A FARM-ECONOMIC ANALYSIS OF WILDLIFE MANAGEMENT IN DUTCH CROP FARMING

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ABSTRACT

This paper presents a methodology for optimising wildlife management on individual crop farms, using integer programming. Availability of data on agriculture and wildlife, indicator choice, temporal and spatial aspects of wildlife management as well as opportunities for use of the model by farmers and policy makers are discussed.

1. INTRODUCTION

Agriculture does not only produce food and fiber; it also helps shaping the rural environment. Increasingly, modern society values the environmental benefits which may arise as joint outputs with primary land use, including e.g. semi natural habitats and wildlife. In Western Europe, rapid changes in primary land use have jeopardized the supply of these benefits (Lowe and Whitby, 1997). Specialization by region and within individual farms, as well as intensification, through use of fertilizer and pesticides, have increased. Land amelioration (viz. defragmentation, exchange of land, alterations in accessibility) has also contributed to such. These developments have resulted in a loss of habitat for many wild species, and consequently a rapid decline in numbers and populations. The Common Agricultural Policy has been criticized for supporting these changes and over the last decade European policy makers have begun to respond to such criticism. EU-regulations 1760/87 and 2078/92 mark the acceptance that supporting farmers to conserve wildlife and countryside might help to curb overproduction. These regulations also promote a specific approach: supplementary to a distinct geographical segregation of agricultural and wildlife functions both functions should to a large extent blend within the rural environment. While nature reserves will always be important, there is a shift of attention increasingly to the preservation of biological diversity within the major forms of primary land use (Edwards and Abivardi, 1998). This transformation of agricultural policy being an agri-food policy to more of a countryside and wildlife policy calls for investigation of the mechanisms that would help satisfy the following criteria (Lowe and Whitby, 1997): that payments are targeted to ensure cost-effectiveness; that the level and targeting are responsive to public demands; that the benefit is clearly tangible. The first step towards an effective policy to conserve and restore wildlife in agricultural areas, is investigation into the trade-off between wildlife quality and agricultural production and income. In this task agricultural economics has an important role to play.

The interactions between agricultural production and wildlife and associated decision making are most pronounced at the farm level. The goal of this study is to present a wildlife-costs frontier at the farm level: i.e. the definition of best (least cost) management strategies for obtaining different possible wildlife quality levels. Such an optimization procedure has to account for both time and spatial aspects of agricultural production and wildlife presence and abundance. This particularly applies for crop farming where the spatial situation differs from year to year due to the crop rotation.

Despite the importance of the issue and the wide policy interest, the list of quantitative studies on wildlife conservation within agricultural areas is limited. Previous ecological and economic studies of wildlife management at the farm level have generally focused on the impact of land use regimes on farm income and biodiversity. For example, the positive effects of refraining from pesticide in northern European agriculture on the abundance of flora and fauna was reported by e.g. Rands (1985), Tew *et al.* (1992), Boatman (1994) and by De Snoo (1995). Economic studies at the whole farm level generally involve a comparison of specific land use regimes by analysis of accounting data and/or farm level modeling (e.g. Van Eck *et al.*, 1987).

None of the studies mentioned pays attention to the dynamic and spatial aspects of the joint production of agricultural outputs and wildlife. The presence and abundance of wildlife species, however, not only depend on present management practices but also on management practices in previous year(s). Also, wildlife quality depends highly on site specific biophysical conditions and on spatial aspects such as the distribution of conservation activities.

The literature on the spatial aspects of agricultural production and the environment focuses on optimal pollution control in relation with water quality of an agricultural watershed: e.g. Braden *et al.* (1989); Braden *et al.* (1991); Moxey and White (1994); Lintner and Weersink (1996). The spatial dimension, however, is also important in the case of the positive externalities of agricultural production, i.e. wildlife. Ecologically, the spatial distribution of species is important for their changes of propagation. Economically, the 'where' question is of importance because of the advantages of selective control, i.e. protecting where it is most effective and least costly. Selective control requires identification of the most effective wildlife management options and also where to apply these (Wossink *et al.*, 1997). In the literature, studies in the field of site selection are carried out on a regional level and identify the smallest number of reserve sites to realize a number of targeted wildlife criteria; see for example Camm *et al.* (1996) Pressey *et al.* (1996) Nichols and Margules (1993); Underhill (1994). The economic aspects of site selection, however, are not considered in these studies.

The outline of this paper is as follows: section 2 presents an overview of the interactions between agriculture, and more specifically crop farming, and wildlife. Management options for promoting wildlife abundance in agricultural areas are discussed. Section 3 presents a generic model for optimal wildlife management on crop farms. Next section 4 presents the requirements for implementation of the model. A discussion concludes the paper.

2. CROP FARMING AND WILDLIFE

The interactions between agricultural practices and the presence and abundance of wildlife are complex. Two major developments in agricultural practice have caused a reduction in the state of wildlife the last decades. The use of chemical inputs, in terms of pesticides and nutrients, and monocultures of crops have left little opportunities for wildlife survival. Emissions of chemical inputs to non-agricultural habitats have also contributed to such. Furthermore the number of non-agricultural habitats is reduced through field enlargement, merging of farms etc., decreasing the chances of survival for wildlife.

Research into ways of enhancing wildlife in arable farming has predominantly focused on unsprayed and/or uncropped field margins and on alternative management of fallow land. Field margins receive much attention because of their relative disadvantages from the economic point of view. Yields in margins, especially on headlands are often lower due to a higher pest and weed pressure, soil compaction or shady conditions (Boatman and Sotherton, 1988; De Snoo, 1995). On the other hand, wildlife abundance is also higher in margins, owing to the unfavorable growing conditions and the location often next to non-agricultural biotopes such as ditches or woodland. From an agricultural point of view, enhancing wildlife in field margins may cause yield reductions in the center of the field due to weed invasion and wildlife damage. On the other hand positive impacts of unsprayed field margins are reported through biological control of pests in the fields (Boatman and Sotherton, 1988; De Snoo, 1995). Fallow land offers special opportunities for wildlife as no chemical inputs are usually used. Furthermore financial compensation may be obtained through the EU-set aside scheme. However, when set aside is applied in margins a minimum width of 20 m is necessary for financial compensation.

Apart from alternative management of field margins and fallow land other opportunities for enhancing wildlife in crop farming are available. Winter cover crops are used in agriculture to save nutrients and for maintaining organic matter content in the soil. For wildlife these crops may provide cover and food over the winter period. Furthermore, non-agricultural habitats may receive alternative management aimed at enhancing wildlife. Ditch banks offer special opportunities for vegetation development by creating a poor nutrient situation. On the other hand rough vegetation may be created on these banks providing cover and nesting opportunities for mammals and birds.

3. GENERIC MODEL

The theoretical model meets two criteria (Braden *et al.*, 1989): (1) it accounts for the effects of management restrictions on wildlife quality at the farm level; and (2) it identifies the pattern of management activities on the farm that maximizes farm income over a predefined period. The model is formulated in a dynamic linear programming context. Index $t=1...T$ denotes the number of years and index $j=1... J$ denotes the number of management units recognized on the farm (e.g. field margins, field centers, ditches etc.). Let f denote the production relationship between agricultural inputs and outputs, and let h denote the relationship between agricultural inputs and wildlife "outputs".

(1a) $$Max\ Z = \sum_{t=1}^{T} \sum_{j=1}^{J} p' y_{j,t} - C(y_{j,t}, r_t, x_{j,t}; l_j)$$

(1b) s. t. $$f_{j,t}(y_{j,t}, w_{j,t}, x_{j,t}; l_j) \leq 0 \quad \forall\ j,t$$

(1c) $$\sum_{t=1}^{T} \sum_{j=1}^{J} h_{j,t}(w_{j,t}, x_{j,t}; l_j) \geq N$$

and

(1d) $$x_{j,t} \in X_{j,t} \quad \forall\ j,t$$

Z	=	farm income
C	=	cost function
p	=	vector of prices of agricultural outputs
y	=	vector of marketed outputs
r	=	vector of prices of agricultural inputs
x	=	vector of farm specific management activities
X	=	vector of all management activities
l	=	vector of bio-physical and other site-specific characteristics
w	=	vector of wildlife "outputs"
N	=	wildlife quality

Solving the equation set yields x^*, the vector of agricultural management activities including management restrictions that satisfies the requirement for wildlife conservation as expressed by N. Varying N gives a wildlife conservation costs frontier $Z(N)$ for the total farm studied.

4. IMPLEMENTATION OF THE GENERIC MODEL

4.1. Agricultural production function

Implementation of the generic model requires information on the production relationship between agricultural inputs and outputs, $f(.)$, see equation (1b). The production level of agricultural outputs, the amount of marketed product(s) per hectare, y, is determined by biophysical conditions, l, and by production techniques and methods applied as expressed by the activity set, x. The activity set is predominantly determined by the farming strategy applied, i.e. organic, integrated or conventional farming. Farm specific constraints such as the availability of labor and machine equipment further reduce the activity set.

4.2. Wildlife production function

Second, implementation of the generic model requires information on the relationship between agricultural inputs and wildlife results, $h(.)$, see equation (1c). The wildlife situation, w, in a farming situation is characterized by bio-physical and other site-specific characteristics (l) such as distance to reserves and the abundance of natural habitats. Also, present and past farming practices on the farm, x, both on fields and on non-agricultural habitat influence the wildlife situation.

Whereas agricultural outputs are easy to quantify and measure in terms of marketable yields, wildlife results are much more difficult to assess. A direct measurement of the presence and abundance of all wildlife on a farm is not feasible; therefore indicators of wildlife quality have to be used.

Main requirement for equation (1c) of the generic model to be implemented is an indicator at the farm level to provide a complete picture of the state of wildlife at the farm. Furthermore the relationship of the indicator outcomes with farm management practices has to be clear. Therefore we use an indicator recently developed by the Center for Agriculture and Environment (CLM; Buys, 1995). This 'yardstick' for biodiversity consists of a limited though representative set of species from the following species groups: vascular plants, mammals, birds, butterflies, amphibians and reptiles. To each species a rating (0-100 points) has been assigned based on rarity, population development and international importance (protection need). Ratings are used together with results from census methods to calculate the significance of wildlife (for each species group separately) on farms:

$$(3)\ W(s) = \sum_{j=1}^{J} \sum_{k=1}^{K} cv$$

$W(s)$	= *yardstick score of species group s*
J	= *number of biotopes on farm*
K	= *number of selected species in species group s*
c	= *census units of species j*
v	= *protection value (rating) of species j*

4.3. Optimization procedure

In order to model and optimize wildlife management, the farm is divided in spatial units ($j=1...J$). In a conventional farming situation, different crop fields and non-productive biotopes such as woodland and ditches can be observed. Management on crop fields or within a non-productive biotope type will normally be uniform. Incorporating wildlife management options may result into more activities per field and thus an increase in the number of spatial units to be recognized. Each spatial unit however is assumed to be treated uniformly. Therefore it is necessary to formulate the model in an integer context. Management activities now are integers forcing the model to select only one management activity per spatial unit j per year t.

Solving the equation set from section 3 may require considerable computation time due to the integer context of the problem. Also other factors may affect the computation time: (1) the length of the planning period, (2) the number of management units (sites) recognized, (3) the number of management alternatives to each unit and (4) the combinatorial complexity of the problem. We discuss these aspects in more detail.

Ad (1): Decisions regarding incorporating wildlife management are made on the tactical and strategic level. For the present study a planning horizon of one crop rotation (usually lasting 4 years) is considered appropriate. Impacts of past activities influencing wildlife and or agricultural production in following years can therefore be incorporated in the model.

Ad (2): Without specific attention being paid to wildlife management, an individual field will generally be treated uniformly. However with the introduction of wildlife management alternatives, management on field margins may be different from the field center. Moreover distinction between headlands and longitudinal sides should be made for their differing agronomic and economic features. Besides non-agricultural habitats need separate consideration.

Ad (3): When all available activities may be applied on each site the selection problem is huge. Therefore it looks appropriate to define an optimal baseline situation, considering crops and whole fields only. After this baseline run, for each site the standard crop activity is known and wildlife management alternatives may be defined for new optimizations to be carried out.

Ad (4): Combinatorial aspects have to do with the influence of past on present activities on sites, and with activities on certain sites influencing the wildlife or agronomic situation on other sites. Furthermore farm level constraints on top of site constraints add to the combinatorial character of the model.

A schematic representation of the optimization procedure is presented in Scheme 1.

5. DISCUSSION

The model presented enables farmers to select best management practices to obtain different wildlife quality levels. Furthermore the model outcome gives policy makers information on costs associated with different wildlife quality levels. Incentive development and cross compliance instruments may therefore benefit from the model outcome. However before using the outcomes for policy design a study on the acceptance of the proposed wildlife activities is necessary as perceptions and preferences among farmers towards wildlife conservation may vary.

Many of the private initiatives currently taken to enhance wildlife quality in agricultural areas depart from cooperation of farmers on a regional level. When considering an analysis on a regional scale spatial connections e.g. linking of important ecological objects (ecological networks) needs special attention (Lintner en Weersink, 1996; Wossink *et al.*, 1997). An optimization to be carried out on a regional scale may well lead to different contribution efforts by farmers to meet the regional determined wildlife objectives. Equity among participants therefore also needs special attention (Onal *et al.*, 1997). The model presented here does not account for these two aspects. However, the farm specific outcomes of the model may well serve as a basic input for aiding decision making on a regional scale. In this respect Walpole and Sinden (1997), offer an interesting approach using farm level benefit-cost ratio's and GIS predictive modelling, to aid land degradation management on a regional scale. Such an approach would also offer great potential for supporting regional wildlife management decision making.

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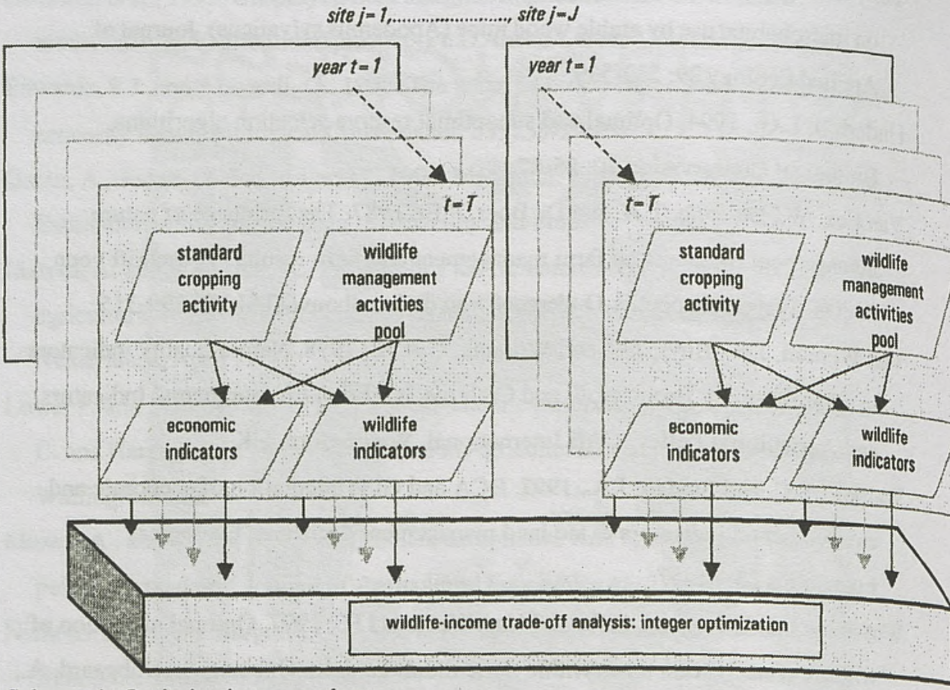

Scheme 1: Optimization procedure