Preserving nature reserves; the government as an actor in an application of Game Theory in a case study in The Netherlands

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Abstract
The protection of a collective good, such as a nature reserve, in the setting of a non-cooperative game, requires governmental actions to promote cooperation. However, at the moment the legal use of land changes, for example from farmland into a nature reserve, the government may pop up as an actor in the acquisition of this land or to compensate the loss of market value. The government and the farmer appear as players in a game. The government may suddenly show non-co-operative behaviour with intention to minimise spending of public money whereas farmers intend to maximise compensation.This splits the government as a facilitator of co-operative behaviour based on equity or as participant in a non-co-operative game directed to efficiency. We analyse this dilemma for three governmental strategies to reduce N-deposition by industrial farming near a nature reserve. The efficiency and effectiveness of these strategies to increase the nature reservation acreage are evaluated in the framework of game theory. The conclusion is that both cost-effectiveness and equity may go together in a governmental strategy that is also preferred by a large part of the farmers. We end with recommendations to improve environmental policy in comparable settings.

Introduction

The Netherlands is the most densely populated country in Europe and is also between the ones with the most elaborated and detailed spatial planning. There is no single square (centi)metre without a owner and a label i.e. allotted for agricultural purpose, factory grounds, infrastructure, residential land, nature reserve etc. A change of existing and permitted use of land into another results in a very large change in the price of land and therefore requires meticulous legislation. At the moment that the legal use of land changes, for example from farmland into a nature reserve, the government may pop up as an actor in the acquisition of this land or to compensate the loss of market value. The government and the farmer appear as players in a game (Bacharach, 1976; de Zeeuw, 1998). The government may suddenly show non-co-operative behaviour with intention to minimise spending of public money whereas farmers intend to maximise compensation and are also reluctant to reveal their preferences.This splits of the government as a facilitator of co-operative behavior based on equity and as participant in a non-co-operative game directed to efficiency, hampers effective decision making (Sandler; 1998). In this paper we analyse the efficiency and effectiveness of three governmental strategies to protect nature reserves from environmental pollution. These strategies differ in equity (equal compensation for all farmers) and environmental effectiveness (those farmers which pollute most get the largest compensation to stop (N)-nitrogen emission). The deposition of potential acidifying and eutrophying nitrogen is one of the most important environmental threats to Dutch nature. The contribution of ammonium from factory farming to N-deposition is between 40-50%. The deposition of ammonium decreases rapidly if the distance between emission sources, such as stables and meadows, increases. About 5-15% of total N-deposition originates from sources at a distance between 0-500 m from the nature reserve and about 60% from that from a zone of 0-250 m (van Hinsberg et al; 2003). To improve scenic quality and protect Dutch nature reserves a new environmental policy is developed - the so-called reconstruction policy. This means that farming is finished or farms are relocated out off the area around the nature reserve. The Dutch national government reserved a delimited budget to finance this operation which should be carried out by local governments in consultation with the farmers involved. Principles for governmental actions and strategies based on these principles are:

- equity: every farmer should be treated equal and gets a equal compensation for stopping or relocation
- efficiency: minimise spending of public money and compensation depends on the state of affairs of the farmer (small or big farm, financial situation, age, successor etc)
- effectiveness: reduce a maximum of environmental pressure and compensation depends on the contribution of a farm to the N-deposition on the area, which is generally a function on distance to the nature reserve
- cost-effectiveness: maximum avoided amount of N-deposition for a minimum amount of money by combining efficient and effective strategies

If the state of affairs for farmers differs they may opt for different strategies. Categories of farmers may be:

- young farmers or farmers with a successor and financial healthy will incline to relocate their farm
- older farmers without successor will consider to stop farming and incline to sell
- middle aged farmers which are financially not very healthy but not very much inclined to stop may considering a sideline job and compensation for agricultural management of farmland under strict environmental conditions

Because farmers intend to maximise compensation they may be reluctant to reveal their real preferences. Because preferences differ, we should not strictly assign one strategy to one category of farmers but assign a chance to the choice for a specific strategy.

In this paper we assess different strategies of the government and farmers on equity, cost-effectiveness and environmental effectiveness as a possible elaboration of Dutch reconstruction policy.

The data set

The farms and their contribution to N emission and deposition

At the Dutch Environmental Assessment Agency an elaborate data set is available which contains data of:

6475 farms in the Netherlands distributed over
20 area's which are close to 20 different nature reserves with
the location of the farms with respect to the nature reserve which is in one of 12 zones (circles) of 250 m around the nature reserve (distances between 0-3000m)
lifetime and depreciation of stables; compensation for demolition of stables and investments for new stables
Yearly capital cost for the government (maximum about 20 mln€/year)
the number of animals in a zone
the emission (kgN/year) of the farms in a zone in an area
the deposition (molN/ha/year) of the farms in a zone to the nature reserve close by

Table 1: overview of available financial and environmental data of the farms

A selection: Mariapeel and Deurnsepeel

For this analysis we selected from the entire data set an area in the south-east of the Netherlands: Mariapeel and Deurnsepeel, where some 540 pig and poultry farms are close to a nature reserve and of which more than 100 farms are eligible for finishing or relocation.

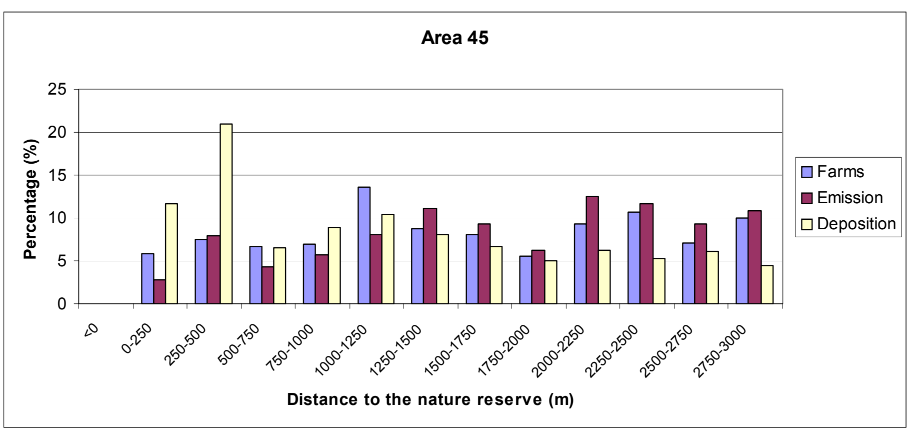

Figure 1. Bars show the number of farms in a zone (%), the contribution of the emission in that zone (%) and the contribution of the deposition from that zone to the deposition in the nature reserve (%) as a function of distance from the nature reserve.

It can be noticed from this figure that up to a distance of 1250 m the ratio deposition/emission is < 1 and after that changes to > 1. This means that up to 1250 m a relatively larger part of the emission deposits into the nature reserve.

Cost-curves

From the database we calculated for each zone the capital costs of demolition of the stables and the investment cost of new stables and the contribution of the farms in that zone to the deposition in the nature reserve. The costs of removal of 1 mol N as a function of distance from the source is shown in figure 2.

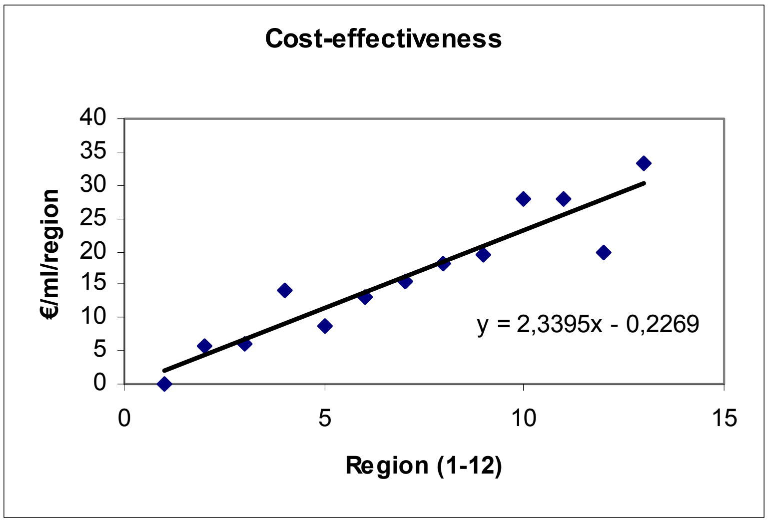

Figure 2. This figure shows the costs of removal of 1 mol N/€ as a function of distance from the nature reserve. The marginal cost of the removal of 1 mol N raises about 2,3 € for each additional zone (1-12) farther away from the nature reserve.

Data of the farmers

Based on data of the Dutch Central Bureau of Statistics (CBS 20001) we divided the farmers into six categories for which we assume a different state of affairs and preferences, see table 2.

Theory and Method

Options

The question is whether optimal (Pareto equilibrium) or sub-optimal (Nash equilibria) solutions could be identified in this case. Can private and collective needs be satisfied simultaneously?

We can identify some options:

- buying/selling of the farm, demolishing of the stables and finish farming
- buying/selling of the farm, relocation and building of new stables
- continue farming but the government and farmer make a contract which settles financial compensation for farming under strict environmental conditions

The government may evaluate these options in terms of:

slightest costs, environmental optimum or most cost-effective

The farmer may evaluate these options depending on his state of affairs and may have his preferences ordered according to:

Cat	Description	share	Most likely preference
1	Young, financial sound	15%	Relocation
2	Age over 55 with an adult successor	15%	Relocation
3	Age between 40-55 with a young (< 18 years) successor	10%	Depends on financial position whether relocation or farming under environmental conditions
4	Age between 40-55; financially not sound and without successor	20%	Farming under environmental strict conditions
5	Age over 55 without successor	25%	Sell
6	Inclined to finish (too small, financially not sound)	15%	Sell

Table 2: categories of farmers and their share (%) in the total population of farmers and the different preferences of the farmers depending on their state of affairs

The question is how to discover the appreciation of the players for the different options. For the government this may depend on a choice for lowest costs, an environmental optimal result or cost-effectiveness and for the farmer this may depend on the amount of money which is offered, his state of affairs, the perceived risk and fairness of government acts.
Additional considerations may be:

- relocation: least effective for environmental quality and least appreciated by the government. For the young farmer most costly and for older farmers who consider to stop farming not attractive
- Selling: for the government environmentally very effective but this is only attractive for a part of the farmers
- Farming under environmental conditions: for the government least costly but only attractive for a small part of the farmers

<u>Strategies</u>
The process of reconstruction under the direction of environmental policy has started only recently and we lack sufficient empirical data about the behaviour of local governments and farmers. We therefore define three different strategies which may be used by the government and evaluate the effectiveness of the strategy by taking the chance of accepting or rejecting the bid by the farmers into account.
The strategies of the government are:

1. Every farmer is offered the same compensation for selling irrespective of his state of affairs or contribution to environmental pressure (amount of deposition). This is illustrated in figure 3 as the horizontal line 14€/mol. The sum of the average compensation matches the total estimated costs.
2. Compensation depends on the contribution of the farmer to the N-deposition. This is shown in fig 3 as the straight line 14/2,3 €/mol/zone. This means that a farmer

gets more compensation if his share to the N-deposition is higher. The total compensation matches the total estimated costs

3. If non-linear compensation is chosen the compensation depends even more on environmental effect. The ratio of N-deposition/emission is >>1 up to a distance of 1250 m (figure 1). Compensation up to 1250 is 1,5 times the compensation of option 2 and 0,75 times the compensation of option 2 after 1250m. The total compensation is less than the total estimated costs of option 1 and 2.

This means that for the strategies 2 and 3 a farmer in area up to 1250 m gets a substantial additional bonus on top of his compensation for demolition costs and investment loss. The chance that the farmer accepts the bid of the local government will increase substantially, even for the category 1 farmers (table 1). However the chance that farmers at larger distance than 1250 accept the bid will decrease very rapidly because they get offered a compensation which is even lower than the total costs of demolition and investment losses. This may only be attractive for cat 5 and 6 farmers. We add that the total compensation offered by the government by law is limited to 40% of the value of a newly build farm. This means that the multiplier of 2,5-3,5 for farms closest to the nature reserve (see figure 3) is in the right order of magnitude for full compensation and is not exceptional high. The question is whether the higher price and the increased participation of farmers close to the nature reserve outweighs the decreased participation of farmers farther on. An additional aspect could be that the strategies 2 and 3 of the government may be considered as increasingly iniquitous which decreases the willingness to accept the bid.
N.B.: This game is considered to be static because it consists of only one move, both players stake simultaneous and do not have information about the move of the other player.

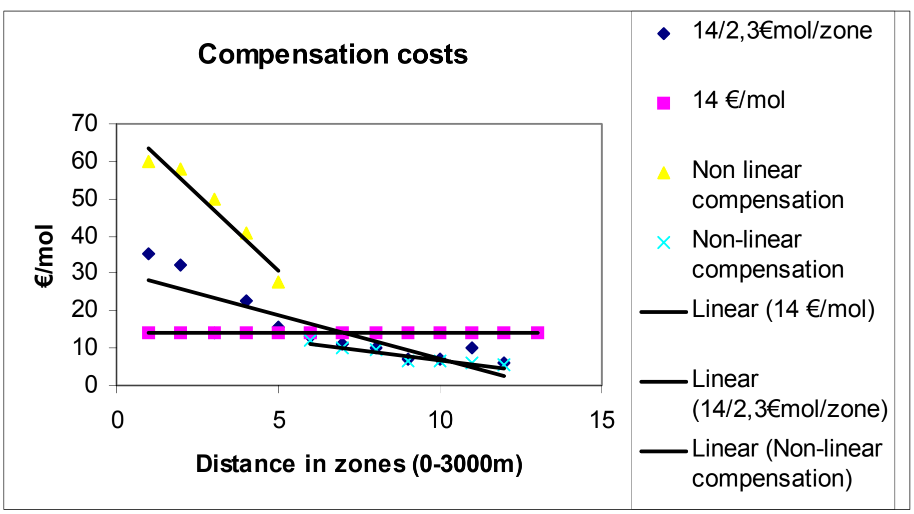

Figure 3 shows the three compensation regimes according to the three strategies. This means a compensation of 14€ mol emission irrespective of environmental impact or 14/2,3 € mol/zone

Preferences and choices of farmers
The chance to accept or reject the bid by a farmer depends on the height of the bid and his state of affairs. The chances to accept the bid is shown in tables 3-5

Strategy 1

Cat	**Description**	**% which accept the bid**
1	Young, financial sound	0,4
2	Age over 55 with an adult successor	0,5
3	Age between 40-55 with a young successor	0,6
4	Age between 40-55; financially not sound	0,8
5	Age over 55 without successor	0,90
6	Inclined to finish (to small, financially not sound)	0,98
	Total share of farmers which accepts the bid, weighted according the percentages of table 2	0,75

Table 3: strategy 1: chance to accept the bid depends only on the state of affairs of the farmer (equal bid)

Strategy 2

Farmer	**1**	**2**	**3**	**4**	**5**	**6**	**% which accept the bid**
Region 1	0,80	0,90	0,95	0,95	0,95	0,98	0,93
Region 2	0,60	0,70	0,80	0,90	0,95	0,98	0,85
Region 3	0,50	0,60	0,70	0,80	0,90	0,98	0,78
Region 4	0,4	0,5	0,6	0,75	0,9	0,98	0,73
Region 5	0,35	0,4	0,5	0,65	0,8	0,95	0,65
Region 6	0,1	0,2	0,3	0,6	0,7	0,9	0,52
Region 7	0	0,1	0,2	0,55	0,65	0,85	0,45
Region 8	0	0	0,1	0,5	0,6	0,8	0,4
Region 9	0	0	0	0,4	0,5	0,7	0,32
Region 10	0	0	0	0,3	0,4	0,6	0,26
Region 11	0	0	0	0,2	0,3	0,5	0,20
Region 12	0	0	0	0,1	0,2	0,4	0,14
Total share of farmers which accepts the bid, weighted according the percentages of table 2							50

Table 4: strategy 2: the chance to accept the bid depends both on the state of affairs of the farmer and on the distance from the nature reserve

Strategy 3

Farmer	1	2	3	4	5	6	% which accept the bid
Region 1	0,95	0,95	0,95	0,98	0,99	0,99	0,97
Region 2	0,95	0,95	0,95	0,97	0,98	0,99	0,97
Region 3	0,90	0,95	0,95	0,95	0,97	0,99	0,96
Region 4	0,9	0,9	0,9	0,95	0,98	0,99	0,95
Region 5	0,8	0,9	0,95	0,95	0,95	0,98	0,93
Region 6	0,20	0,40	0,50	0,60	0,65	0,70	0,54
Region 7	0,1	0,2	0,3	0,4	0,45	0,5	0,35
Region 8	0	0	0,1	0,2	0,3	0,3	0,18
Region 9	0	0	0	0	0,1	0,2	0,06
Region 10	0	0	0	0	0	0	0
Region 11	0	0	0	0	0	0	0
Region 12	0	0	0	0	0	0	0
Total share of farmers which accepts the bid, weighted according the percentages of table 2							50

Table5: strategy 3: the chance to accept the bid depends both on the state of affairs of the farmer and even stronger than the case in strategy 2 on the amount of N-deposition to the nature reserve

Results and Discussion

Optimum strategy for the government

Using the yearly capital costs of finishing farming, relocation and emission and deposition data as described in table 1 and the data from the tables 3, 4 and 5 the yearly costs, the avoided deposition and the cost-effectiveness of the three government strategies can be calculated. The results are shown in table 6.

Strategy	Participation of farmers	Yearly costs (€)	Avoided deposition	Cost-effectiveness
Strategy 1	75%	15 mln	75 %	1
Strategy 2	50%	20 mln	60%	0,6
Strategy 3	50%	19 mln	65%	0,7

Table 6: an overview of participation, yearly costs, environmental profit and the cost-effectiveness of the three environmental strategies of the government

The conclusion is that the government strategy 1, based on equity, performs best in cost-effectiveness. An additional benefit of this strategy is that it probably fits best as a appropriate strategy for a public body.

Strategy for the farmers

Whether a strategy is acceptable for a farmer depends very much on his state of affairs. For the categories 4-6 of the farmers who consider to stop anyway the height of the compensation is less important than for the farmers who prefer to continue farming. But for those farmers in the regions 1-4, the financial compensation of the strategies 2 and 3 could be attractive enough to consider stopping or relocate their farm.

We may define the following two yield matrixes

	Farmers in region 1-4 (N=151)			
	Government	Farmer Cat 1-3	Government	Farmer Cat 4-6
Strategy 1	1	0,3	1	0,9
Strategy 2	0,6	0,6	0,6	0,95
Strategy 3	0,7	0,9	0,7	0,98

Table7: This matrix shows the combined preferences of government and farmers in the region close to the nature reserve (number of farmers in this area is 151)

	Farmers in region 5-12 (N=409)			
	Government	Farmer Cat 1-3	Government	Farmer Cat 4-6
Strategy 1	1	0,3	***1***	***0,9***
Strategy 2	0,6	0,2	0,6	0,6
Strategy 3	0,7	0,1	0,7	0,5

Table8: This matrix shows the combined preferences of government and farmers in the area farther away from the nature reserve (number of farmers in this area is 409). The Nash equilibrium is shown in bold italic.

The tables 7 and 8 show that the only one Nash equilibrium is possible for farmers in cat 4-6 (which consider to stop) in the area farther away from the nature reserve and a government using strategy 1 (equal compensation). This may appear disappointing at a first glance but it confirms the value of strategy 1 based on equity while the number of farmers who consider this strategy as optimal is still about 45% of the total of 540 farmers. This is the largest coalition possible in this situation

Conclusions and recommandations

The government may experience a dilemma between acting as a protector of a collective good, standing above parties, promote co-operation, be credible by being transparent in preferences or act in the same way as the farmer by trying to maximise profit and reveal preferences.

Conclusions:

- there is no univocal optimum for all payers
- however, there a preferential strategy for a majority of the players; the largest coalition can be identified
- a cost-effective strategy may go together with a strategy which also holds equity as a principle
- as equity is important for the legitimacy of the government this may promote societal acceptance of a particular policy

Recommendations for the government:

- invent and investigate various strategies instead of only one (i.e. one rule to compensate)
- analyse whether these strategies are under the law
- take, besides the aspect of environmental effective or cost-effective, also the aspect of social acceptable or credibility of a public body into account

Recommendations for farmers:

- as the state of affairs differ greatly, analyse the possibility of coalitions

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