due to economic growth in the agricultural sector, in both scenarios RULEX shows a gradual disappearance of small farms owned by old farmers as the result of farm cessation (Bakker et al. 2014). As these are the typical sellers of land, the amount of farmland placed on the

market also gradually declines. This is reflected in the simulated curved lines (Figs. 2, 3, 5), which become particularly clear for the GE scenario, in which the surplus of buyers is likely to be largest. These trends reflect several modelling decisions that affect their interpretability. RULEX assumes a stationary relationship between farm size and the probability to sell or buy as well as a fixed threshold of (economic) farm size below which succession was considered unlikely. Alternatively, one could argue in favour of adjusting these rules and equations for the average farm size (e.g. setting the successor threshold at a certain quantile of economic farm size rather than at a fixed, absolute value), which would probably lead to a more constant ratio between buyers and sellers. However, our decision was supported by (a) a decreasing trend in the number of quitting farms from the year 2000 onwards as shown by national statistics, and (b) the experience by the governmental body organizing land trade that remaining farms have grown increasingly competitive (Van der Wal, account manager at the Government Service for Land and Water Management, personal communication). This suggests that land acquisitions for the NEN should be made sooner rather than later, and that budgets should therefore be made available accordingly.

We only explored increases in the WPT_N up to 50 %. Increasing the WTP_N further would probably lead to more land acquisitions, but this is a sensitive issue. Such increases imply that bids by NCOs would exceed $40,000€\ ha^{-1}$ (Fig. 9), which may be considered to be unfair by outcompeted farmers and hence market distorting. As a consequence, NCOs or other intermediate parties tend to be cautious in their bidding strategy. This is at odds with the idea of a free land market that underlies the newly proposed way of organizing land purchases for the NEN, but then a truly free market mechanism can only exist when multiple bidders and suppliers of the services nature areas offer (ecosystem services) become active in the land market. This would be difficult to realize, as for some intrinsic values of nature no direct demand may exist, even though society attaches value to it. In such a case, it may be claimed that the government should protect such value, but from a market perspective, a government is a monopolist because of its great purchasing power and even its power to expropriate when deemed necessary. Given these dilemmas, it would appear to be more appropriate to return to the situation in which the (national or provincial) government plays an intermediate role by means of a land bank.

Conclusions

Future land acquisitions for the NEN are jeopardized by the following constraints: (1) budget limitations, (2) the abolition of an intermediate party organizing land trade, with support from a national land bank, (*3*) strong competition for land by farmers whose economic prospects are improving, (4) a gradual loss of typical land-selling farms, and (5) the low willingness to pay for land by NCOs. Climate change may alleviate the competition between farmers and NCOs when it leads to higher groundwater tables, but will increase competition when it leads to lower groundwater tables. Out of the five constraints listed above, 3 and 4 concern global or autonomous developments against which policy-makers can do very little. The other three constraints can, however, be influenced by policy. Budget increases would be useful, but only if NCOs display a higher willingness to pay. However, since this might involve undesired market distortions, addressing constraint 2 represents a better way forward. This would involve the re-establishment and maintenance of an intermediate party to organize land trades with the support of a national or provincial land bank.

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