Analysis of future agricultural change

a farm economics approach applied to Dutch arable farming

Ada Wossink

STELLINGEN

1. Gezien de benodigde afweging tussen milieu effecten en economische effecten van de agarische bedrijfsvoering voor een meer duurzame ontwikkeling van de landbouw dient in het economische onderzoek meer aandacht te worden gegeven aan de "technology set". Lineaire programming is hiertoe een geschikte methode.

   Dit proefschrift

2. Door in bedrijfseconomisch onderzoek aan een normatieve analyse een positieve benadering toe te voegen kan dit onderzoek niet alleen dienen om de planning op bedrijfsniveau te ondersteunen maar tevens de invulling van het overheidsbeleid met betrekking tot de landbouw.

   Dit proefschrift

3. De discussie tussen agronomen en economen over een efficiënt gebruik van hulpbronnen in de landbouw spitst zich toe op het verloop van de produktiefuncties. Hierbij dient ook de relatie met het draagvermogen van het agro-ecosysteem in beschouwing te worden genomen. Dit betekent dat niet alleen moet worden gelet op het gebruik en de emissie van meststoffen en biociden per eenheid produkt maar ook op de waarden per ha oppervlakte.

   Dit proefschrift

4. De realisatie van akkerbouwsystemen met een grotere duurzaamheid, opgevat overeenkomstig het aangekondigde milieubeleid, is meer een institutioneel probleem dan een technisch probleem.

   Dit proefschrift

5. De inkomensgevolgen van het voorgenomen markt- en prijsbeleid voor de Nederlandse akkerbouw zijn aanzienlijk groter dan die van het aangekondigde milieubeleid.

   Dit proefschrift

6. Bij een gelijkblijvend verschil in ondernemersbekwaamheid zal een groeiende verscheidenheid in technische en economische mogelijkheden resulteren in toenemende verschillen in bedrijfsresultaat.

L.C. Zachariasse (1974) *Boer en bedrijfsresultaat*, Proefschrift Landbouwuniversiteit Wageningen

Het omgekeerde, d.w.z. dat een beperking van de technische en economische mogelijkheden ten gevolge van bijvoorbeeld overheidsmaatregelen leidt tot kleinere verschillen in bedrijfsresultaat, geldt alleen bij een statische beschouwingswijze.

7. Het feit dat in de WRR studie "Grond voor keuzen" relaties op gewasniveau direct worden ingevoerd in een model op regionaal niveau en aldus het bedrijfsniveau, oftewel het besluitvormingsproces van de agrarische ondernemer, wordt overgeslagen impliceert dat de voorspellende waarde van dit onderzoek beperkt is.

8. Voor beide doelgroepen, beleidsmakers en onderzoekers, geldt dat modelontwikkeling een investering is, die vooral bij voortgezet gebruik tot zijn recht komt.

A. Boorsma (1990) *Mogelijkheden voor akkerbouwbedrijven in de Veenkoloniën*, Proefschrift RU Groningen, p. 281

9. De methode van groepsindeling in het bedrijfsstijlenonderzoek, welke uitsluitend is gebaseerd op R-factoranalyse, is theoretisch onjuist. De overeenstemming tussen boeren is hierbij gedefinieerd in een multidimensionele maat die als zodanig geëvalueerd dient te worden, bijvoorbeeld door een aanvullende clusteranalyse.

J.F. Hair, R.E. Anderson and R.L. Tatham (1987) *Multivariate Data Analysis*, New York: Macmillan
D.W. Stewart (1981) The application and misapplication of factor Analysis in marketing research, *Journal of Marketing Research*, Vol. XVIII, pp. 51-62

10. Verandering van de bestaande wijze van verdelen van projectgerichte onderzoeksgelden door het Ministerie van LNV in een open inschrijvingssysteem zou een teken zijn dat het Ministerie een heldere koers voor het toekomstig onderzoek heeft gevonden.

11. Het feit dat oude examens herhaaldelijk gebruikt kunnen worden zonder dat de resultaten verbeteren suggereert dat de theorie van de morfogenetische resonantie van Sheldrake niet opgaat dan wel dat het niveau van de student en/of van het wetenschappelijk onderwijs daalt.

12. Het leeftijdsonderscheid dat de Koninklijke Nederlandse Atletiek Unie (KNAU) maakt tussen mannelijke veteranen (≥ 40 jaar) en vrouwelijke veteranen (≥ 35 jaar) verdient heroverweging.

G.A.A. Wossink
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Wageningen, 7 mei 1993

ANALYSIS OF FUTURE AGRICULTURAL CHANGE

a farm economics approach applied to Dutch arable farming

Promotor: dr.ir. J.A. Renkema
Hoogleraar in de Agrarische Bedrijfseconomie

Ada Wossink

ANALYSIS OF FUTURE AGRICULTURAL CHANGE

a farm economics approach applied to Dutch arable farming

Proefschrift
ter verkrijging van de graad van doctor
in de landbouw- en milieuwetenschappen
op gezag van de rector magnificus,
dr. H.C. van der Plas,
in het openbaar te verdedigen
op vrijdag 7 mei 1993 des namiddags te vier uur
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Government policies should be chosen on the basis of their fruit before trying them out on a real economy. Experimenting on a model of an economy is a way of doing this.

From G. Orcutt (1970) Simulation of Economic Systems, *American Economic Review*, Vol. 50, p. 896

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CONTENTS

Appendices Chapter VI

Appendices Chapter VII

CHAPTER I

General introduction

1. Background and scope

Farm managers are forced to continuously adjust their farm organization to be able to stay in the farming business and earn a living. The present study focuses on the future of specialized Dutch arable farms against the background of their changing circumstances.

Indicators summarizing the economic developments over 1965-1990 for arable farms in the Netherlands are presented in table I.1. Table I.2 gives data on the development of the number of arable farms and their size. Most significant in table I.1 is the increase in gross productivity. This increase is attributable to technical development, *i.e.* to improvements in input/output relationships. The production per hectare increased both by changes in the rotation scheme and by an intensification of the cropping technique. The former is reflected by the number of sfu[1] per hectare which increased from 4.9 to 5.6 when comparing the averages for 1965-69 and 1981-85, for example (LEI, 1987). The growing of higher yielding varieties accompanied by increases in variable inputs (fertilization, crop care) led to significantly higher physical output levels. For arable farms in the Netherlands the average gross output per ha for 1981-85 was 37 percent higher than in 1965-69, for instance (LEI, 1987). Mechanical developments reduced the labour requirements and as a result one farm worker could farm an increasing area of land even in the case of a more intensive cropping pattern.

As is often indicated, the rapid growth of production is also characterized by a number of drawbacks. At EC level the economic advantages of the increase in total output rapidly turned into budgetary difficulties (paying producers for surplus output) and trade problems. Production restrictions and pressure on the intervention prices have been the consequences.

[1] In Dutch agricultural statistics the economic size of agricultural activities is measured in standard farm units (sfu) which are based on the standard net value added.

At farm level the increase in productivity has apparently not resulted in improving incomes, as indicated by the returns to costs ratio in table I.1. Most advantages were passed on to the consumers by falls in output prices. The continuous process of innovation together with the low rates of labour outflow and farm discontinuation resulted in problems of farm size mainly because of a surplus supply of labour on the smaller Dutch arable farms. As a result of this lack of adjustment to changing circumstances the 'farm problem' shows itself as an income problem for the category of farmers concerned[2].

Apart from the socio-economic and farm economic problems, the course of agricultural development in the Netherlands is criticized for actual or potential environmental pollution and because of damage to nature and landscape brought about by intensification of the cropping patterns and by the increase of the production per crop. In arable farming pesticide use is the main source of environmental pollution. Currently there is pressure from several directions to reduce pesticide use ("green" consumers and environmentalists and the formulation of the pesticide reduction programme MJP-G (Long-term Crop Protection Plan) (Min LNV, 1990)). Moreover, producers themselves are often confronted with agronomic problems (e.g. yield reductions caused by deterioration of the biological soil fertility) due to intensive cultivation practices.

Given these problems, decisions have to be made regarding the future of arable farming both at the farm level (farm management) and at the aggregated level (agricultural policy). There are significant interactions between these two levels of decision making. On the one side the national agricultural and environmental policy and the CAP policy regulations form the external conditions for management decisions at the farm level. On the other side, an impression of the reactions of different categories of farmers in respons to alternative policy regulations and instruments can be very informative in the process of policy development.

The foregoing implies complex relations between the economic, technical and ecological components of agricultural production and the dynamics thereof. To improve the insights in this complex of forces, research is required both in the field of farm management and in the field of agricultural policy making. The present study intends to contribute to the insights needed.

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[2] Schultz (1953, p.19) was the first to define the "farm problem" as a lack of income parity caused by the inability to adjust to economic growth. This view has dominated the literature ever since (Van Dijk *et al.*, 1986).

1.2 Objectives of the research

The research described in this thesis aims to contribute to investigating and modelling the adaptation processes of family farms in reponse to changing external conditions. To this end the effects are analysed of different forms of technical innovation, agricultural price policies and environmental regulations with respect to farm organization (cropping pattern and physical production levels), farm income and the environmental quality of production. The study focuses on specialized arable farms. The insights from this analysis can be used to support (a) farm management decision making (planning) and (b) agricultural policy development and the selection of policy instruments (conditional forecasting).

Given the two objectives the study covered the following phases:

(1) development of a model system based on farm economics to assess the impact at farm and regional level of different scenarios concerning technical developments, agricultural price policies and environmental regulations;

(2) assessment and description of technical developments and alternative policy options for Dutch arable farming by means of a number of scenarios;

(3) application of the scenarios and part of the system to arable farming in the North East Polder, the region that served as a case study for implementing and testing of the system. The application involved:
   - (3a) defining categories of arable farms in the North East Polder;
   - (3b) assessing of the implications of the scenarios by comparative-static LP computations;
   - (3c) further analysis of the adaptation process based on external information.

The attention paid to scenario development and, in particular, the integration of aspects of environmental quality, distinguishes the present study from those of Bouma (1988) and Boorsma (1990) who also deal with agricultural change at farm level in regions of the Netherlands.

The North East Polder was selected as a case study because of its intensive cropping pattern, because it is a distinct geographical entity and because of the availability of data in particular. It covers about 41 000 ha and is part of the province of Flevoland located in the centre of the Netherlands (see map on page 197). The Polder was reclaimed in World War II and about 1800 farms were rented out during the period 1947-1957. Almost all the land is still state-owned (Wijnen, 1990). The study population was restricted to 864 specialized arable farms out of the total of 1486 farms registered in the 1988 national Farm survey.

1.3 Outline of the thesis

Chapter II presents a review to indicate the significance of studying technical and institutional developments and agricultural change in terms of farm economics. The Structure-Conduct-Performance concept is presented as the basis for a framework for analysing the development of the family farm and the factors that determine that development. The various elements of the framework are identified and discussed in relation to previous research results and evidence. The framework is used to draw up requirements for a model system.

Chapter III contains a description of the MIMOSA system (MIcro MOdelling to Simulate changes in Agriculture) that was developed for the present research. MIMOSA is a system to analyse future changes in Dutch arable farming at farm and regional level. Special attention is given to the selection of modelling techniques and the construction of a modular set-up.

Chapters IV to VIII each deal with part of the MIMOSA system and its implementation and application to arable farms in the North East Polder. Chapter IV presents the assessment of the scenarios. Chapter V describes the identification of representative farm types for the population concerned. In Chapter VI, the structure and data use of the environmental economic LP (linear programming) model in the MIMOSA system are discussed. The selection of environmental criteria and the collection of data for the LP model are treated extensively. An inventory was made of the environmental effects to be incorporated into the LP model and of the methods to assess these effects (De Koeijer and Wossink, 1990). Because no ready to use data were available for the environmentally-friendlier cropping variants, a pre-analysis, financed by the province of Flevoland and the Ministry of Agriculture, was conducted (De Koeijer and Wossink, 1992).

Chapter VII presents the results of the LP computations indicating the implications of the alternative scenarios for one of the representative farm types. Up to the LP calculations the investigation is static and normative.

Chapter VIII demonstrates the potential of the MIMOSA system to incorporate external information, which enables innovation adoption and farm continuation to be studied.

In the final Chapter (IX) the farm economic approach in general is discussed and the research is evaluated. Priorities are given for further research.

Table I.1 Development of volumes and prices of inputs/outputs and productivity for arable farms[1] in the Netherlands

Annual changes (%)	1965/66-1970/71	1970/71 1975/76	1975/76-1980/81	1980/81-1985/86	1985/86 1990/91
Gross input volume	+ 0.4	- 2.5	+ 1.6	+ 0.1	- 2.1
of which: labour	- 1.2	- 2.4	- 0.6	- 0.8	- 0.4
Gross output volume	+ 5.7	- 2.2	+ 4.8	+ 1.2	+ 2.1
Input prices	+ 5.8	+10.9	+ 5.2	+ 4.4	+ 2.2
of which: labour	+ 3.2	+ 5.3	+ 1.8	+ 1.8	+ 0.5
machinery and contract work	+ 1.2	+ 2.0	+ 1.0	+ 1.0	+ 1.1
Output prices	- 0.8	+13.7	- 2.1	- 0.7	+ 1.9
Gross productivity[2]	+ 4.8	+ 0.2	+ 2.9	+ 1.1	+ 4.3
Production costs per unit of product	+ 1.0	+10.7	+ 2.2	+ 3.2	+ 1.0
Returns/costs ratio	- 1.8	- 2.7	- 4.2	- 3.8	+ 2.9

[1] Established from the statistics on 'specialized larger' farms. In Dutch agricultural statistics farm size is measured in standard farm units (sfu) which are based on the standardized net value added. Since 1984/85 the limit between large and small farms has been 158 sfu. Comparable figures for former periods are not available.
[2] Ratio of the annual changes in output volume and input volume.
Source: (LEI,1987; Poppe,1992)

Table I.2 Development of the number of farms by production capacity and size for arable farming[1] in the Netherlands

	1975	1980	1985	1990
	number of farms in % of total[2]			
Sfu-class				
10- 70	32 (8)	36 (8)	38 (8)	37 (7)
70-110	16 (10)	13 (8)	11 (7)	10 (6)
110-150	14 (13)	12 (11)	10 (8)	9 (7)
150-190	12 (14)	11 (14)	10 (11)	10 (10)
190-250	12 (18)	12 (18)	12 (17)	12 (17)
250-350	9 (18)	10 (19)	11 (22)	12 (22)
350 or more	5 (19)	6 (22)	8 (27)	10 (31)
Number of farms	15 137	16 707	17 516	16 213
Hectares per farm	34.4	34.1	33.6	35.2
Number of workers per farm[3]	1.6	1.5	1.4	1.5

[1] Specialized arable farms according to the VAT-typology, *i.e.* farms with 60 % or more of their sfu under arable crops.
[2] In brackets the share of sfu in % of total sfu.
[3] In full-time equivalents, established from the statistics on farms ≥ 79 sfu.
Source: (LEI,1987; Jager,1992)

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CHAPTER II

Agricultural change: theoretical framework[1]

Abstract

A micro-economic approach for analysing agricultural change is suggested in this chapter. It is stated that agricultural change comes about by farmers' reaction to external forces, of which technical and institutional developments are considered as most decisive. An assessment of the effects of both developments according to micro-economic production theory is presented. Internal determinants related to the technical and financial status of the farm and to behavioural and family-related factors are also involved in the decision-making process at farm level. These are analysed as well. Finally, further model research integrating the external and internal determinants is outlined.

1. Introduction

As pointed out in the previous chapter, present-day agriculture in the Netherlands is confronted with a range of problems both at sector and farm level. This is the impetus for researchers and decision makers to find and compare options for a solution that helps to direct future changes towards "sustainable" agriculture. If the economic discipline is to be helpful in this process of finding a way out, it should start with research to clarify the complex of forces involved in agricultural change and subsequently assess effective policy control mechanisms.

This chapter first deals with the concepts of agricultural structure and agricultural change. It is argued that in the processes of agricultural adjustment two external determinants merit special attention, namely technical and institutional developments. Both are reviewed, as well as their interrelationships. To arrive at a farm economics approach in assessing future agricultu-

[1] A former version of this chapter was presented as a paper at the 23th EAAE seminar: Managing long-term developments of the farm-firm: strategic planning and management, 6-8 November 1989 Copenhagen (Wossink, 1990; see also Wossink, 1988).

ral changes, the external determinants are then combined with internal determinants pertaining to the technical status of the farm firm and to behavioural and family-related aspects. This results in an analytical framework used to identify and discuss the possibilities of further research.

2. Agricultural structure

Before discussing factors involved in agricultural change a specification of the concept of structure is required. With regard to agriculture the word "structure" is used in two senses, that are interrelated (Petit, 1976a). A pragmatic economic definition of the concept of structure, applied to the entire sector is that it is concerned with the size, number and location of firms in an industry and with the basic spatial, organizational and institutional characteristics of the industry. Structure at sector level further includes the size and composition of the working population, the level and type of mechanization, and the organization of marketing and distribution. In fact structure is investigated according to this definition when dealing with agricultural change.

The foregoing can also be applied to the individual farm firm. At this level, structure is defined by the quantities of various input factors and by input-output relationships. Hence, farm structure in a micro-economic sense[2], is closely related to the state of technology and to natural conditions (Van Dijk *et al.*, 1986a). Note that the structure elements at farm level are the basis for structure at sector level. The overlap consists of elements such as farm size, level of specialization and mechanization, financial status *etc.*

The potential or optimal farm structure or organization of production[3] follows from the given or expected technical state-of-art and the price ratios of inputs and outputs. Technical development and price and market situations and policies affect this optimal farm organization and thereby induce structural change. In order to provide insights for analysis of future agricultural change, both technical and institutional developments are analysed in the next sections.

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[2] In this study "micro" economics and "farm" economics are used as synonyms, although micro economics includes both consumer's and producer's behaviour and farm economics is usually confined to the theory of the farm firm. In section 4 it is stated, however, that aspects of consumer behaviour should be integrated in farm economics as well.

[3] Farm organization and farm structure are used as synonyms.

3. Concepts and relevance of technical and institutional change in agriculture

3.1 General concepts of technical change

The economic literature on technical developments may lead to some confusion, as the concepts used are not always defined in the same way (Rutten, 1989). So, before investigating the effects and determinants of technical developments it is useful to clarify these and some other related terms. To illustrate the many different forms of technical change economic literature frequently refers to Schumpeter's views. This author (Schumpeter, 1961) describes technical change as the introduction of new combinations of products and means of production. These 'new combinations' must be understood rather generally, as they include: (a) introduction of a new good or a new quality of a good, (b) introduction of a new production method, (c) utilization of new raw materials or semi-finished products, (d) opening up of new consumer markets and (e) re-organization of the branch of industry. Considering technical change more specifically in a technical sense, that is as changes in input-output relations, a definition connected with the production function (being the formal representation of the technical relationships between inputs and outputs) is needed. A well-known definition of technical change as a change in input-output relations, is given by Cochrane (1958):

> " .. an increase in output per unit of input resulting from a new organization, or configuration, of inputs where a new and more productive production function is involved".

Note that the last two cases of 'new combinations' mentioned by Schumpeter do not fit in this context (Willer, 1967).

To define some terms that are closely related to technical change it is illustrative to consider a process at the level of the agricultural sector that is determined by five elements (Rostow, 1953): (a) the propensity to develop pure science, (b) the propensity to invent, (c) the propensity to innovate, (d) the propensity to finance innovation and (e) the propensity to accept innovation. The first two phases of this process then concern the increase in knowledge. The first must be associated with fundamental, scientific research and the second with applied science. Together these phases are indicated by the term technological change[4]. The third phase in the process deals with the application of newly acquired technological knowledge, resulting in new techniques of production (for example, the introduction of fertilizer after the discovery that plants need minerals). The last three elements of the process, namely the propensity to innovate, finance and to accept innovations, cover the diffusion of new techniques or innovations. This element is particularly important with regard to the present study.

When considering the diffusion of innovation the names of Griliches (1957) and Cochrane (1958) must be mentioned. The former showed, in empirical research on the introduction of hybrid corn, that the rate at which a new practice is adopted can be explained in terms of profit potentials. The core of Cochrane's "treadmill" theory is formed by the contrast between these micro-economic profit potentials and the macro-economic effects of technical change. As the farmer is a price-taker, to him the gains from the adoption of an improvement consist of a reduction of unit costs. After widespread adoption of the improvement product prices will normally fall. Which means that most of the profit is passed on to the consumers. The last producers to adopt will gain little. However, they are forced to accept the innovation. As an improvement lowers per-unit costs, adoption at least reduces the loss in net revenue which would result from keeping to the old production practice. The result is a never-ending process in which the farmer is forced to participate.

The difference in expected profit potentials that results from differences in farm organization is an important indicator for assessing opportunities for adoption (Van Dijk *et al.*, 1986b). Changes in farm organization can, however, be induced by other external determinants apart from technical development. These should be included in an analysis of agricultural change as well.

[4] Rutten (1989, p. 17): "In conclusion we could say that technical change is to be understood as the addition (or substraction) of one or more techniques in relation to the existing ones in use, whereas technological change refers to changes in the quantity or quality of potential techniques".

3.2 General concepts of institutional change

In the present study the development of EC agricultural price and market policy plus the development of (Dutch) agricultural, environmental and general policy are covered by the term "institutional changes". The word "institution" connotes both a set of commonly accepted rules and practices, and the social organizations responsible for enforcing them. Institutions are usually created by public authorities in respond to some social need (Petit, 1976a). In the present study the term is used as a global indication for policy regulations.

Governments develop agricultural and environmental policies in order to achieve improvements in the agricultural and environmental aspects of the economic system under their jurisdiction. A study of agricultural and environmental policy therefore involves considering the problem of ranking the present and the alternative future economic situations into categories of "better" and "worse". The basic theory relevant to the study of this problem is that of welfare economics.

As the objectives of the Treaty of Rome[5], for instance, indicate, agricultural policy can be based on a number of precepts. Nevertheless this list of objectives, the tendency of farm income to fail to keep pace with rising incomes elsewhere has been responsible for the manner in which agricultural policies have developed in most developed countries (Ritson, 1977). A wide variety of policy instruments is available to support agricultural income. These instruments can be classified according to whether they are directed towards reducing farm costs, increasing farm revenue, or reducing farm labour. The former two measures are indicated as agricultural price and market policy, the latter as structural policy. In the present study instruments of structural policy are not further analysed. Those available for price and market policy are specified in section 3.6.

Environmental policies have one clear objective: to counter environmental deterioration. Regulations are required in this context, as environmental problems result from failures in the economic system. Quality of the environ-

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[5] The common agricultural policy has as its objectives: (a) To increase agricultural productivity by developing technical progress and by ensuring the rational development of agricultural production and the optimum utilization of the factors of production, particularly labour; (b) To ensure thereby a fair standard of living for the agricultural population, particularly by increasing the individual earnings of persons engaged in agriculture; (c) To stabilize markets; (d) To garantuee regular supplies and (e) To ensure reasonable prices in supplies to consumers (Article 39, Treaty of Rome, 1958).

ment is considered a "common property" or a "social good". Deterioration of this asset due to pollution appears costless to producers and consumers. Hence, environmental quality is not included automatically in production decisions, not even when nature is an important production factor, as in the case of agriculture. At farm level the production decisions will be made after considering the available economically efficient technical options. In the absence of regulations, environmental quality will be disregarded in this selection as long as it does not affect production efficiency. Governmental interference by means of environmental policy instruments aims at shifting production towards environmentally friendlier techniques. In section 3.6 measures for this purpose are specified.

3.3 Relationships between technical and institutional changes

With regard to changes in farm organization due to technical changes, Cochrane's (1958) definition of technical change as the result of a new production function is most useful. The actual change in the production process, however, will not take place until the individual farmer has adopted the innovation. This means that a distinction can be made between the technical possibilities at a certain moment, or the objective production function, and the techniques in practice on the individual farm at the same time, *i.e* the subjective production function (Heertje, 1973, p. 149).

In the literature on the economic determinants of innovation adoption the farm is explicitely considered as a production unit, consisting of an input-output system, or technology set, enclosed by input constraints and economic and non-economic objectives (Petit, 1976b; Lund and Hill, 1979). When starting from such a concept, the diffusion of a certain innovation can easily be explained by the extent to which this improvement anticipates a particular obstruction to farm organization. The variety in the impact of institutional changes according to the adaptability of the specific farm organizations can be assessed in the same way. Moreover, technical and institutional changes can be combined in one analysis as to compare policy measures accounting for the effects of technical innovation. For instance, environmentally friendly technologies will be invented and more rapidly accepted if the market prices of biocides or fertilizer increase by comparison with other factors of production.

By regarding the farm as a dynamic system of a technology set, surrounded by constraints and objectives, innovation diffusion can be related to the theory of induced innovation and the evolutionary theory of technical development. The theory of induced innovation states that the direction of possible technical changes at the aggregated level can be seen as induced by micro-economic stimuli, namely by resource endowment proportions (Hayami and Ruttan, 1985; Binswanger and Ruttan, 1978). Environmental quality aspects can be added. The need for production practices which are less harmful to the environment is becoming an important impuls for innovation.

Trajectories and paradigms are central in the evolutionary approach of technical development that also stresses the role of micro economics (Nelson and Winter, 1977). The technological trajectories are paths of "normal" development on the grounds of a technological paradigm, in which course solutions are found for the particular obstructions in farm organization that arise (Dosi, 1984). Such solutions, *i.e.* innovations, will affect the technology set of the producers, resulting in the development of technology paths and technology clusters at sector level. Initial choices, as among alternative techniques, may be economically rational, given all the available options considering relative price-costs characteristics. Once such a selection has been made, however, there are forces that trigger movement along a trajectory, except when major shifts in factor prices or scientific knowledge induce a jump to another path (Feller, 1987).

A technological paradigm defines the type of relations to be investigated and the methods and abstractions regarded as legitimate within a particular problem area (Rausser and Hochman, 1979). It can also be seen as the problem-solving model applied in constructing the trajectories, based on certain premises from science. When these premises become obsolete, a new problem-solving model is needed (Roobeek, 1987). The current environmental problems in agriculture can be regarded as the start for a new paradigm and new trajectories, which includes ecological quality of farming practices (Hutten en Rutten, 1990).

3.4 Technical and institutional change in production theory

To solve the economic problem of the optimal farm organization it is postulated in neo-classical theory that the agricultural entrepreneur has certain knowledge concerning the relationships between the various possible combinations of inputs and the various possible outputs. This set of production possibilities is thought of as embodied in the production function. The notation of this relationship is given as:

$$Q = f(K, L, \ldots, N)$$

Where Q denotes total farm output, K, L and N are inputs and f denotes the functional form by which combinations of inputs are converted into output. Implicit in this formulation are a set of technical blueprints -- technical efficient variable combinations of inputs -- that can be used to produce a given level of output as shown by the production isoquant (see figure II.1). Implicit within the production function is an objective function, so that it is possible to deduce whether there is a move in a preferred or non preferred direction. Technical change may be represented by a shift of the isoquant to the origin, denoting increased output per given combination of input.

Figure II.1 implies that farm technology consists of a continuous set of production possibilities. But the different points of the curve still represent different processes of production, and associated with each of these processes there will be certain technical knowledge specific to that technique. As the number of production processes known increases (in an activity analysis or blueprint approach), the production possibilities can be more and more closely approximated by a smooth curve. Normally there is both finiteness and discontinuity within the set of available technologies. This suggests that the production function consists of discrete combinations of inputs (and of knowledge), each characterized by a fixed coefficient process. This perspective leads to another, namely that technical change may occur only in a localized area, affecting some combinations of input but not others, instead of a shift of the total isoquant (Atkinson and Stiglitz, 1969). See figure II.2.

In terms of activity analysis, technical development means an enlargement of the technology set available at farm level. Whether a specific farm changes to the new technique depends on its prevailing technical status. The approach suggests that in this way the technology paths (section 3.3.) come into being.

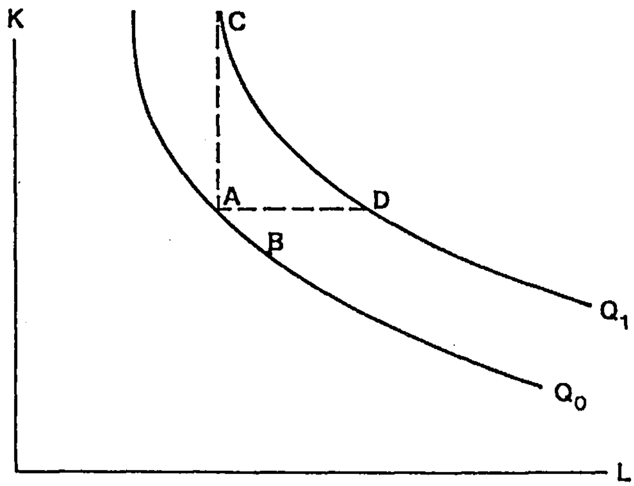
Institutional changes in the context of the EC agricultural price and market policy directly or indirectly lead to changes in input and/or output prices in the agricultural sectors of the member states (see section 3.6). In the case of the conventional production isoquant (figure II.1) a change in price relations will be followed by a movement along the curve. Present farming techniques are based on assorted variable input combinations whose complementarity means that the adaptability of a specific process to changing price ratios is very limited. In crop production, the mixes of fertilizers and pesticides with high-yielding varieties are examples of such fixed coefficient processes. So, distinct price change will usually induce a shift to another process, that is another selection will be made from the technology set (Schulte, 1984).

Environmental regulations by price incentives or by direct control such as input quotas, try to reduce the level of chemical input used or the level of emission of the input to the environment. Both types of regulations can be translated into an increase in cost prices. Input quotas imply that as well as or instead of the market prices of the input concerned, the opportunity costs of its application in alternative production activitities on the farm are to be considered. Direct controls requiring investments in emission-reducing equipment *etc.* lead to an increase in production costs. Reducing the foregoing to the "two inputs - one output" situation the same inferences hold as with regard to market policies.

Because of their opposite effects environmental regulations can be seen as the mirror image of traditional (*i.e.* output increasing and cost price decreasing) innovations (Renkema and Wossink, 1989). Including environmental quality as an additional selection element in technical development leads to a shift from output increasing towards more input saving and emission-reducing innovations. In this way the cost price increasing effects of environmental regulations can be partly compensated for by technical development. The part not compensated for will ultimately result in higher prices for consumers. As reactions to market policy and environmental policy regulations depend of the technology sets prevailing at farm levels, these technology sets should be of major concern in a study of future agricultural change (Kling and Steinhauser, 1986; Gebhard, 1986; England, 1986).

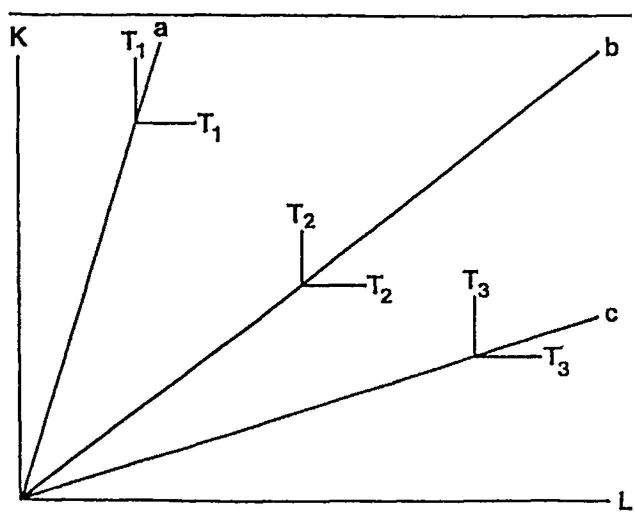
Mathematically the technology set can be represented in different ways. Farm economists frequently use the Leontief production function, or fixed coefficient production function. With this production function there is no substitution between inputs. Hence, the isoquant for each level of a specific output is a right angle as in figure II.2. The total collection of input mixes available is gathered into an input-output system at the farm level. By adding input constraints and a linear objective function to this Leontief input-output system a linear programming (LP) model evolves, by which the optimal farm organization can be assessed.

Fig. II.1 Conventional production isoquant



Note: Coordinates of points (A,B) denote different combinations of inputs(K,L) that produce a level of output Q_0. Implicit in each combination is a specific technique ('blueprint'). Given the existing set of techniques, increased amounts of at least one input (the coordinates C or D) are required to produce a higher level of output (Q_1).
Source: (Feller, 1987).

Fig. II.2 Production function as a series of discrete techniques (a,b,c)



Note: T_1 T_2 and T_3 denote different production isoquants.
Source: Feller, 1987

3.5 Specification of technical change

In literature two general forms of technical change are frequently discerned: (a) changes that link up with the production process ('process innovations'), and (b) changes which are directed at the output, that is new products or a new quality ('product innovations'). The first category covers both the introduction of new or improved inputs and a better organization of production, *i.e.* improvement of management. The factor management should be regarded, for instance by adding it to labour. Then, organizational improvements, increased education and learning by experience can also be represented by setting up a new production function (Uhlin, 1985).

With regard to agriculture, new production methods are usually further diversified into: (1) mechanical innovations, (2) biological and chemical innovations, and (3) organizational and informational innovations. Mechanical innovation has to do with the improvement in design and performance of farm machinery, buildings and installations. The results of biological technology or biotechnology pertain not only to the more traditional methods to improve crop varieties and livestock breeds, but also to DNA techniques. Chemical innovations can be described as the outcome of improvements in fertilizer technology and methods of controlling pests and diseases by chemical methods. Because these two types of innovation apply directly to the physical performance of plants and animals, they are often combined. The third kind of technical change concerns the changes in the field of farm management. Organizational innovations improve the efficiency of old and new inputs. Many totally different examples can be given, such as: the introduction of crop rotation and grazing schemes or the specialization of a mixed farm. Information technology, that is innovations connected with the application of micro electronics, can be divided into two major categories: (a) process automation and control by process computers, and (b) decision support systems, such as farm accounting systems, and other related developments presenting internal and external information flows. Recent innovations in this field tend to integrate both categories, resulting in the development of information linkages.

Looking at the development in agriculture in recent decades it is obvious that biological and mechanical innovations have been very important. High yields in plant and animal production demonstrate the success of biological and chemical progress. Mechanical progress, the substitution of capital for labour, has been seen in machinery and buildings. Pesticides were included in this substitution process. On most arable farms in the Netherlands, labour input has already been reduced to just that of the farmer himself. Bigger tractors and machines will hardly result in a reduction of labour costs and, therefore, are only attractive if more land is acquired. This is rarely achieved easily. Mechanical innovations in future are therefore expected to be increasingly characterized by saving on non-factor inputs instead of reducing labour input, by improving the quality of the harvested products and by reducing the environmental pollution of operations such as weed control and fertilization.

The different types of technical change will become more interrelated. Saving on non-factor inputs, with help of both mechanical and biochemical innovations, implies that farm management becomes more important. Technical control can be improved by process automation, the automatic control of machinefunctions so that their technical potential is fully used ('fine-tuning'). With regard to management as decision making, information systems can be of help in reducing the gap between potential farm results and those realized in practice, for instance by reducing the farmer's technical and marketing risks.

3.6 Specification of institutional change

In the context of the present study institutional changes relate to measures that intend to (1) raise farm income and/or stabilize markets of agricultural products and measures that intend to (2) reduce environmental pollution from agricultural production.

The policy devices used by governments when intervening in agricultural markets to raise income from farming, can be categorized according to the economic variables upon which they operate. A distinction can be made between measures that aim at reducing costs and those that try to increase farm revenue (see section II.3.2). The main policy mechanism for reducing farm costs is the payment of subsidies on inputs. With regard to the EC agricultural price and market policy the second option is more important, namely raising farm revenues by increasing the prices the farmers receive for their produce or by increasing the efficiency of production by means of research, education and extension. Theoretically, four alternative methods of subsidizing producer prices exist: subsidy per units, restricting imports, or control of agricultural supply by quotas or set-aside (Ritson, 1977).

The CAP developments are most important with regard to indications of future price and market policy devices. In order to halt the growth of the EC budget expenses there are two main policy directions: one of reducing price support and one of production restrictions. In a study of future agricultural change, output prices have to be formulated based on these alternative policy views. In addition, price developments have to be indicated for fixed and variable inputs.

Governmental interference with regard to the preservation of the environmental quality of agricultural production starts with assessing policy objectives. These objectives will be formulated in terms of reduction percentages to be achieved within a certain period, or as maximum levels for the emission of certain inputs or components thereof to soil, water or air. For agriculture specifically, these inputs and input components are nutrients and pesticides.

Baumol and Oates (1979) have four categories for the policy instruments to achieve formulated objectives: (a) moral persuasion by publicity or social pressure, (b) direct controls, (c) methods that rely on market processes (price incentives) and (d) direct governmental expenditures for the construction and operation of projects that improve the environment[6]. Of these the first three are techniques to influence pollutors behaviour. The methods that rely on market processes can be categorized in: (a) taxation of environmental damage by means of input levies or taxation of emissions, (b) subsidies per unit of emission reduction or for emission-control investments, or (c) issue of a limited quantity of transferable pollution licences.

At the moment direct controls are the most widespread form of policy instrument for environmental protection. Direct control regulations are popular among legislators and regulators, whereas economists support market incentives as these are less disruptive to economic efficiency. Three types of direct controls can be distinguished: (a) quotas on the levels of polluting activities, (b) regulations requiring the use of specified techniques or equipment that reduce input use or emission and (c) quotas on the quantity of inputs. The variety in policy instruments indicates that the designation of environmental

[6] There is a variety of purposes served by these outlays: *e.g.* waste treatment facilities, designation and eventually management of protected areas and also research, education and extension.

policy and assessing its farm economic consequences requires extensive analysis.

In the Netherlands the problems caused by nutrients in particular relate to the overproduction of manure in intensive livestock farming on too small an area of land. In order to reduce the negative external effects of emission of nutrients, legislation restricting the use of manure and fertilizer has been passed, which also has several consequences for arable farming. With regard to future regulations alternative policy views can be discerned, for instance to apply the standards for drinking water as the limit for emission of nitrogen in agriculture. The use of pesticides in Dutch agriculture is subject to a special law defining criteria for their authorization. And there is a special list of chemical products whose use is prohibited in water-collection areas. In addition to this authorization policy there are special requirements with regard to the maximum concentration of pesticides in drinking water. In the last couple of years, however, it has become obvious that unacceptable effects of chemical crop protection are not prevented by the current regulations. New official guidelines are currently being discussed (see for example Min LNV, 1990).

4. Towards an economic approach based on the individual farm

4.1 Need for a farm economic approach

Despite the importance of characteristics at micro-level in processes of structural change, until recently, economists' research on future prospects for agriculture or other sectors had an accent on forecasts on macro and sector levels[7]. Prognoses of agricultural change mainly concentrated on aggregated figures, regarding agricultural production, markets for agricultural inputs and outputs and effects of alternative agricultural policies in relation to technical progress, for example.

If policies are to be efficient, the driving forces behind changing production systems must be correctly understood. A micro economic approach might give additional insights that can counter the shortcomings of sector studies. Jochim-

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[7] A farm based modelling concept for sector analysis, *i.e.* the representative farm type approach, was used by Walker and Dillon (1976), Hanf (see Hanf and Noell,1989) and Thomson and Buckwell (1979), for example. See also Sharples (1969).

sen (1974) gives three causes[8] for the failings of macro economic forecasts: (a) having insufficient data, (b) the influence of innovation that could not be ascertained by the information available at sector level, and (c) the fact that agricultural changes are the result of farmers' decision making, a process not simulated in sector models. The latter two aspects stress the need for a micro economic, in this case at farm level, underpinning of the analysis of agricultural change with regard to technical and institutional development.

To arrive at a farm economics approach two more issues will be discussed in this chapter, namely: (a) the internal determinants of agricultural change and their influence on farm organization, (b) how the internal and the external determinants can be combined in an analytical framework from which the possibilities for further research (modelling) can be identified.

4.2 Dynamics of farm organization

The approach so far adopted gives a first synthetic view of the relationships between major determinants of agricultural change. For assessing future changes an "actor oriented" approach is required that indicates the adaptations in farm structure resulting from the external determinants described. To gain the insights needed it is necessary to focus on the decision-making processes of individual family farms. As highlighted in Chapter I there are two viewpoints in this analysis, namely the assessment of the economic optimal changes in the organization of production (planning) and the assessment of the changes to expect (conditional forecasting).

An analytical framework of changing farm structure, based on the SCP concept[9], is depicted in figure II.3. The economically optimal organization of production can be assessed from the natural conditions, external determinants and the technical and financial status of the farm. For actual farming, other internal determinants separate from the technical and financial status must be

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[8] Also included in his first reason are "using wrong data or statistical techniques" which seem to relate more to the researcher than to macro-economics.

[9] Structure, Conduct and Performance. This concept originates from analysis of industrial organization (Bain, 1968). For a recent review see Clarkson and Leroy Miller (1982), for instance. Van Dijk *et al.* (1986a) discuss the use of the SCP framework for the analysis of agricultural change in developed countries.

considered. In the present study these are categorized as (a) behavioural and (b) family-related factors.

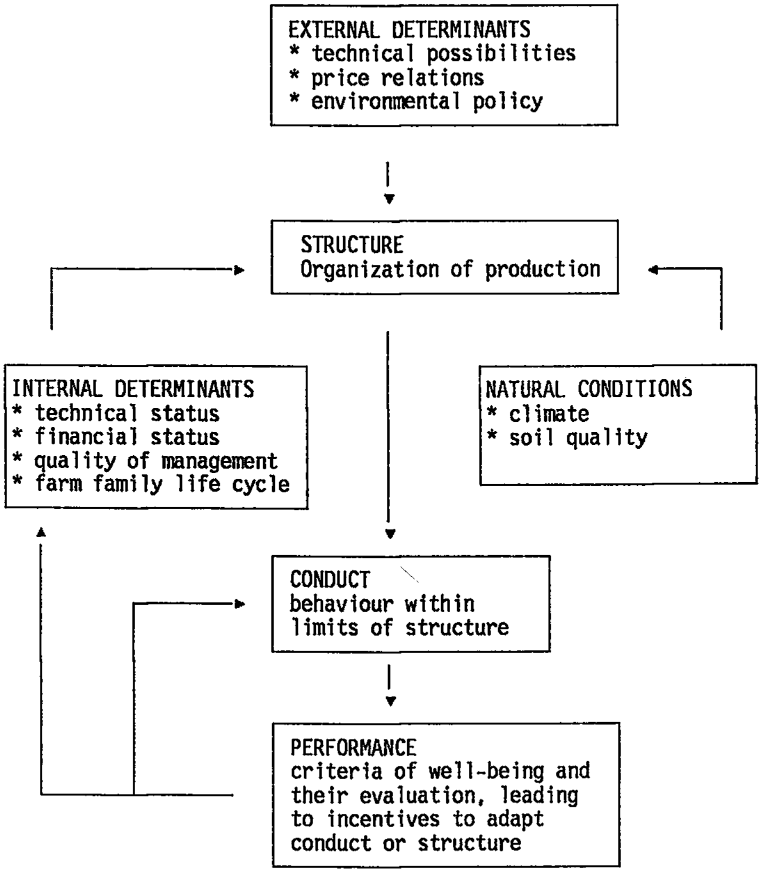
In farm economics it is realized that among farmers there is a large variation in capacity and willingness to reach the potential production level. This behavioural aspect, therefore, determines farm structure by altering the selection from the technology set (static situation) and also by differences in adaptations to changes regarding the external determinants (dynamic situation). In sociology, these aspects resulting in different levels of productivity under similar natural, social-economic and technical conditions are referred to as "styles of farming" (Van der Ploeg, 1990). Behavioural elements not only relate to the personal characteristics of the entrepeneur but also to the special type of enterprise in agriculture, namely the family farm. The farmer's age and the prospects for succession, *i.e.* the family situation, will influence the decision making about changes in farm organization, as these factors imply additional or modified objectives. Hence, the style of farming is related to the family situation. This relationship follows logically from the intermediate position of the farm manager between farm firm and his family. The foregeoing implies that research on future agricultural change must pay attention to the farmer's family situation, apart from his personal psychological characteristics, in order to understand his long term strategy and, consequently, his reactions to changes in external determinants. A classification based on characteristics of the family situation, apart from the one based on technical-economic and financial features of an agricultural enterprise, can have significant implications for research on future agricultural change (Petit, 1976b; Gebauer, 1987).

The SCP framework presented in figure II.3 indicates the dynamic process of agricultural change at farm level. As pointed out the confrontation of the natural conditions, the technical and financial status of the farm and the goals and objectives of farming with the prevailing external determinants gives the potential farm structure. Conduct, that is behaviour within the limits of structure, refers to the behavioural factors described in the foregoing. Performance implies an evaluation that can lead to incentives to adapt conduct or structure for the next decision-making process.

In terms of a linear programming model the actual technical status of the farm can be represented by a selection from the matrix of technical possibilities available. If in the next period a new technology set becomes relevant this does not yet mean that the technical status of the farm is altered automatically.

As indicated by the SCP framework, changes in farm organization go back to the decision-making process at farm level, where behavioural elements are important in addition to the economic (*i.e.* profit-maximizing) motives. This means that the optimal production organization resulting from linear programming is filtered by behavioural constraints. In the present study this filtering pertains to innovation adoption in particular. If, for instance, economic motives were the only basis for accepting improved agricultural practices these would be adopted as soon as their economic advantages could be demonstrated. In fact the time-lag between the introduction of a new profitable production practice and its adoption is considerable. For innovations that require high investments the time-lag can partly be explained by the economics of fixed assets. But innovations in variable inputs also take a certain time to diffuse, because of a wait-and-see attitude. How rapidly a specific innovation will diffuse within a group of farmers depends on the character of the innovation (its extent of uncertainty, for instance) and on the resistance among the farmers (Petit, 1976b and sources mentioned). Hence, variations in adaptability merit a special position in modelling changing farm structure in the context of conditional forecasting.

Fig.II.3 Farm structure and structural changes at farm level



5. Conclusions

The main conclusion from this chapter is that change in agriculture can be largely explained by the institutional and technical changes the individual units are confronted with, considering the differences and bottle-necks in the technical and economic status of these units.

The review of the theory presented revealed that in modelling agricultural change special attention should be given to: (a) the decision-making process on family farms, (b) the development of external determinants and their interrelationships, (c) the technology set available and (d) the environmental aspects of agricultural production. With regard to modelling, linear programming appeared to have interesting features, particularly for planning. With regard to conditional forecasting the LP approach has to be augmented to take account of behavioural aspects.

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CHAPTER III

Modelling agricultural change: The MIMOSA system

Abstract

Considering the theoretical framework in Chapter II and given the objectives in Chapter I the specific requirements for modelling agricultural change were ascertained, and the MIMOSA system was developed. The core of MIMOSA is a linear programming model. This presents technical, socio-economic and environmental outcomes at farm level. In addition to the usual farm activities the LP model covers an environmental component of the input and discharge of nitrogen and pesticides. The LP model indicates the optimal organization of the individual farm firm and can be used for planning. Modules representing feedback within and between family farms were added to the LP model. The combined system is intended for conditional forecasting.

1. Introduction

By modelling the quantitative and the qualitative implications of developments in alternative technologies and institutions, economists can contribute to finding solutions for the problems prevailing in agriculture. In the present study the MIMOSA (MIcro MOdelling to Simulate changes in Agriculture) system[1] was developed to analyse agricultural change at farm and regional level.

As the primary objective of the study (see Chapter I) is to ascertain the development of the single farm firm in response to changes in its socio-economic environment, the farm level was chosen as the starting point of the system. The second objective of the study was to elucidate the implications of policy

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The first part of this chapter, together with a summary of the LP model and an application for a levy on pesticide use (see Chapter VII) was published in Sociologia Ruralis (Wossink, De Koeijer and Renkema, 1992). For useful suggestions the author is grateful to E.M.T. Hendrix, Department of Mathematics, Wageningen Agricultural University.

[1] For MIMOSA system is used instead of model because more than one modelling technique was used.

alternatives at regional level. The system therefore also includes the aggregation of the results from the various representative farm types.

This chapter begins by reviewing general concepts of modelling agricultural change. Possible model approaches are discussed and confronted with requirements. Finally, the structure of the MIMOSA system and its components are described.

2. Modelling agricultural change

2.1 Theoretical background

Before developing any model of agricultural change two decisions have to be made: (a) which main determinants of agricultural change should be part of the model, and (b) what type of model is needed. To answer both questions the concept of the individual farm manager as an "adaptive man" is helpful (developed by Cyert and March (1963) and Day (1975; 1976), for a review see Brandes, 1985). According to this concept the individual farmer tries to adapt the existing farm organization to the changing environment -- including developments in technology, price changes, production restrictions and environmental regulations *etc.* -- in the light of his goals and objectives. So, modelling such adaptive processes must begin with a breakdown of reality into two parts, one representing the behaviour of the individual family farm and the other, indicated as the "environment", representing the external determinants (Day, 1976). These internal and external determinants of the process of adaptation of the individual family farm through time can be represented in one dynamic framework of Structure-Conduct-Performance (SCP) as visualized in figure II.3.

As illustrated by the SCP framework, entrepreneurial decisions are conditioned by an interaction among external determinants (technical and institutional developments), internal determinants (technical and financial status, quality of management and the goals of the farmer in relation to the farm-family life cycle) and natural conditions. A model system simulating changing farm organization through time should therefore have the following general qualities (Jochimsen, 1974): (a) it must take account of the fact that a family farm is a complex of a family household and a farm firm, (b) it should have dynamic elements to indicate the process of adaptation, (c) it should reflect the decision making process of production, investment and financing in relation to changing technical, institutional and capital constraints, (d) it must take account of the interrelations between the individual farm units, by way of the markets for agricultural inputs and outputs[2] and (e) it must take account of the fact that farmers' decision making is influenced by uncertainties and behavioural restrictions.

Regarding the research objectives (see Chapter I.2) the model system should indicate the development at farm level of: cropping pattern with selected cropping techniques and output levels, the level of variable inputs, investments, environmental pollution caused by the production activities and net farm result or farm income for different scenarios. In addition the model system should be able to indicate the development of these variables at the regional level: the number of farms per category, regional cropping pattern and output levels, totals for variable inputs, and the variation in farm income, environmental pollution and adoption of innovations. The basic approaches available for modelling are reviewed in the next section. The integration of environmental aspects is discussed separately in section 2.2.2. Section 2.2.3 focuses on quality a and sections 2.3 and 2.4 on quality c and d, respectively. These sections describe whether these general qualities were taken into account in constructing the MIMOSA system with the techniques possible. In section 2.5 the integration of the qualities b and e, *i.e.* dynamics and behavioural restrictions, is discussed. Uncertainties were not included in the MIMOSA system.

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[2] This quality is not related to the individual farm but to the aggregated (regional or sectoral) level.

2.2 Approaches to model construction

2.2.1 Model orientations

Generally, models are constructed to provide information about real systems. Depending on the research objectives they have one or more of the following orientations (Rauser and Hochman, 1979): descriptive, explanatory, forecasting or decision making and control. The system that was developed in the present study covers the latter two categories as its intentions are firstly to assess optimal farm organization strategies for different external conditions (planning at the level of the individual farm) and secondly to support agricultural policy making by analysing and evaluating the effects of potential policy measures (conditional forecasting at the level of a group of homogenous farms or at the regional or sector level, which implies aggregation over different groups of farms). The first orientation of describing the relation between variables is also important. Both economic and environmental aspects of agricultural production are considered in the model.

There are basically two approaches to economic analysis of production: econometric models and optimization models. An econometric (or positive) model is based on statistical analysis of historical data. Its advantage is that real behaviour is represented; a concomitant disadvantage -- especially for the present study -- is that only past behaviour can be covered. The effects of innovations such as sustainable farming, for instance, can hardly be ascertained by an econometric model as there is a lack of empirical data on this type of farming.

An optimization (or normative) model is based on two assumptions, namely that decision making pursues specific objectives and that it can be simulated by assessing the normative behaviour appropriate to these objectives. Optimization models are of special interest for the present study as they are frequently employed for planning purposes, *i.e.* to assess the optimal strategy for farm organization. Moreover, when based on mathematical programming techniques they are well suited for environmental economic research, because: (a) many activities and restrictions can be considered simultaneously, (b) an explicit and efficient optimum-seeking procedure is provided, (c) once formulated, the results from changing variables can be calculated easily and (d) new production techniques can be incorporated by adding additional activities to the model. The ability to investigate detailed technical and environmental questions makes the mathematical programming technique an attractive approach. A drawback is that a gamut of information on technical relationships and input and output prices is required to contruct the programming model.

With regard to the other orientation of the model, policy analysis, which calls for conditional forecasting, the major disadvantage of optimization models is that they represent the normative behaviour of the decision maker. Optimization models are based on the assumption that behaviour is guided by optimal decision strategies and based on perfect information. Incentives perceived by the decision maker to deviate from the optimal strategy are not incorporated, although they may be essential to the dynamics of change. In this respect the econometric model has major advantages as it represents the continuous response to changed exogenous conditions.

In an evaluation of the programming and the econometric approach for conditional forecasting Bauer (1989) gives a summary of their relative advantages and disadvantages. He concludes that both methods needs to be classified into different categories on basis of their essential features and that they should be seen as complementary, rather than as alternatives.

In conclusion: for planning a normative approach by means of optimization techniques such as mathematical programming is well suited, for conditional forecasting a combination of the normative and the positive approach is preferable. Such a combined model system can incorporate economic behaviour to represent rational choice, taking into account that economic decisions are taken sequentially, not simultaneously, and that choice is conditioned by behavioural rules.

2.2.2 Integration of environmental aspects

Environmental pollution was formerly not considered in decision making at farm level, or when modelling this process, because relevant market incentives were lacking and environmental regulations for agriculture were not common until recently. To be able to assess the effects of alternative environmental policy instruments the interactions between production practices and intensity, environmental aspects and income must be understood. To acquire this insight the economic models used in research have to be extended with parameters for the environmental effects of the production activities considered.

Environmental pollution in arable farming is caused by the use of nutrients, in particular nitrogen, and pesticides. Depending on the method of application and characteristics of the specific inputs they may have adverse effects on the environment, namely: emission into groundwater and surface water, emission into the air and accumulation in the soil. Measuring the environmental damage as such is very difficult. Instead, criteria are usually chosen as indicators of the actual or expected damage. With regard to nitrogen the concentration of nitrate in the groundwater is used as the standard measure. For pesticides the concentration in the groundwater, the emission to the surface water and the toxicity to aquatic organisms are well-known criteria. Ascertaining the environmental parameters of the production activities, requires the use of ecological models. These models translate input quantities per crop into levels of environmental pollution, such as the nitrate concentration in the groundwater, taking account of the natural conditions.

As pointed at, mathematical programming techniques are well suited for environmental economic research. The output parameters of the ecological models can be incorporated as quasi-external data into a programming model (Wossink, De Koeijer and Jarosch, 1990). Economic and environmental aspects can be simultanously considered in the optimization procedure in this manner, and a separate module to link the economic model and the ecological model is not necessary.

2.2.3 The farm-firm versus the family-household

A study of agricultural change must recognize the close interrelationship between the farm-firm and the family-household. This interrelationship implies that, at least in the short run, there are two conflicting objectives to consider, namely maximization of the family's consumption and continuity of the farm. The economic farm household theory, linking these two objectives, was originated by Chayanov (1966, see also Tschajanow, 1923). A mathematical framework on this basis was presented by Nakayima (1986). A survey of agricultural household models built on Nakayima's framework is given by Singh *et al.* (1986). For a recent application for Dutch agriculture see Elhorst (1990).

As farms in Western Europe are usually commercial, *i.e.* have access to markets of inputs and outputs, the farm-family decision making process can be divided into two stages. In the first stage, given the family supply of labour and money capital and the availability of fixed assets such as land and capital goods, the farm-firm decisions on production and investment are made and income is maximized. Additional labour and money capital, apart from those at the family's disposal, can be obtained via the markets of these inputs. In the second stage family-household decisions are concerned with allocating current income between consumption and savings (which can be made available for farm investments) and with allocating labour capacity between leisure, employment on the farm and employment outside the farm. The theory assumes that family labour input and non-family labour input are perfect substitutes and also that on-farm and off-farm wages are equal. For a discussion of whether the conditions for recursivity are fulfilled in the Dutch situation see Elhorst (1990).

With regard to labour, Thijssen (1988) concludes, based on on a study of Dutch dairy farms, that both the short-term production and the short-term price elasticity of family labour in agriculture are small and that endogenizing family labour in a model of the family farm does not have much influence on farmers' process of adaptation. Analysis by Elhorst (1990, p. 138) also yielded small price elasticities for on-farm and off-farm family labour supply, specifically for arable farming in the Netherlands. Therefore in the MIMOSA system family labour supply is fixed and off-farm family labour supply is disregarded.

Regarding the family household decision on income, the level of family expenditure, corrected for price changes, has been found to be almost constant for Dutch family farms (see for instance Van Bruchem and Tamminga, 1989, p.144). Further, Elhorst (1987, p.8) found that in Dutch agriculture the level of investments is not stimulated by a high level of liquidity, *i.e.* family savings, nor restricted by a low level for the population and the range of liquidity levels he observed.

In summary, farm decisions and household decisions can be separated in modelling and for the Dutch situation household decisions appear to vary little in time. Hence, in modelling the decision on family labour supply and the relationship between own financial resources and farm investments can be considered as less important in the present study.

2.3 Assessment of policy options for modelling: scenarios

An analysis of future agricultural structure should include an investigation of the external factors. For such an analysis it is preferable to employ the scenario method, as the external determinants are interrelated and should be seen more or less as one package. After assessing these scenarios a translation into LP model constraints, input-output coefficients and objective function values is necessary. By choosing contrasting scenarios the boundaries of the future state of the research subject, *i.e.* a specific farm population, can be indicated (Bright and Schoeman, 1973). Further the trade-offs between policy objectives can be presented for the alternative scenarios. Chapter IV deals with the assessment of the scenarios for the present study.

With scenarios the time horizon is an important element. Given the objectives of this research it would have been preferable to take 20-30 years but it was decided to set the horizon at 15 years (until 2005) because of the uncertainty of predicting technical and institutional developments over a longer span of time.

2.4 Aggregation over farms

Because the present study is not restricted to the farm level but includes analysis of agricultural change at the regional level aggregation is required. The attendant aggregation bias is a major problem in agricultural economics and may be defined as the error in predicting aggregate outcomes for a group of farms by using models at a certain degree of aggregation, rather than modelling each farm individually. The aggregation problem has two aspects: heterogeneity within the group of farms and interrelations between the individual units.

The first aspect has to do with the fact that very many micro models are required to represent the behaviour of all farms in a population. This makes the application of detailed micro analysis unattractive. When using the programming technique one approach is to break down the population into a number of categories of farms and to model a representative farm type for each category. Another option is to use a sample of individual farms in the population (see Boorsma, 1990). Day (1963) stated that farms to be represented by a single LP model must be technically homogenous. An additional requirement in the case of dynamic analysis is that the farms to be represented by one LP model react identically to changes in the external conditions. The first condition can be partly dealt with by a mathematical approach, cluster analysis for instance (Buckwell and Hazell, 1972). This finding from literature is the starting point of Chapter V which deals with the identification of representative farm types for the population of arable farms in the North East Polder.

The second aspect of the aggregation problem is caused by the interrelations between the individual farms on the markets of inputs and outputs. Different procedures exist to take account of the most important interrelations[3]. Brandes (1985) mentions: (a) combining the representative farms or sample farms into one optimization model, and (b) modelling the units separately and summing the results. The first procedure accounts for the interrelations by restrictions in the aggregate optimization model. The approach, however, cannot express the fact that decision making takes place at the micro level. Önal and McCarl (1989) propose a modified stepwise method to include farm level constraints and responsiveness in the aggregate model. The first step involves formally developing LP models for representative farm types and repeatedly solving all these models under a sufficiently wide set of relevant circumstances that prevail at the aggregated level. In the next step, the individual model solutions obtained for every set of conditions are summed and then translated into a range of activities for the aggregate model. This yields an aggregated representation.

In the case of the second method of aggregation, interfarm relations can be examined by simulating aggregate feedback. Here, a link with the first aspect of the aggregation problem may occur, namely if the feedback implies a distortion of the technical homogeneity within the farm groups. In that case additional representative farm types need to be specified.

[3] Lerner (1960) indicated that this problem per se cannot be solved: " Micro economic analysis legitimately ignores effects which cannot be neglected at the macro economic level. These effects result from feedback from the sector to the farm, ... some ... can be taken into account but it is of course impossible to handle all of them".

2.5 Time dimension and research organization

As the central issue in this research was the adjustment in the organization of agricultural production brought about by farmers reconsidering their strategic decisions, a dynamic system had to be used (Rauser and Hochman, 1979). With regard to research organization it is preferable to handle the time element in phases, starting with a static comparative approach and subsequently integrating the dynamic elements. The total research project was therefore planned into phases:

(1) Comparative static model calculations for different representative farm types to assess the optimal farm organization for different external conditions and to elucidate the working of environmental economics models;

(2) Calculations for farm categories to analyse their path of development over time. Changes in internal and external determinants can be included as well as the influences of feedback within family farms;

(3) Extension to the aggregated level by a weighted summing of the results of the different farm categories and by accounting for interfarm relationships (feedback between family farms).

In accordance with these phases, building the MIMOSA system included: (a) scenario assessment to reduce the different policy views on future price policy and environmental policy (and the expected technical innovations) to a restricted number of consistent, diverging variants; (b) the construction and implementation of an environmental economics model at the farm level; (c) the construction of modules of feedback within family farms to finetune the results of the normative linear programming procedure; and (d) the development of an aggregation procedure accounting for regional interdependence between individual farms.

Note that part d, *i.e.* the extension to the aggregated level was not implemented in the case of the application to the North East Polder.

3. The MIMOSA system

3.1 Basic structure

The first requirement of the MIMOSA system was to indicate the changes in the farmer's strategy brought about by the changing incentives perceived each period. We modelled this process combining a normative linear programming model, which covers the farm-firm decisions, with additional feedback modules. For the topic of the present study a single-period optimization model was preferable to multiperiod or dynamic programming (the latter two are also suitable for representing changing farm organization). A system based on single period programming fits in better with the short planning horizon of the farm manager.

The feedback modules represent feedback both within family farms (decisions on farm continuation and innovation adoption) and between family farms. The modules of feedback within family farms finetune the outcomes of the ordinary comparative static programming model at the level of the farm category by means of external information. The module of feedback between family farms simulates land transfer, also based on external information.

The time interval t used in modelling had to be chosen. In studies using programming models to simulate agricultural change a run generally simulates just one calendar year (De Haen, 1971; De Haen and Heidhues, 1978; Kingma, 1978; Boorsma, 1990). In the present study a period of one year was also chosen, because it is the natural time-unit in the production cycle of arable farming. The scenarios were defined annually, for this reason.

The structure of the MIMOSA system is schematized in figure III.1. The implementation of the different modules is presented in Chapters VI and VIII. The present Chapter is restricted to the specifications of the modules and their relations.

3.2 The farm model

3.2.1 LP model

The LP model simulates the farm-firm decisions in a normative way. As well as the regular items of production, labour supply and requirements, cultivation operations and investments the LP model contains an environmental component that takes care of listing the environmental parameters of the cropping activities.

With regard to the production activities, the different operations per crop and the associated labour requirements had to be analysed in detail to ascertain the effects of adaptations in cultivation practice to technical innovations and environmental regulations. The LP model focuses on these aspects and therefore other elements of farm decision making received less attention. Investments in expansion of capacity[4] were disregarded, for instance. Possible organizational bottlenecks from disregarding investments in additional machinery were accounted for by the option of contract work operations. The model only represents investments in technically superior machinery and replacement of existing equipment. It was assumed that investments in replacement equipment are financed from the depreciations every year; whether the investments can be financed is disregarded.

The linear programming model optimizes the net farm result, being the difference between the total of the gross margins of the crops in the optimal plan and the costs of pesticides, contract work, additional investments, casual labour and fixed costs. For a specific scenario s, year t and representative farm type i the LP procedure assesses the optimal farm organization, indicating: net farm result, cropping pattern and cropping technique per crop, regular and casual labour hours used and the input and discharges of pesticides and nitrate.

The core of the MIMOSA system is a separate linear programming problem for each scenario s, period t and representative farm type i, distinguished by attaching the indices s, t and i to the variables and parameters:

$$\text{Maximize } \{ Z_{s,t,i} = c'_{s,t,i}\, x_{t,i} \}$$
$$\text{subject to } A_i\, x_{t,i} \leq b_{s,t,i}$$
$$\text{and } x_{t,i} \geq 0$$

where:

$Z_{s,t,i}$ = value of the objective function farm type i, period t and scenario s;
$x_{t,i}$ = vector of activities farm type i in period t;
$c_{s,t,i}$ = vector of gross margins or costs per unit of activity;
A_i = matrix of input-output coefficients (technology set);
$b_{s,t,i}$ = vector of constraint coefficients, reflecting capacities and technical and institutional restrictions.

[4] With regard to acreage enlargement it was assumed that if the opportunity of enlargement arose (for which certain conditions must be met, see section 3.3.2) it would always be taken. Therefore it is not considered in the decision making process represented by the LP module.

Note that the vector of possible activities x and the technology set A for a specific farm type i in a certain period t are the same under all scenarios, it are the vectors c and b that differ. The scenarios s are assessed in Chapter IV. The farm types i are identified by cluster analysis in Chapter V. First the result x^*_i indicating the basic situation is computed, i.e. the optimal farm plan for representative farm type i assessed by optimizing with only standard farm activities included (see Chapter VI). The second step is to assess $x^*_{s,t,i}$, *i.e.* the optimal solution of the representative farm for the different scenarios s and periods t (see Chapter VII).

3.2.2 Feedback within family farms

Referring to the analysis in section III.2.2.3, family labour supply was regarded as a fixed supply and consumption as a fixed charge. Further financing was disregarded. In the MIMOSA system, feedback within family farms, therefore, does not cover a household module and is restricted to farm continuation and innovation adoption. The modules for farm continuation and innovation adoption with the LP model form the farm model of the MIMOSA system (see figure III.1).

Continuation module

According to Bouma (1988) the possibility of a farm winding up can be assumed to be dependent on the farmer's age, the presence of a successor, the income obtained from the holding and whether the farmer has an off-farm job. The probability that a farmer will be succeeded by a family member is thought to be determined by almost the same variables. Estimating these probability functions requires a lot of data on individual farms not available in the regular farm survey. Moreover, in the present study the continuation or discontinuation of the farm firm as such is more important than whether a family member is the successor. Hence, following Bouma, two general conditions rule farm continuation in the model. A farm is wound up if: (a) the farmer reaches the age of 64 years in period t[5] and has no successor and if at the same time (b) the farm is less than a certain number of hectares.

Making allowance for the current low incomes in arable farming an extra option is to be added for farm discontinuation, namely by means of bank-

[5] In the study region, the farmer reaching the age of 65 is a crucial factor in farm succession. Almost all the land in the region is state-owned and on normal or long lease. At the age of 65 the lease will be terminated.

ruptcy. Ending the farm for reasons of bankruptcy cannot be simulated by using the outcome of the LP module, *i.e.* the net farm result. It is known that family farms are continued, even when the net farm result is negative for years, because they are largely financed by family capital. In the LP module financing was disregarded, here it cannot be omitted. In the continuation module bankruptcy in period t + 1 is reflected by the level of family capital falling below a certain limit at the end of period t. With regard to winding up of the farm firm in the case of bankruptcy it is assumed that this applies in the case the farm is less than a certain number of hectares. Else, the farm firm is assumed to be let to a new tenant (see section III.3.3). Note that bankruptcy was not implemented in the case of the application of MIMOSA to the North East Polder.

The <u>continuation module</u> in the MIMOSA system follows the approach by Bouma (1988), where the probability of succession depends on the farm size:

$$Psucc_{s,t,i} = d_0 + d_1 \ln (sfu_{s,t,i})$$

where:

$Psucc_{s,t,i}$ = the probability that farms in category i with a manager ≥ L years in period t will be continued by a family member;

$sfu_{s,t,i}$ = standard farm units of the optimal cropping pattern for category i, period t, scenario s.

The discontinuance of farms within category i follows from (see Chapter VIII for a specification):

$$Diss_{s,t,i} = f\,(Ftot_{s,t,i},\ Psucc_{s,t,i},\ \pi_t,\ OC_{s,t,i},\ S_{s,t,i})$$

where:

$Diss_{s,t,i}$ = number of liquidated farms for category i, period t and scenario s;

$Ftot_{s,t,i}$ = total number of units in category i, period t, scenario s;

π_t = minimum size in hectares for a farm in the region to be continued;

$OC_{s,t,i}$ = level of own capital for farm category i, period t and scenario s;

$S_{s,t,i}$ = family savings for farm category i, period t and scenario s.

Further the continuation module assesses the potential number of adopters $Fmax_{s,t,i}$ used in the innovation adoption module. $Fmax_{s,t,i}$ is defined as all farms in category i except those with a manager ≥ L years without a successor. Hence:

$$Fmax_{s,t,i} = Ftot_{s,t,i} - (1-Psucc_{s,t,i}) * \alpha_{t,i}\, Ftot_{s,t,i}$$

where:

$\alpha_{t,i}$ = share of units in category i with a manager ≥ L years period t.

Innovation adoption module

With respect to innovation adoption at farm level Hooks, Napier and Carter (1983) state that information supply and economic aspects are both relevant in understanding this process. The basic premise of the diffusion concept is that access to information is the principal factor affecting the adoption decision. The economic constraints factor is primarily based on the existence of economic barriers that prohibit actual adoption after being informed about an innovation. To this analysis should be added that even if an innovation is profitable for farmers it is not immediately adopted by all of them. This can be called the behavioural constraints factor.

In constructing the innovation adoption module it was assumed that the process of adoption of an innovation by an individual can be divided into three sequential sub-processes (Valkonen, 1970): a) becoming aware of a certain innovation, (b) becoming willing to adopt the innovation and (c) the actual adoption. These three sub-processes cover the three factors mentioned above. In the MIMOSA system the first subprocess is represented by the scenario module and by means of updating the input-output matrix of the LP model for technical innovations. It is assumed that all farmers are equally exposed to information; this implies the same technology set for every farm category. In real life a causal loop is to be expected: those who are likely to adopt innovations tend also to consume more information, which increases the probability that they will adopt further innovations.

Awareness is a necessary condition for the second sub-process, namely becoming willing to adopt the innovation. A crucial factor in the process is the advantage to be gained through adoption: this varies for different farm firms. There are two ways of defining and measuring the relative advantage of an innovation. One is the relative advantage as perceived by the farmer himself. The second manner, chosen in this study, is to use expert knowledge to determine the economically measurable gains. In this way the relative economic gain is clearly differentiated from the willingness to adopt. In the MIMOSA system the economic profitability of an innovation, bearing in mind the technical status of the farm, results from the normative LP module as the difference between the "with" and the "without" situation.

The third sub-process covers the actual adoption. Not only innovation-specific factors, such as the innovation's economic advantage, but also adopter-specific characteristics are important in this process, as they affect the speed of the diffusion process for a specific farm category. Bass's innovator-imitator model was selected to simulate the adoption of innovations with relative economic advantages within farm categories. The parameters of Bass's model were based on external information. In this manner rates of adaptation were established as suggested by Veeneklaas (1990, p. 141).

The innovation adoption module simulates the differences in adaptation among $Fmax_{s,t,l}$ by dividing $Fmax_{s,t,l}$ into a number of classes $ß_{s,t,l}$. Both the number of classes $ß_{s,t,l}$ and the share of $Fmax_{s,t,l}$ in each class follows from the diffusion of the innovations g (g = 1,....,h; h is the total number of innovations included in $x^*_{s,t,l}$). The maximum number of classes $ß_{s,t,l}$ is h+1. Class h+1 covers the farmers that did not adopt any of the h innovations. The group of managers ≥ L years without a successor, which is not included in $Fmax_{s,t,l}$, is added to this extra class.
It is assumed that the diffusion of a specific innovation g starts as soon it is selected in $x^*_{s,t,l}$. The rate of diffusion of each innovation (Fdiff) is simulated by using the Bass innovator-imitator model. This model describes the diffusion process by the following cumulative frequency distribution (p,q ≥ 0):

$$Fdiff_t = \frac{1 - e^{-(p+q)t}}{1 + q/p \; e^{-(p+q)t}}$$

where:
p = coefficient of external influence on the population (innovation);
q = coefficient of internal influence on the population (imitation).

The coefficients p and q are assessed by external information (see Chapter VIII).

The effects of the differences in adaptation of $Fmax_{s,t,l}$ to $x^*_{s,t,l}$ is computed by repeating the LP computations for s,t and i with a modified $x_{t,l}$ for each class $ß_{s,t,l}$. So, for every class $ß_{s,t,l}$ a specific $x^*_{s,t,l,ß}$ and $Z^*_{s,t,l,ß}$ results. Together with the number and the size of the classes $ß_{s,t,l}$ this composes the category result.
In summary: each element $y_{s,t,l}$ of the category result, for instance the activities selected, is assessed by:

$$y_{s,t,l} = f\,(x^*_{s,t,l},\; Ftot_{s,t,l},\; sfu_{s,t,l},\; \pi_t,\; p_g,\; p_g\,)$$

3.3 Regional model[6]

3.3.1. Summation module

The summation module collects the regional totals from the outcomes of the farm model for the representative farm types i, considering scenario s and year t. Total results can be assessed for: farm size distribution and regional cropping (variant) mixes, regional output levels, distribution regarding input and discharges of pesticides and nitrogen, input of casual labour, distribution of farm income and family capital situation and innovation diffusion.

Because of the dynamic approach the number of farms represented by representative farm type i will change from period to period as a consequence of farm liquidation or transition to another category. The outcome of the continuation module for farm category i in period t indicates the number of units to be represented in period t + 1. Note that expansion of area of farms implies a transition of part of the population represented to another or to a new category. In the case of a new category an additional representative farm type in required.

In the regional model, the summation module collects the regional totals from the category results for all categories i. Further, the summation module assesses $Ftot_{s,t+1,i}$:

$$Ftot_{s,t+1,i} = Ftot_{s,t,i} - Diss_{s,t,i}$$

3.3.2. Feedback between family farms: land transfer module

At the aggregated level the interrelations between the categories on the markets of inputs and outputs have to be considered. As the study was restricted to the farm and the regional level this aspect of balancing is less daunting than in the case of sector modelling. The only intermediate market considered is that of agricultural land, which is the most scarce resource for arable farming in the Netherlands. Annually no more than 2 per cent of the total area of agricultural land is put up for sale. The individual farmer is completely dependent on the supply of land from liquidated farms in his area. A low/high percentage of succession results in a high/low supply of land, and hence in a

[6] Not implemented in the case study, *i.e.* arable farming in the North East Polder.

faster/slower enlargement of the remaining farms. The land transfer module enables the land available from the liquidation of farms to be distributed among the remaining farms and determines which farm will obtain what amount of land freehold or on lease.

Only two studies on agricultural changes including land transfer, farm size development and technical innovation in the Netherlands are known (Filius, 1979; Boorsma, 1990). Filius's dynamic regional model was based on Cobb-Douglas functions for individual farms. Liquidated farms were responsible for supply on the land market, so the price elasticity of supply was zero. Demand for land resulted from the individual production functions. Probability functions were employed to simulate land transfer. As land supply in Filius's model was fixed each period, market equilibrium was arranged by modifying total demand. If the regional financial resources were insufficient to absorb total supply of land, the price decreased. To simulate land transfer Boorsma (1990) used an interactive (recursive linear programming) approach assessing the price for which market clearance was best fulfilled. Bouma's (1988) analysis covered land transfer and farm size development, but ignored technical change. His Monte Carlo simulation gave no information on the trends in price of land and did not check whether total demand matches total supply.

In the MIMOSA system supply of land follows the approach developed by Filius (1979), *i.e.* supply of land depends on the liquidation of farms. The supply is distributed over the remaining farms by considering their succession perpectives and their marginal revenue of land. Enlargement is only possible in fixed quantities to safeguard the manageability of the number of representative farm types in period t + 1.

In the case study North East Polder governmental interference has a strong influence in the land consolidation process as almost all the land is state-owned. This implies that for land transfer in this region an alternative, pragmatic approach can be followed[7]. Instead of endogenizing the land market, the reallotment policy of the Domain Board, reponsible for land transfer in the

[7] Note that this was not implemented.

region, can be chosen as the basis for ascertaining whether the total area of a specific farm increases and by how many hectares[8].

The land transfer module reallocates the land from liquidated farms:

$$Sland_{s,t} = \sum_{i} Diss_{s,t,i} * acre_i$$

where:

$Sland_{s,t}$ = supply of land in hectares, period t and scenario s;

$acre_i$ = acreage of the representative farm of category i in hectares;

As land supply is given for s and t, market equilibrium is arranged by modifying total demand. The supply of land $Sland_{s,t}$ is randomly distributed over the farms $Fmax_{s,t,i}$ in the category with the highest marginal revenue of land $MRland_{s,t,i}$ in fixed quantities $\delta land_i$ hectares. Note that $Sland_{s,t}$ may be too small to enlarge all farms $Fmax_{s,t,i}$. On the other hand $Sland_{s,t}$ may be large enough to enlarge farms in the next category according to $MRland_{s,t,i}$. Note further that the classes $\beta_{s,t,i}$ among $Fmax_{s,t,i}$ are not used in the land transfer module because this would mean an unmanageable increase of the number of representative farm types in t + 1.

Finally, land transfer implies a change of the enlarged farms to another category i (changing $Ftot_{s,t+1,i}$) or to a new category i. Hence, in period t+1 the number of representative farms i may differ from i in period t.

4. Concluding remarks

The present chapter can be summarized as follows: (1) to assess the optimal strategy for farm organization (*i.e.* planning) a normative approach is needed, for conditional forecasting at regional or sector level additional information derived from positive analysis has to be added, (2) for reasons of implementation, verification and application a modular structure was selected for the MIMOSA system, (3) a combination of single-period LP with additional feedback based on external information was chosen as the modelling technique

[8] Originally all farms in the North East Polder were let on normal lease. Farm sizes are 12, 18, 24, 30, 36 and 48 ha as the standard field size is 800 x 300 metres = 24 hectares. The Domain Board's policy for land reallocation in the North East Polder is as follows: (a) in the case of liquidation of a 12 hectare farm the land is added to that of another 12 ha farm, (b) an 18 ha farm is split and added to two other 18 hectare farms, (c) in the case of 24 hectares two neighbouring farms of 24 hectares are scaled up by 12 hectares (Westhof and Hazeberg, 1990). Enlargement is of course only carried out when a successor is available.

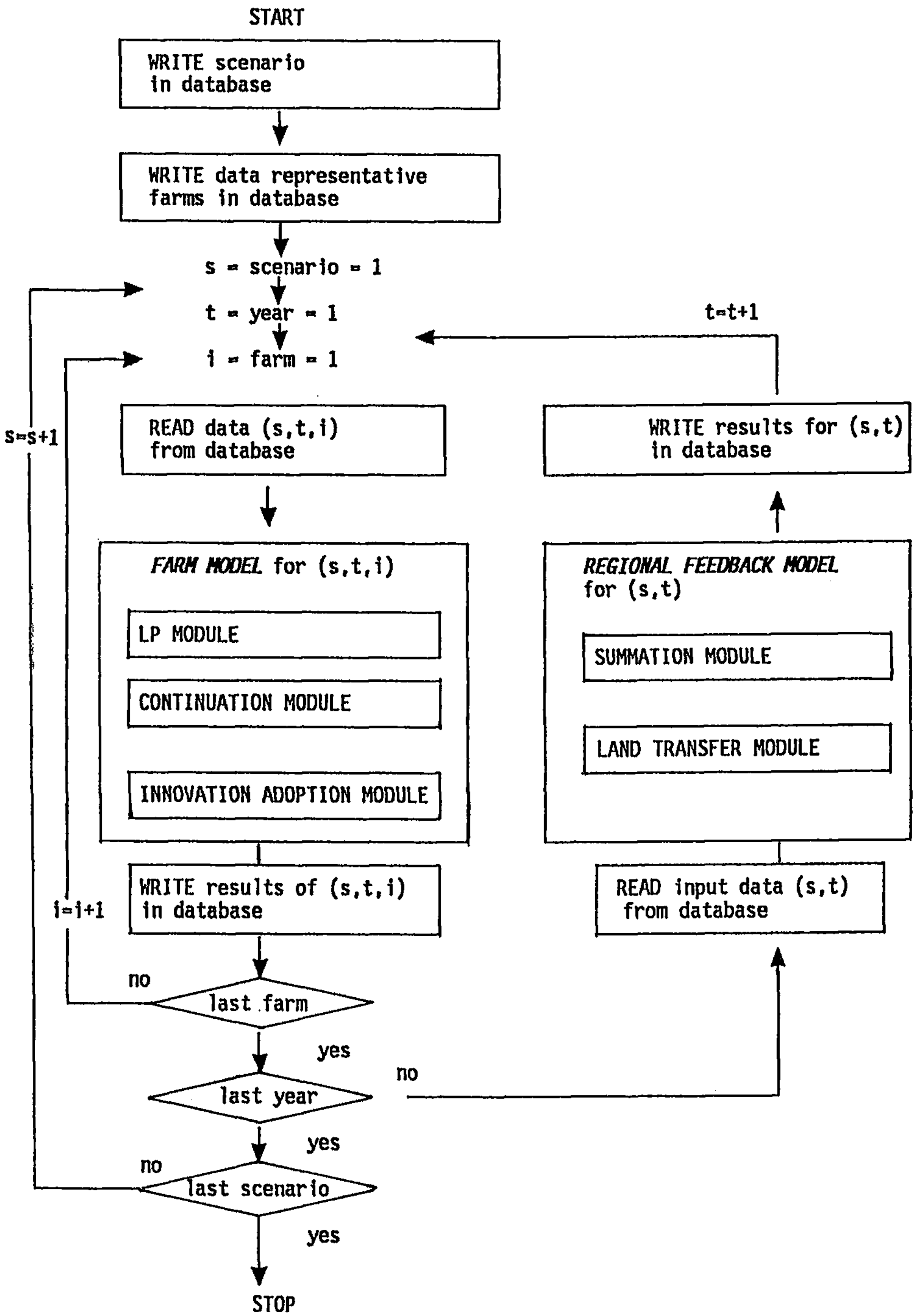
for the MIMOSA system, and (4) to implement and verify the MIMOSA system intensive cooperation with other disciplines and with policy makers is required, in particular for the environmental component of the LP module and for the assessment of the scenarios.

The decision to use an LP model at farm level is rather self-evident as it is virtually the only approach available which can produce projections of structural variables under conditions outside the range of past experience (such as future technological and institutional changes). An important advantage of the LP method is its ability to investigate detailed technical and environmental questions.

The modular set-up of the MIMOSA system enables the complex problem of agricultural change to be investigated in an outwardly spiralling manner, firstly at the farm level, and subsequently at the aggregate level.

The effectiveness of a system like the one described for conditional forecasting depends on whether (a) the external determinants and (b) the reaction of individual farmers to changes in external determinants can be captured. The first item is taken care of by using scenarios. That is, relevant alternatives are formulated regarding technical and institutional developments to enable an assessment of the contraints of the future state of arable farming. With regard to the second item, the addition of feedback within and between family farms to the normative LP procedure is considered a valuable extension.

Fig.III.1 STRUCTURE OF THE MIMOSA SYSTEM



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CHAPTER IV

Scenario assessment integrating technical and institutional developments[1]

Abstract
By application of the scenario development method possible future external conditions of agriculture are investigated. Variants are operationalized for three main fields: agricultural price and market policy and general Dutch price developments, environmental policy, and technical developments. From the possible combinations of the variants six scenarios for arable farming resulted, for use in the MIMOSA system.

1. Introduction

Research on the future of agriculture requires an investigation into possible and/or desirable long term developments. The need to assess such options implies that the scope of the present study goes beyond that of problem "solving", and includes problem perception and problem definition. Questions to be answered are (NRLO, 1987): (1) what are the normative objectives for future agriculture ? (2) what is the present situation ? and (3) how can the present situation be transformed in the preferred one? In the public and political debate on the future of agriculture different views can be discerned concerning the three items, varying with regard to the extent of the changes required, the appropriate time path and in particular how to direct the changes. Insight is needed into the various policy options and into the trade-offs between the different objectives. Research by means of modelling should provide this insight and clarify the discussion.

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[1] A former version of this chapter was presented as an invited paper at the 25th EAAE-seminar: The Environment and Agricultural Resources Management, Viterbo Italy, January 1991. See Wossink and Tamminga (1991).

Policy regulations and technical development are the main external determinants affecting agricultural change (see Chapter II). In this chapter an inventory is presented of these external determinants for crop farming in the Netherlands with the time horizon set at the year 2005. For technical change a so-called decor scenario can be formulated on the assumption that current, or currently foreseeable, developments will continue. Policy scenarios are objective-oriented against the background of the decor developments. As the objectives for agriculture vary over the different interest groups a finite number of variants was composed reflecting these policy views.

The scenarios were used in the MIMOSA system for modelling at farm level. At the Agricultural Research Institute (LEI-DLO at the Hague) they will be used for sector modelling.

2. Method and basic analysis

2.1 The scenario technique

The scenario technique is a recently developed method for studying the future. The objective of a scenario analysis is not to predict but to indicate the possibility of alternative future states. Van Doorn and Van Vught (1981, p.317) define a scenario as: the description of the current situation of a society (or a part thereof), of possible and desirable future situations of this society and of series of events that could direct the current situation to these futures.

The scenario technique can best be visualized by means of a number of funnels, as shown in figure IV.1. Normally there will be a large number of optional scenarios and a selection has to be made. The diagram indicates that by choosing contrasting scenarios future manifestations of the system under study can be explored sufficiently. Generally, in such contrasting scenarios certain parameters are set at extreme values in order to better analyse their importance in the evaluation.

The scenario method has major advantages as it: (a) reduces the unsurveyability and uncertainties of future developments, (b) makes the researcher aware of these developments and makes them easier to discuss and (c) outlines activities that can influence the developments. The scenario approach is particularly suited for long-range planning studies, concerning complex situations determined by several factors which are mainly variable and unquantified.

The scenario method distinguishes four phases for creating the alternatives (Schnaars, 1987): (1) the analysis of the current situation, (2) a survey of possible developments, (3) the design of possible and desirable future situations and (4) the design of series of events that could turn the present state into these future states. In the present study the four phases are indicated as basic analysis, future analysis, policy objectives and regulations, respectively. Note that an interactive readjustment process of the policy regulations or their objectives was not included.

2.2 Basic analysis

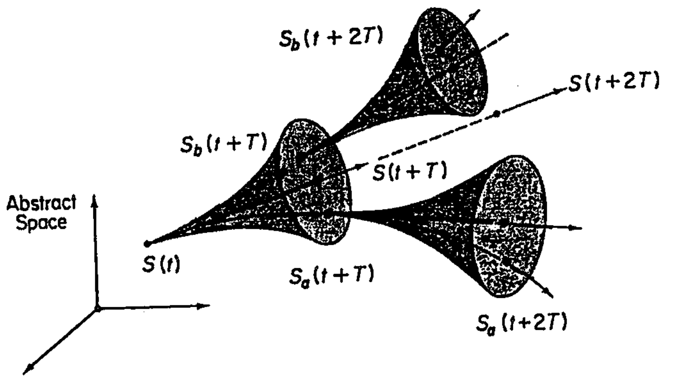
In the basic analysis four steps are taken: (1) enclosing the central system, (2) tracing the surrounding systems, (3) selecting and describing which variables to analyse and (4) examining these variables. As the scenarios presented were intended as input for model studies at various aggregation levels, the central systems concerned differ to some extent. Therefore, the average situation in arable farming in the Netherlands was taken as the starting point.

The exploration of the relevant determinants of agricultural change was based on the concept of "adaptive behaviour" (Brandes, 1985). While considering his goals and objectives the individual farm manager tries to adapt the existing farm organization to an environment that is continuously altered by innovations, price changes, production restrictions and ecological regulations. To define the scenarios, these conditions of agriculture at farm and sectoral level were clustered into three main external determinants:

(a) technical developments;
(b) general national policy, and EC market and structural policy for agriculture; and
(c) environmental policy.

In Chapter II the aspects b and c were combined to form the category institutional developments. In terms of a quantitative model (such as LP approaches) technical innovations imply a change in the activities matrix, whereas institutional change relates to prices and economic and ecological restrictions, which are quantified as elements of the constraints set and of the objective function.

Fig.IV.1 Diagram of the procedure for developing scenarios



Legend:		
	S	= system under study
	t	= time
	T	= timestep
	$Si_{(t+T)}$	= possible alternative futures of the system S

Source: (Gerardin, 1973)

3. Scenario assessment of various long-term views for arable farming

3.1 Technical developments

As pointed out in Chapter II the many different forms of technical change or innovation can be summarized as the introduction of new products or new production methods. New production methods can be subdidivided into: (a) mechnical, (b) biological and (c) organizational and informational technical developments. The mechanical innovations considered in the present study are (see table IV.1): (1) improvements of spraying techniques in crop protection, and (2) introduction or reintroduction of mechanical crop protection techniques. Biological inovations are represented by: (3) increase in yield per hectare of the various crops attributable to genetic improvements. Innovations which combine mechanical, biological and organization elements are: (4) application of low-input or so-called integrated cropping techniques and (5) introduction of ecological cultivation techniques, *i.e.* total abstention from use of chemical fertilizers and pesticides. The introduction of new products is represented by the following crops: (6) hemp (*Cannabis sativa*) for paper and rope production; (7) oil flax (*Linum usitassimum*), for the production of erucic acid, a special type of fatty acid; (8) Corn Cob Mix (*Zea mays*) for fodder and (9) chicory (*Cichorium intybus*) for the extraction of liquid sweeteners. The developments mentioned were quantified by assessing gross margins or changes in gross margins, farm operations and labour requirements and the input and discharge of nitrogen and pesticides.

The information was collected from recent publications and by consulting experts from research institutes. A Delphi procedure was followed meaning that by feedback to the informants a consistent and unambiguous data file was retrieved. These data were the basis for constructing a scenario of technical developments for the period up to the year 2005. It was implicitly assumed that the innovations that might become common practice by then all are already known in research. Hence, technical change forms the background, or decor scenario, for the policy or normative scenarios described in the next section.

A specification of the innovations listed in table IV.1 is given in Chapter VI together with the other LP input data. An exception is made for yield increases; these data are presented in table IV.2. The percentages are based on the assumption that in the medium term (10 to 15 years) a continuous increase in yield potential can be expected by conventional plant breeding as well as by means of biotechnology. Genetic improvement is little influenced by economic and institutional conditions because of the long time scale of biotechnological progress in crop production (Gotsch and Bernegger, 1990). Another motive for using constant percentages is given by Weber and Ehlers (1988). They used a logistic function[2] to simulate the development of yields over time in relation to the theoretical maximum and indicate that near the point of inflection of such a curve the annual yield increase can be assumed to be constant. This situation applies for crop production in the Netherlands.

3.2 Policy objectives and regulations

To derive variants for the institutional developments we started by analysing the relevant literature (reports, notes and documents, discussion papers *etc.*) produced by the different interest groups involved in the public and political debate on agriculture. Next, representatives of these groups were consulted. The resulting information was compiled in three variants of policy objectives plus their associated regulations to protect the environment and two for the agricultural price and market policy.

3.2.1 Two price policy variants

With respect to output prices, the Dutch farmer is directly and indirectly dependent upon the Common Agricultural Policy (CAP). In order to halt the growth of the EC budget expenses for price support of cereals and other crops, there are two main policy directions: one of reducing price support and one of production restrictions. Therefore, we developed two variants (see table IV.2A). The "market oriented" variant assumes sharp price reductions, supplemented by voluntary set-aside regulations as currently existing. The other variant reflects a policy of "production restrictions". In this case price decreases are moderate, whereas EC expenses are kept within bounds by a production restriction policy of set-aside or lower production levels per ha (extensification). In addition to the assumptions about output prices, price developments for fixed and variable inputs

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[2] $$Y = \frac{h}{1 + EXP(-k(x-w))}$$

where Y = yield; theoretical maximum h = 12.8 ton/ha for C_3 cereals; w = year of inflection; k = increase in per cent per year and x = year. It is assumed that the conclusion can be extrapolated to other crops.

are also a part of the variants. For the prices changes of pesticides a distinction was made between the two price policy variants (table IV.2B).

3.2.2 Three environmental policy variants

In line with the current debate concerning environmental regulations, we drafted three options to reduce the use of pesticides and nutrients (see tables IV.3 and IV.4). The more moderate variant represents the vision of the Board of Agriculture ("Landbouwschap") in the Netherlands, which argues that the introduction of environmentally-friendly innovations in farming practice should be stimulated instead of a set of prohibitions. The standard variant follows the proposed policy of the Ministry of Agriculture and the strict variant is drafted according to the ideas of the eco-movement.

Nutrients

In the Netherlands, problems of pollution by nutrients are mainly caused by an overproduction of manure in intensive livestock farming on too small an area. Legislation has been passed restricting the use of manure and fertilizer. This has several consequences for arable farming. According to the governmental regulations the application of phosphates and nitrates will have to be reduced in four phases, until the application and crop uptake of these minerals are well-balanced. Regarding the main arable crops, this will particularly have repercussions for potatoes growing. Potatoes are rather inefficient in using nitrogen. To reduce losses from leaching, a reduction of the application of nitrogen seems the only solution. In sugarbeet, part of the applied nitrogen ends up in the tops and leaves. After harvesting, these residues are usually left on the fields, causing a mineral loss into the soil and groundwater. Requiring farmers to collect the tops and leaves from the field could prevent this leakage of minerals.

Further policy proposals on the nitrate concentration in groundwater are currently under consideration. The EC guideline for drinking water is 50 mg nitrate per litre (Beugelink, 1989). The Dutch Ministry of Environmental Affairs advocates the tighter limit of 25 mg NO_3^- per litre.

The moderate variant implies no interdictions. According to this policy view, adding a green manure crop to the rotation scheme and technically advanced methods of N-dressing will be sufficient to counter the pollution problems. The strict variant proposes a compulsory switch to ecological farming.

Pesticides

The use of pesticides in the Netherlands is subject to a special law, indicating the criteria to be met. The authorized products are registered in the "Gewasbeschermings-gids" (Crop protection guide). There is also a special "black list", listing products whose use is prohibited in water collection areas. However, in the last couple of years it has become obvious that unacceptable effects of chemical crop protection are not prevented by the present regulations.

The standard variant follows the objectives for reducing the use of pesticides given in the Long-term Crop Protection Plan (Min LNV, 1990): (a) to reduce the input of pesticides (in kg active ingredient compared to the average over 1984-88) by 35 % in 1995 and 50 % in 2000, (b) to replace chemical methods by non-chemical techniques and (c) to reduce the emission of chemicals to groundwater, surface water and to the air. Each sector of agricultural production will have to contribute to the target reductions (see table IV.4). The Long-term Crop Protection Plan therefore gives detailed goals, this is known as the "volume policy" (because it affects the volume of pesticide use). No policy instruments to achieve the percentages have yet been defined, though an incentive levy was suggested as an option at the unveiling of the Long-term Plan in June 1991. In addition to the "volume" policy the "products" policy stresses that the list of pesticides currently authorized has to be reorganized, in line with the Environmental Criteria Policy Document (Min VROM, 1989a). Three criteria have been selected for this purpose: emission to groundwater, toxicity to aquatic organisms and persistence in the soil. The Long-term Plan covers lists of products whose banning should be given priority. The Plan also contains lists of products that should be further tested on their possible damaging effects. With regard to the emission to groundwater the proposed limits are the EC drinking water standards. In concrete terms this means (Van Duijvenbooden, 1989): (1) the concentration of a single chemical should not exceed 0.1 μg per litre groundwater for every crop, and (2) total concentration of the chemicals used in a specific crop should not be more than 0.5 μg per litre.

The moderate variant of environmental policy advocates the introduction of new spraying techniques and mechanical systems for weed control, for instance, instead of bans. The strict variant is intended to force a switch to ecological farming techniques.

3.3 Composition of six scenarios

By combining the provisions of technical innovations with the variants for EC market policy and those for environmental policy, in total 1*3*2 = 6 scenarios can be constructed, as shown in figure IV.2.

Scenario I:	technical innovation/ market-oriented variant price policy/ moderate variant environmental policy
Scenario II:	technical innovation/ market-oriented variant price policy/ standard variant environmental policy
Scenario III:	technical innovation/ market-oriented variant price policy/ strict variant environmental policy
Scenario IV:	technical innovation/ production restriction variant price policy/ moderate variant environmental policy
Scenario V:	technical innovation/ production restriction variant price policy/ standard variant environmental policy
Scenario VI:	technical innovation/ production restriction variant price policy/ strict variant environmental policy

In terms of figure IV.1 the selected scenarios refer to different "cones" of development of the system. Scenarios I and VI form the two most contrasting combinations. By comparing the outcomes of Scenarios I and II and of Scenarios IV and V the effects of environmental constraints can be assessed, whereas Scenarios I and IV and Scenarios II and V indicate the impact of the two price policy variants. Scenarios III and VI represent the impact of a compulsory switch to ecological farming. Scenarios I, II and V were considered as the combinations with the greatest practical relevance.

The technical developments and the different variants for price policy and environmental policy are summarized in tables IV.1 to IV.4. As mentioned, a detailed description of the technical innovations highlighted here will be given in Chapter VI when discussing the LP modelling.

4. Discussion

This discussion of the analysis includes (a) the experiences in drafting the scenarios and (b) their application in modelling research. Regarding the first item we were well satisfied with the method of scenario construction. A structured and integrated approach to screening prices, environmental regulations and technical developments seems to be extremely valuable for exploring the institutional and market forces affecting the agricultural sector.

In drafting the scenarios the environmental aspects were the most difficult to handle. This will need special attention in LP modelling as well. For every cropping activity, not only are the regular data on labour requirements, machinery hours *etc.* required, but also the input and discharge of minerals and nitrogen. The latter depend on many factors such as soil type, precipitation and adsorption coefficient, a research field rather unfamiliar to economists.

Note finally that the scenarios cover only the innovations that are known in research at the moment. This means that the present study might underestimate the opportunities of technical development, particularly for the last part of the period up to 2005.

Fig.IV.2 Construction of the scenarios for the MIMOSA system

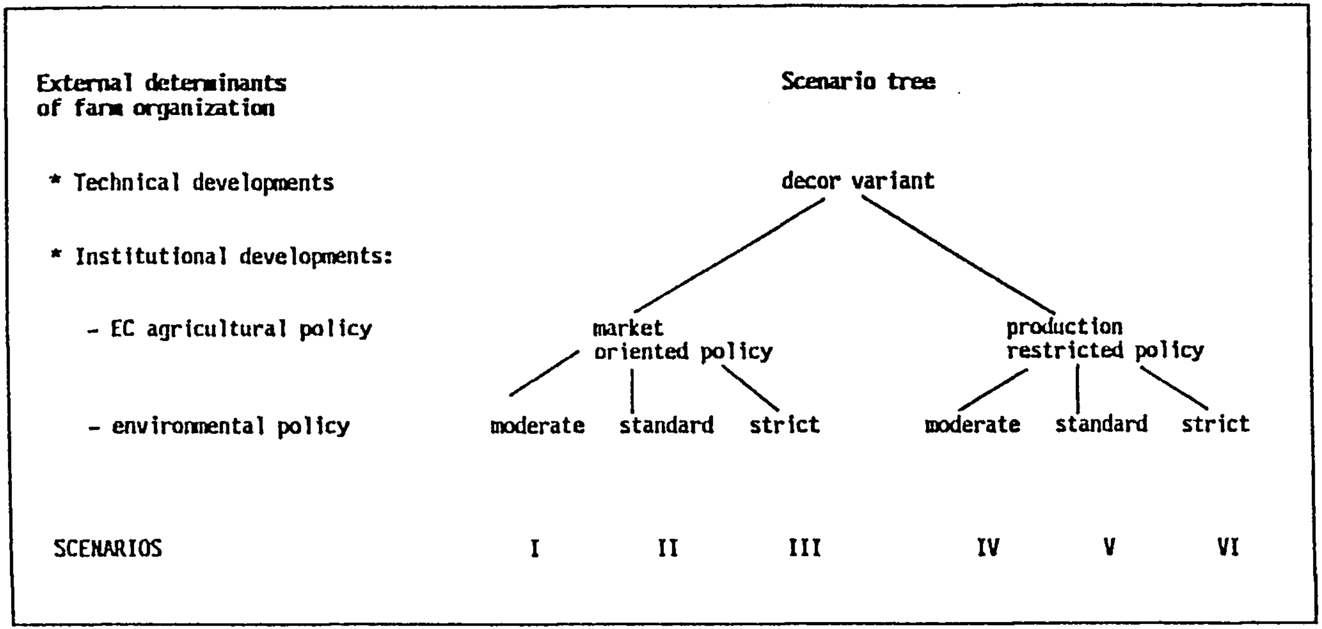

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Table IV.1 Summary of technical developments in arable farming in the Netherlands, used in the scenarios of the MIMOSA system

I. Developments in production techniques

Mechanical innovations:

(1) Introduction or reintroduction of mechanical crop care techniques
(2) Improvements in spraying techniques in crop care

Biological innovations:

(3) Increase in yield per hectare due to genetic improvements

Mixed innovations:

(4) Integrated cropping variants[1]
(5) Ecological cropping variants[2]

II. Introduction of new products

(6) Hemp (Cannabis sativa) for paper and rope production
(7) Oilflax (Linum usitassimum), for the production of erucic acid, a special type of fatty acid
(8) Corn Cob Mix (Zea mays) for fodder and
(9) Cichory (Cichorium intybus) for the extraction of liquid sweeteners

[1] Also known as low input cropping techniques.
[2] Total abstention from use of pesticides and chemical fertilizer.

Detailed information is presented in Chapters VI and VII with the application of the scenarios.

Table IV.2A Price policy variants and yield increase, used in the scenarios of the MIMOSA system

	Product prices in NLG (base year=1989)	Annual price change in % [1] Market oriented: price policy 1	Production restriction: price policy 2	Annual yield increase in % [2]
Current crops				
- Wheat	0.41/kg	-4.5	-2.5	0.9
- Sugarbeet	97/ton	-4.0	-2.2	1.4
- Ware potato				
Bintje	0.16/kg	-2.0	-1.1	0.4
PSR variety[3]	0.15/kg	-2.0	-1.1	0.4
- Onion	0.13/kg	-3.4	-1.9	1.1
- Peas	0.65/kg	-4.3	-3.4	2.0
- Seedgrass	2.00/kg and NLG 1008 per ha	- NLG 90[4]	- NLG 50[4]	0.0
- Carrots	100/ton	-2.9	-1.6	1.0
- Chicory (vegetable)	0.055/chicon	-2.9	-1.6	1.0
- Tulips	0.14 /bulb	-2.0	-1.1	1.0
New crops				
- Oilflax	0.60/kg and NLG 1426 per ha	- NLG 144[4]	- NLG 80[4]	2.5
- CCM	0.25/kg d.m.	-6.2	-3.5	1.5
- Hemp	300/ton and NLG 895 per ha	- NLG 190[4]	- NLG 106[4]	2.0
- Chicory (inulin)	120/ton	-3.1	-1.7	1.0
Additional measures				
- Set-aside		voluntary	15 % of area obliged	
EC premium per ha		NLG 1500 per ha for the first 50 % of the farm land and NLG 1300 for the remainder, annually reduced by NLG 90 [4]	no premium	

[1] The price changes for wheat are the starting point for the annual reduction of the other crops. The price reduction is assessed which gives the same gross margin change as for wheat (for pp1 NLG 90 per year and NLG 50 per year for pp2). Yield increases are accounted for. Example (for pp2):

	price in NLG	yield in kg/ha	returns in NLG	by product in NLG	total returns in NLG	variable costs in NLG	gross margin in NLG per ha	% yield increase	% price change	gross margin change
Wheat										
year 0	0.41/kg	7500	3075	376	3451	1093	2769			
year 1	0.395/kg	7568	3025	376	3401	1093	2719	+0.9	-2.5	-50
Sugarbeet										
year 0	f97/ton	61 ton	5917	-	5917	1301	4616			
year 1	f94.8/ton	61.8 ton	5861	1301	4560	1301	4566	+1.4	-2.2	-50

Shading indicates the results of the computation.

[2] Based on trend analysis LEI-DLO, not published.
[3] PSR = Potato sickness resistant.
[4] For seedgrass, oilflax, hemp and set-aside the EC ha premium is annually reduced for the gross margin change of wheat, accounting for the yield increase of the crop concerned.

Table IV.2B Price developments of fixed and variable inputs, used in the scenarios of the MIMOSA system

Input		Annual price change in %
Variable costs accounted for in the gross margin calculations		
1. Sowing seed and planting material		0
2. Fertilizer and manure		-1.0
3. Sundries[1]		0
4. Total per crop[2]		
wheat/onion/seedgrass		-0.4
sugarbeet/potato/peas		-0.3
carrots/chicory (vegetable)		-0.5
tulips		0
oilflax		-0.4
CCM/hemp		-0.6
chicory (inulin)		-0.2
bait crop potato		0.0
Variable costs separately specified in the lp model		
5. Energy		2.0
6. Pesticides	price policy1:	1.5
	price policy2:	3.0
7. Contract work		0
8. Casual labour		1.125
Fixed costs		
9. Machinery		1.5
10. Labour		1.125
11. Land, buildings etc.		0

[1] Costs of insurance, soil tests, product quality tests, drying/cleansing etc.
[2] Assessed by the weighted average based on the gross margin calculation per crop for the base year (1989).

Table IV.3 Three variants of policy objectives for nutrient use, used in the scenarios of the MIMOSA system

<u>Standard variant: continuation of the currently proposed policy</u>[1]

* Reducing phosphate application to the level of uptake by the crops:

	Arable land		Fodder maize	
	1990	2000	1990	2000
Phosphate kg/ha	125	70	250	75

* For nitrogen an equivalent approach will be followed. The objective is to realize nitrate concentrations below 2 metres of the groundwater level of not more than 50 mg/l (Min VROM, 1989b).

<u>Moderate variant: encouraging environment-saving technologies</u>

No regulations; innovations in fertilization methods will be sufficient for balancing phosphate and nitrogen use.

<u>Strict variant: a forced switch to ecological farming</u>

An accelerated reduction of nitrogen and phosphate use, registered by a nutrient bookkeeping system. From 1998 on a green manure crop will be obligatory.

[1] Source: Neeteson and Wadman, 1991

Table IV.4 Three variants of policy objectives for pesticide use, used in the scenarios of the MIMOSA system

Standard variant: continuation of the currently proposed policy

* Reduction targets for pesticide use in arable farming

Category	Reduction in 2000 compared to 1984-88	
	1995	2000
Soil fumigants	46	70
Herbicides	30	45
Insecticides	15	25
Fungicides	15	25
Others	42	68
Total	39	60

* The quality of groundwater for drinking water purposes has to be considered; maximum concentration level for individual products 0.1 μg/litre and for the total of products used in a specific crop 0.5 μg/litre groundwater;
* Emission to surface water: minus 50 % by 1995 and 90 % in 2000;
* Sustainable farming systems on 30 % and 100 % of the cultivated area in 1995 and 2000 respectively.

Moderate variant: stimulation of environment saving technologies

The following reductions can be realized by technical innovation:

	1994	2000
Potatoes		
- soil disinfection	- 50 to 70 %	- 65 to 80 %
- herbicides	- 35 %	- 50 %
- fungicides	-	-
Sugarbeet		
- insecticides	- 90 %	- 90 %
- herbicides	- 60 %	- 75 %
Cereals		
- herbicides	- 15 %	- 25 %
- fungicides	- 15 %	- 25 %
- growth regulators	- 5 %	- 10 %
Total	- 30 %	- 40 %

Strict variant: a forced switch to ecological farming

An accelerated reduction of pesticide use. By 2000 ecological farming is to be the common practice.

CHAPTER V

Identification of representative farm types

Abstract
This chapter presents an approach using cluster analysis to derive the representative farm types to be included in the MIMOSA model system. The North East Polder served as a case study. The eight farm types selected represent the most relevant categories of specialized arable farms in this region.

1. Introduction

As indicated in Chapter I the two main orientations of the present study on agricultural change were (a) to support strategic farm management decision making (*i.e.* planning) and (b) to support agricultural and environmental policy development and the selection of policy instruments (*i.e.* conditional forecasting). The first orientation implies the assessment of the optimal farm organization under changing conditions with respect to technical and institutional developments. Such calculations are particularly interesting if they concern the type(s) of farms most common in practice. In the case of conditional forecasting at the regional level this is even more important because in that case aggregation is desirable.

The category approach (see Chapter III.2.4) means that the total number of units in the population concerned is broken down and a separate LP model is created for the so-called representative farm type[1] of each category. The figures for the region in total can be calculated by a weighted adding of the results of

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[1] Characteristic, typical or modal farm would in fact be better terms. "Representative farm" is common in literature. Throughout the thesis "representative farm type" is used.

the individual models. This approach implies an assessment of: (a) the criteria and method for classification and for deriving the data for the representative farm types, and (b) the consequences of temporal change (*i.e.* the scenarios) and of feedback within and between family farms on the representative farm types to distinguish. In this chapter the first item is discussed. The latter item is dealt with in Chapter VIII.

As the North East Polder was selected as a case study for the application of the MIMOSA system the identification of representative farm types discussed relates to this area.

2. Minimizing the aggregation bias

2.1 Choice of method

In Chapter III.2.4 the concept of the aggregation bias and the conditions for consistent aggregation were discussed. It was concluded that if a number of farms are to be represented by a single LP model these farms must be technically homogeneous, *i.e.* have (1) the same LP activities and input-output relationships and have (2) proportional factor endowments and similar expectations of returns. These two aspects also cover the restrictions of corresponding objectives and managerial qualities as these are incorporated in input-output coefficients and constraints. In the case of a dynamic analysis a third condition can be added, namely that the farms should have (3) similar changes in returns and constraints and identical adoption rates for technical innovations.

Buckwell and Hazell (1972) state that the aspect of relative factor endowments is the only one manageable by a mathematical approach and they use the method of cluster analysis to retrieve the grouping and to construct the constraint vectors of the representative farm types[2]. For the conditions of equal technical opportunities and price relations they advise a regional differentiation. Kennedy (1975) employs regression analysis: on the assumption that the input mix is proportionally related to farm size the available factor endowments r are estimated by $r = a + bx$ where x is farm size. This information is used in a parametric LP model. The results are translated into a number of farm classes.

[2] Note that in the present study cluster analysis was also used to account for the condition that the farms must have the same LP activities.

For the present study cluster analysis was considered to be the most practical approach to assess the representative farm types. In the first place it enables an elementary grouping. Next, the cluster results provide information for directly constructing the constraints vector and the activity matrix of the LP model for the representative farm types. In the present study data availability was not a major restriction; this was an additional motive for selecting the cluster method.

Using cluster analysis only deals with the reduction of the total population in the basic situation to a number of representative farm types. Considering temporal change and feedback within and between family farms is discussed in Chapter VIII and IX.

2.2 Grouping with cluster analysis

The purpose of cluster analysis is to group and distinguish comparable units, and to separate them from differing units. In cluster analysis a matrix is computed of N objects and V quantitative variables which is broken down into a number of groups of objects based on the similarity or dissimilarity of their scores on the variables. The resulting clusters (groups) are characterized by maximum internal homogeneity and maximum external heterogeneity for the variables used in the cluster procedure.

A preliminary investigation before the actual cluster procedure can be useful to elucidate the interrelated structure of the variables. A suitable approach is to employ Pearson correlation analysis. This enables the number of variables in clustering to be reduced by indicating those with substantial intercorrelations. Another option for data reduction is principal components analysis. By this method the collection of variables is reproduced as a smaller number of factors, without loss of relevant information. This has advantages for the interpretation of the variables used and reduces the computer storage and solution time required for clustering.

In the present study correlation analysis and principal components analysis were applied and the similarity between the objects was calculated based on their scores on the different factors resulting from the principal components analysis.

The next phase was the actual grouping by means of this similarity, which can be measured by several coefficients. Frequently used are coefficients based on the so-called Euclidean distance (D) measuring the similarity of two objects as the linear distance between their respective points in m-dimensional space, where m is equal to the number of factors or variables. Similarity coefficients based on the Euclidean distance are (Hair *et al.*, 1987): (1) the distance D as such or squared, (b) the standardized D, which has the advantage of being unaffected by scale transformations, (c) the weighted D, with the possibility to vary the relative importance of the variables used in clustering and (d) the Mahalanobis distance, which not only incorporates standardization but also adjusts for intercorrelation among the variables.

Apart from the similarity coefficient a cluster procedure as such had to be selected: hierarchical or non-hierarchical clustering or a combination. Non-hierarchical clustering requires a priori information about the number of clusters or the internal homogeneity desired. Though the number of resulting clusters should be limited to facilitate modelling there was no a priori indication of an acceptable internal heterogeneity and therefore non-hierachical clustering was not suitable for the present study. At each step hierarchical methods minimize some functional relations between the objects and groups and indicate the resulting increase in heterogeneity. Several methods exist, differing in the way the heterogeneity is measured. The two methods applied in the study were:

1. Complete Linkage (furthest neighbour), based on a minimax citerium, *i.e.* all objects in a cluster are linked to each other at some maximum distance or by minimum similarity[3].
2. Method of Ward (Error Sum of Squares = E), based on mimimizing the loss of information when reducing the number of clusters.

In the present study both cluster procedures were used, as in the literature no priority is given (Churchill, 1983). After clustering, the F-ratio and T-value were used to ascertain the cluster profiles, *i.e.* the variables that determined the different groups[4].

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[3] The Single Linkage method (nearest neighbour) based on the minimum distance between objects of two clusters is not considered as this algorithm is known to form chains, *i.e.* resulting in a small number, very large clusters. Complete linkage eliminates this snaking problem.

[4] $\text{F-ratio}(C,i) = \dfrac{\text{var}(C,i)}{\text{var}(V,i)}$

where:

V(i)	= variable i in the cluster procedure;
var(C,i)	= variance of V(i) in cluster C;
var(V,i)	= variance of V(i) over all objects

The software used for the calculations was SPSS-X run on a VAX-machine. The data used were from the 1988 farm survey.

3. Identification of the representative farm types

3.1 Data retrieval and procedure

The study area, the North East polder, covers 41 032 hectares and is one of the oldest of the Ysselmeerpolders in the centre of the Netherlands. The soil in the North East polder is predominantly sandy clay, with a low humus (1-3 % organic matter) and a high lime content (more than 1-2 % calcium carbonate). The standard field size is 800 * 300 metres = 24 hectares. Because of these standard fields the farm size classes range from 12 to 48 hectare with steps of 6 hectare. Generally, the smaller farms ($\leq$ 24 hectares) are located on the less heavy soils in the polder. These have a lutum percentage of 12. The larger farms on the more heavy sandy clay soils have an average lutum content of 17 percent (Langen, 1988). The population studied was restricted to 864 specialized arable farms, out of the total of 1486 according to the 1988 farm survey, defined as those with 60 percent or more of their total sfu's[5] in arable farming activities. As the farms of the smallest size classes in the region, *i.e.* 12 and 18 hectares are normally not arable these were excluded in assessing the research population.

Labour supply and farm area were considered as the most important physical resources with regard to arable farming in The North East Polder. Differences in capital resources could not be assessed from the farm survey data nor could

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$$\text{T-value}(C,i) = \frac{x(C,i) - x(i)}{s(i)}$$

where:

x(C,i) = the average of variable i in cluster C;
x(i) = the total average of variable i for all objects;
s(i) = the standard deviation of i

The F-ratio and the T-value are not to be confused with the well known F- and t-test, to indicate significant differences in comparison of group averages.
A high or low T-value (<-1 or > 1) indicates that the specific variable is respectively relatively more or less represented in a specific cluster. Variables with high T-values and extremely low F-ratios are important in the cluster procedure (Pirklt, 1983).

[5] sfu = standard farm unit, measure for the economic size of a farm based on the standard net value added.

these figures be added from other sources. As investments in machinery and buildings are associated with specific crops cultivated, the initial cropping pattern indirectly reflects variation in capital resources. A large share of potatoes is generally associated with potato storage capacity, for instance. The cropping pattern was also assumed to be an indication of the degree of specialization in certain crops. This accounts for the restriction of equal input-output relationships and similar expectations of net revenues.

Apart from farm area and labour supply, the type of soil was considered as a major determinant of farm structure as it is a distinguishing factor regarding technical opportunities. A regional subdivision before clustering is the usual approach (Buckwell and Hazell, 1972). However, the type of soil is not recorded in the annual farm survey. It was obtained retrospectively from the size class of the farms and their cropping patterns.

Additionally the conditions of similar expectations of changes in net returns and constraints and of identical normative innovation adoption had to be considered. Expectations with regard to net returns and constraints, in other words the expected consequences of the EC price policy and of environmental regulations, relate directly to the cropping pattern. For arable farming environmental regulations in particular means restrictions and bans on the use of pesticides. As the use of chemicals for crop protection largely depends on which crops are grown, the cropping pattern is an important indicator for future differences in constraints and returns to expect. Finally, innovations in crop farming pertain also mainly to specific crops (see Chapter IV).

Using the 1988 farm survey 81 variables were selected from the 224 variables available for each farm. The 81 variables were considered to be relevant with regard to the aggregation requirements. To prevent scale influences in clustering the values on the variables were converted into classes ranging from 0-100 or into percentages. The resulting basic collection of variables used in clustering (Kramer, 1990):

1.	V1	: age of the farm manager;
2.	V2 to V30	: labour, measured in percentages contributed by the different categories of workers and whether the farmer has an additional job;
3.	V31 to V34	: livestock, in percentages of total farm sfu;
4.	V35 to V61	: cropping in percentages of total farm sfu;
5.	V62 to V68	: field vegetable production in percentages of total farm sfu;
6.	V69 to V70	: growing of apples and pears in percentages of total farm sfu;
7.	V71 to V73	: bulb growing in percentages of total farm sfu;
8.	V75 to V80	: area of the different categories 4 to 7 in percentages of total farm hectares;
9.	V81	: total farm hectares

Figure V.3 shows the procedure followed in clustering. The first step was to standardize the variables to be used in the calculations. Next the interrelations between the variables were investigated by assessing the Pearson correlation coefficients. This reduced the total number to 80, as two variables were found to be highly correlated. Next a second collection was formed by selecting a restricted number of the 80 variables. This was done because it was feared that a possible redundancy in variables might blur the classification. The categories 1 (age of the farm manager) and 9 (total farm area) were maintained as they cover only one variable. Category 6 (pomiculture) was skipped, as on specialized arable farms this is seldom found. Each of the remaining categories was reduced to the variables most relevant with respect to the aggregation conditions, resulting in a collection of 33 variables.

Principal components analysis of the two collections resulted in two additional data sets consisting of the scores on 36 and 15 factors[6] (see figure V.3). The Complete Linkage method appeared to give no usable results in clustering the 864 farms on any of the four data sets. Consequently, four classifications were retrieved by Ward's method. Table V.1 gives the main results.

[6] The analysis was restricted to variables with eigenvalues of 1 or more, as default in SPPS-X.

Table V.1 Results of the cluster procedures

Classification	Percentage of variance explained[1]	Number of clusters[2]	Percentage of farms not represented[3]
A	31	17 (6)	4.6
B	62	17 (5)	3.5
C	63	22 (14)	3.1
D	63	28 (17)	4.2

[1] Assessed by Total Variance - E / Total Variance, where E = Error Sum of Squares and Total Variance after standardization is equal to the number of farms multiplied by the number of (standardized) variables used in a specific cluster procedure.
[2] In parentheses the number of usable clusters, *i.e.* with 10 or more farms.
[3] The percentage of total farms classified in clusters with less than 10 farms.
Source: (Kramer, 1990)

Classification A was evaluated as unusable because of its low percentage of explained variance and its poor distribution; one of the resulting clusters covered as much as 707 of the 864 farms in the population. The second cluster procedure resulted in a rather indistinct classification, and was rejected for this reason.

A detailed comparison of the two remaining classifications showed that classification D can be seen as a further diversification of C. For instance, in classification D separate clusters were formed of farms with an accent on pig husbandry or on summer barley. This additional information was not very relevant for the aim of the present study. As a small number of clusters was an important advantage in the modelling procedure, classification C was chosen.

Next the cluster averages, expressed in terms of the original farm entities, were calculated for the 14 clusters with more than 10 farm entities selected from classification C. In turn these cluster averages were used to construct the representative linear programming models.

3.2 Defining the representative farm types

As in the present study farm size and the type of soil are considered as main determinants of farm structure (see section V.3.1), the 14 selected clusters were grouped accordingly (table V.2). As pointed out previously, the type of soil was identified retrospectively from the size class and the cropping pattern. The size class was derived from the clusteraverages. The location of the larger farms on the heavier soil type is in accordance with the actual distribution.

Constructing an LP model for each of the clusters presented in table V.2 was rejected after comparing the likely gains in information against additional efforts and costs. It was possible to combine several clusters according to their distribution over size classes and type of soil, as the essential differences were maintained. By doing so and dropping cluster 9 with an accent on cattle and pasture, eight representative farm types were derived. A characterization of the representative farm types was obtained from the cluster profiles, *i.e.* from the variables that determine the different groups. These are mentioned in table V.2.

The 13 clusters used in constructing the resulting 8 representative farm types have a coverage as high as 94% of the total number of 864 arable farms and 38 357 ha (93%) of the total arable area.

3.3 Specification of the representative farm types

The description of the eight farm types is based primarily on the information derived from the results of clustering. This source yielded the information on labour and land, cropping patterns and the age of the farm manager. Subsequently the cluster averages for cropping pattern and labour supply were reviewed by consulting experts. For fixed labour supply this resulted in a reduction of 20 percent. With regard to the major crops in the cropping patterns (wheat, sugarbeet and potato) the cluster averages gave consistent information in accordance with farming reality. For the minor crops the information was scattered. Hence, a selection of these crops for the different farm types was made with the help of experts. The resulting characteristics of the representative farm types are given in table V.3.

4. Discussion

In the cluster process a number of decisions had to be made, such as (1) the number and type of variables to use and whether or not to apply principal components analysis in advance, (2) the choice of a similarity coefficient and (3) the selection of a cluster procedure as such. With regard to the first point foreknowledge about the data and about the criteria for the classification played an important role. Foreknowledge was also important to combine the clusters to farm types and to review the clusterresults concerning labour supply and the minor crops in the cropping pattern. Seen in retrospect, the final result as given in table V.3 might have been found by a procedure purely based on regional experts' insights and foreknowlegde. However, the approach presented here has a mathematical basis which reduces the risk of misclassification compared to a pure subjective approach.

Finally, the resulting eight representative farm types had to be evaluated using the criteria described in section V.2.1. The additional requirements in the case the representative farms are intended for a dynamic analysis are especially interesting, *i.e.* those of similar changes in returns and constraints and of identical rates of adoption of technical innovations. Essentially these conditions mean that all the farms in a category are assumed to be confronted by the same (governmental) regulations as well as with the same technical opportunities and that they are assumed to react to these changes in the same way. In Chapter VIII differences in these reactions among the farms in one category will be explicitly taken into account.

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Table V.2 Assessment of the representative farm types

Size classes (ha)	Representative farm types[a] light sandy clay soil	heavy sandy clay soil
24	Farm type I: Cluster 5 (96) + cluster 8 (45) Accent on horticultural crops	Farm type II: Cluster 3 (42) + cluster 10 (17) Accent on labour input of non-family workers and farmers children, incl. part time farms
30	Farm type III: Cluster 6 (38) + cluster 7 (29 Accent on flowerbulbs Farm type V: Cluster 2 (228) Accent on seed potato	Farm type IV: Cluster 1 (211) + cluster 4 (28) Accent on potato
36		Farm type VI: Cluster 11 (37)
42		Farm type VII: Cluster 12 (11) + cluster 14 (21)
48		Farm type VIII: Cluster 13 (10)

[a] In parentheses the number of farms in each cluster

Fig.V.3 Scheme of the clustering procedure used on the farm survey data from the North East Polder

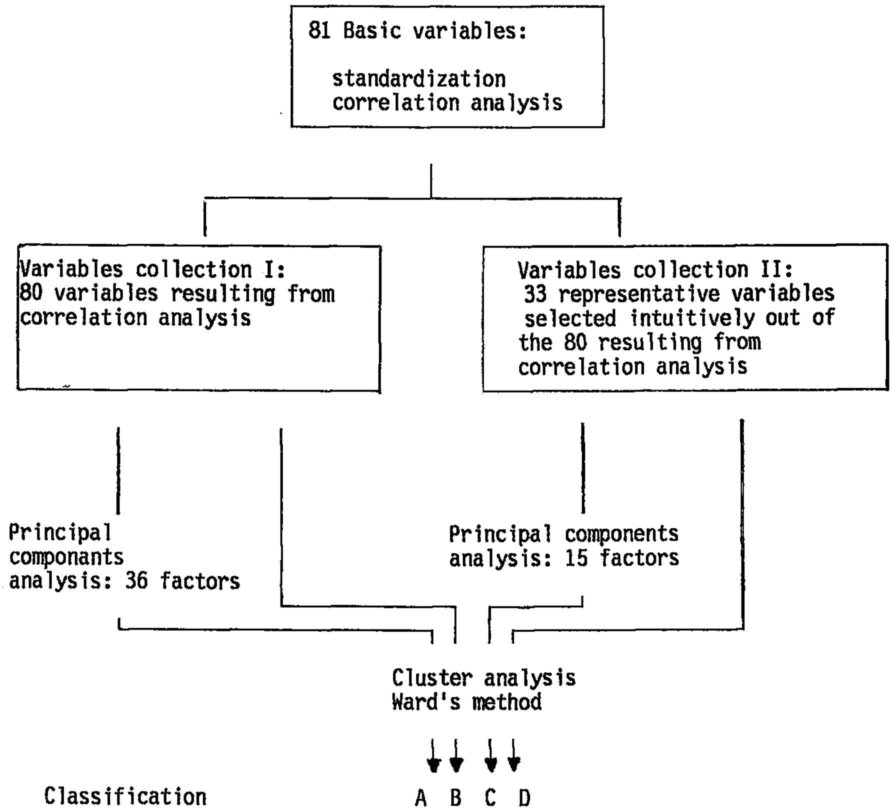

Table V.3 Characteristics of the representative farm types

Characteristic	FARM TYPE I	II	III	IV	V	VI	VII	VIII
1. Number of farms represented[a]	141	59	67	239	228	37	32	10
2. Average farm size (ha)								
- light sandy clay	24		30		30			
- heavy sandy clay		24		30		36	42	48
3. Average farm size in sfu[a]	195	175	240	185	220	240	245	285
4. Labour available (hours/year)								
- Total fixed[a]	3400	3650	3520	2795	3215	3200	3260	3200
- Seasonal labour[a]	1175	290	2980	122	240	280	215	425
Fixed labour in full time equivalents[b]	1.2	1.3	1.3	1.0	1.1	1.1	1.1	1.1
5. Crops in % of ha[b]								
. winter wheat/ summer barley	13.0	19.0	11.5	21.6	15.0	21.0	20.0	24.0
. sugarbeets	21.0	23.0	25.0	25.0	25.0	25.0	26.0	23.0
. seed potato	13.0	10.5	25.0	-	33.3	5.5	12.0	13.5
. potato	20.0	23.0	8.0	33.3	-	22.0	16.5	15.5
. onions	11.0	8.0	11.0	6.7	11.5	18.5	11.0	10.5
. carrots/ chicory	19.0	10.5	3.5	6.7	10.0	4.0	9.5	8.3
. tulips	-	-	5.0	-	-	-	-	-
. other crops	3.0	6.0	11.0	6.7	5.2	4.0	5.0	5.2
6. Age of the farm manager[a]	44	50	46	50	47	44	46	49

[a] Resulting from cluster analysis of 1988 Farm Survey data.
[b] After experts had reviewed the results of clustering.

CHAPTER VI

The LP model in the MIMOSA system: structure and data use[1]

Abstract
In this chapter the LP model of the MIMOSA system is defined and implemented for arable farms in the North East Polder. Data collecting and processing for the environmental component of the environmental economic model, *i.e.* the assessment of emission figures and of the cropping variants, is given particular attention. The verification and validation of the LP model are also discussed.

1. Introduction

In Chapter III the rationale for including an environmental economic LP model in the MIMOSA system to indicate the changes in farm organization induced by technical and institutional developments was explained. This chapter describes the construction of this LP model and how it was implemented for specialized arable farms in the North East Polder, the region that served as a case study. In section VI.2 the requirements and basic structure of the LP model are presented. The processes of obtaining and processing the required data are described in section VI.3[2] and the validation of the model is discussed in section VI.4.

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[1] A summary of the LP model presented here and the experiments concerning a regulatory levy on pesticide use (see Chapter VII), was published in Agricultural Systems (Wossink, De Koeijer and Renkema, 1992). See also De Koeijer and Wossink (1990 and 1992).

[2] All the data for the specification of the LP model relate to the base year 1989, except for section VI.3.3 which covers the elaboration of the technical innovations highlighted in Chapter IV, and as such does not belong to the basic situation. As the innovations (except the change in yield levels) had to be translated into additional LP activities before they could be used in modelling, this information is presented here, with the other LP data.

2. Requirements and basic structure of the LP model

2.1 Background and purpose

In Chapter III the linear programming (LP) technique was chosen as the basis for the MIMOSA system. The LP model indicates the optimal farm organization for different future circumstances regarding agricultural policy, environmental regulations and technical change. In order to be able to consider these external conditions the LP model had to meet certain requirements. This is analysed in the next section.

2.2 Conditions for incorporating the scenarios

To indicate the change in the external conditions of the individual farm six scenarios were drafted (see Chapter IV). All the technical innovations included in the scenarios, except the change in yields, had to be translated into new LP activities. In the modelling we assumed that increases in yields can be fully accounted for by higher net return figures in the objective function. This implies disregarding possible changes in labour requirements and in variable inputs *etc.* that accompagny higher physical productivity levels.

Further, the scenarios developed cover two variants of future agricultural policy and three variants of future environmental regulations. In the price policy variants changes in output prices and in prices of variable and fixed inputs are indicated. Changes in input and output prices are translated into changes in the net return figures in the objective function of the LP model. Changes in the prices of fixed inputs can be reflected by the costs of a compulsory LP activity "fixed charges". Further the price policy variants include set-aside for farm land at different premiums per hectare. This is accounted for by set-aside being one of the production alternatives in the LP model.

The moderate variant of future environmental policy encourages the rapid introduction of new, environmentally-friendlier, production techniques instead of any prohibitions on the use of pesticides or nutrients. In the modelling, this was already covered by including technical innovations. The strict variant was covered in the same way. Additional model requirements became obvious when the standard variant for environmental policy was considered. The standard environmental policy variant follows the objectives of the Ministries of Agriculture and Environmental Affairs: (a) reduction percentages in kg active ingredients for the specific categories of chemicals (nematicides, herbicides *etc.*), (b) maximum concentrations for nitrate and for pesticides in groundwater and (c) a phased change-over to integrated production techniques. To model the foregoing the LP model has to be able to register and, if necessary, limit the use of pesticides and nitrogen and their emission into the environment.

2.3 Basic structure and data needs

The general structure of the model is shown in Appendix VI.A and has the mathematical form of the familiar linear programming problem:

$$\begin{aligned} &\text{Maximize} && \{ Z = c'x \} \\ &\text{subject to} && Ax \leq b \\ &\text{and} && x \geq o \end{aligned}$$

where:

x = vector of activities

c = vector of gross margins or costs per unit of activity

A = matrix of input-output coefficients (technology set)

b = vector of constraints

The activities x out of which the optimal combination is to be chosen by the solution procedure, are shown across the top in Appendix VI.A under six headings: production activities representing different crops and cropping variants per crop, variable operations (own mechanization versus contract work and options for methods of weed and pest control), casual labour, 0/1 activities representing new machinery for pesticide and mechanical crop care, a range of pesticides and an activity representing fixed charges (costs of land, fixed labour, machinery etc.).

To represent the technical opportunities for changing farming practice the LP model covers several activities producing the same product but differing in economic and environmental values. These so-called cropping variants vary with regard to the process variables, i.e. in terms of tillage, N dressing and crop control alternatives, for instance.

The rows of the matrix indicate the type and form of the constraints included: total land, rotation restrictions, supply of fixed and of seasonal labour, several coupling restrictions and the input and discharges of pesticides and nitrogen to groundwater. Thus, each unit (hectare) of a production activity requires inputs represented by the coefficients in its specific column in the matrix. Among the inputs the type and quantity of pesticides (in kg active ingredients) related to a production activity is specified. Hence, the gross margin figures of the production activities do not include the costs of these inputs. These are given separately for every pesticide in guilders per kg of active ingredients and are linked to the production activities by coupling constraints. In this way the LP procedure takes account of listing the total use of pesticides and a levy is easily incorporated by raising the prices of these inputs. The model also registers the input of nitrogen. Here the costs have not been separated, as a levy on N-fertilizer was not considered in the calculations[3].

The figures for the leaching of pesticides and nitrate into the groundwater are added to every cropping variant as quasi-external data. The assessment of the emission figures is described in section 3.2.

The LP model optimizes the net farm result, *i.e.* total returns minus variable and fixed costs, and indicates changes in cropping pattern, labour used, and the selection among variable operations. For a specific scenario s, year t and farm i (see figure III.1) the LP model assesses the optimal farm organization indicating: net farm results, cropping pattern and cropping variants, variable operations, additional investments, labour and tractor hours used and input and emission of pesticides and nitrate.

3. Implementation of the LP model

To represent the specialized arable farms in the North East Polder eight representative farm types were identified from cluster analysis of farm survey data (see Appendix VI.B). The programming models for the eight representative farm types differ with regard to the coefficients for hectares of land; fixed and seasonal labour; cropping pattern; fixed charges and labour requirements because of variation in mechanization. The matrix of a specific representative farm type (base year) contains about 200 activities and circa 210 constraints. The basic farm situation is specified by circa 70 non-zero right-hand-side values, depending on the number of crops in the rotation scheme.

[3] If necessary the model can easily be adapted to include this option.

The base year used when constructing the model was 1989, *i.e.* the information on prices, quantities of inputs and outputs *etc.* relates to that year.

3.1 Basic situation for the production component

3.1.1 Activities and objective function

Production and operational activities

In order to keep the LP matrix within manageable proportions, only the most relevant crops in the region were explicitly specified. The percentages of these crops on the representative farm types were ascertained by means of the cluster averages (see table V.3). The crops selected in this way for the region of the North East Polder include winter wheat, summer barley, sugarbeet, seed potato, ware potato, spring sown onions, seedgrass, carrots, chicory, peas (intended for drying) and tulips. The cluster averages were used to assess the cropping pattern of the basic situation[4]. In this assessment the areas under seed potato were added to those under ware potato, because for seed potato no data were available for constructing cropping variants (see VI.3.3).

The base year data for the crops were obtained from the Handbook for Farm Calculations (PAGV, 1989). Differences in yield level or product prices between the representative farm types because of differences in specialization, for instance, where not considered. The LP model distinguishes a maximum of 6 different operations per crop, namely: land preparation, ploughing, seedbed preparation, planting/sowing, fertilization, crop care and harvesting. In addition there are different methods for several operations, as will be described in section VI.3.3. As the main objective of the study is to indicate the influences of technical innovations and ecological regulations, in combination with different price policies, such a detailed specification is a prerequisite.

Labour requirements per hectare were not modified with respect to the farm size in hectares. The only distinction made concerned less heavy own machinery (OM I) versus heavy own machinery (OM II).

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[4] For the model runs the restrictions reflecting a fixed cropping pattern were replaced by rotation restrictions (see section VI.3.1.2) to allow for modifications with regard to crops and cropping variants.

Most field operations on crops have to be performed during a certain period. To cater for the temporal elements of cropping and resource use, the LP model divides a year into periods of two weeks. The months December, January and March were excluded from modelling, as these are periods with minor labour demands, and therefore do not influence the model results. The requirements relating to these three months, and those for general work, are taken account of by means of the restriction on total annual labour supply.

Fertilization

The data for the fertilization of the standard cropping activities were taken from The Handbook for Farm Calculations (PAGV, 1989), except in the case of potato. It was assumed that in the North East Polder spreading organic manure in autumn before growing potato is the common practice. So, 9 tons of dried chicken manure were the standard for each rotation in the basic situation (De Koeijer and Wossink, 1990). The costs of organic manure are fully ascribed to the potato crop (see option 1 of N-dressing in Appendix VI.C.2).

Objective function

The model optimizes the net farm result, which is the difference between the total of the gross margins of the crops in the optimal plan minus the costs of pesticides, contract work, variable operations, additional investments, seasonal labour and fixed charges[5].

3.1.2 Resources and contraints

Farm-specific resources[6]

As mentioned before the cluster averages were used to retrieve the factor endowments and other characteristics of the eight representative farm types for the base year. Land and labour were distinguished as factor endowments. Machinery and other assets such as buildings were not explicitly modelled, they

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[5] Included in the fixed costs are the costs of : machinery, land, buildings, field roads, farmyard surfacing, drains, store, sorting place and fixed labour (incl. the farmer).

[6] More accurately, the resources specific to the eight representative farm types.

are only distinguishable as part of the fixed charges. Production quotas (for sugarbeet) are accounted for by hectare restrictions.

Land

The holding's total area is the major limiting resource factor. In the North East Polder almost all the land is state-owned. After the land had been reclaimed from the sea, farms ranging from 12 to 48 hectares were offered as the standard field size is 300 x 800 m = 24 hectare. The eight representative farm types presented in Appendix VI.B belong to the size classes between 24 and 48 hectares.

Constraints reflecting the rotation scheme

In order to simulate the effects of changing prices, ecological regulations and innovations on the organization of the individual farm the LP models was formulated without stringent restrictions regarding changes in cropping pattern[7]. Rotation restrictions were imposed to be taken into account for agronomical reasons: (a) a restriction for potato to an intensity of not more than 1:3 and for sugarbeet of 1:4, (b) rootcrops (potato, sugarbeet, onion, carrots and chicory) were restricted to 75 % of the cultivated area, (c) onions to a maximum of 15 % because of price risks, (d) peas to a maximum of 12.5 %, (e) carrots to a maximum of 1 hectare, chicory 2 hectares and together not more than 2 hectares, as contracts are required for these crops and (f) all land is to be used.

In the extended LP model, the new crop chicory for inulin production is subjected to the same restrictions as chicory for vegetable production. Oilflax and hemp are restricted to 33.3 % of the total area, CCM is not limited. In the case of a market-oriented price policy, set-aside is voluntary and a premium per hectare is offered. The production restriction policy makes set aside (without a premium) compulsory for at least 15 % of the area.

For Scenario III and VI, additionally the rotation restrictions regarded in an ecological arable farming system were imposed to the model (Vereijken, 1990): (a) rootcrops are restricted to 50 % and (b) all crops to a maximum of 1:6 except for grass and green manure crops (*i.e.* set-aside in the LP model).

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[7] This directly relates to the normative approach selected for the first phase in the MIMOSA project; *i.e.* comparative static assessment of the optimal adaptations in farm organization regarding changes in external conditions.

Labour

Labour availability was incorporated per period of two weeks to account for periods of peak demand and the engagement of seasonal labour. The amount of fixed labour including the farm manager on each farm is given in Appendix VI.B. It was supposed that the labour supply per full-time farm worker per period is as follows:

- 70 hours: December to February inclusive;
- 80 hours: March, October and November;
- 90 hours: April1, May1 to September1 inclusive;
- 110 hours: April2;
- 120 hours: September2.

The claims for general work were derived from the Handbook for Farm Calculations (PAGV, 1989). This source advises a standard of 400 hours per holding per annum, increasing by 5 to 10 hours per hectare, depending on the disposition and size of the fields. As there are no problems of scattered and small fields in the North East Polder the increase was set at 5 hours per ha. General work can be done during periods without peak demand. Hence, in the model it does not claim labour supply of a particular fortnight, but does ask for part of the total annual labour supply.

Apart from fixed labour there is the option of hiring seasonal labour. This is restricted by a total number of hours per annum, varying per farm type. The upper limit was set arbitrarily at twice the total number of hours actually measured (see table V.3). Seasonal labour can be employed from April until November1, the costs were set at NLG 30 per hour for the base year. Seasonal labour was restricted per period (see Appendix VI.B) to account for the fact that total regional supply is limited. This is important regarding future changes to environmentally-friendlier cropping systems which usually require more manual work.

Equipment and machinery

The machinery resources considered consist of a fixed part and a variable part. The fixed part is equal for every representative farm type. The variable part covers a collection of machinery, with the option of light/heavy own machinery or contract work for every item of equipment. Farm types I to V are considered to be less mechanized, the others have a large stock of machinery. In Appendix VI.D.1 a specification is given. The variable costs of fuel, lubricants *etc.* were set at NLG 8 per tractor hour.

The costs of the operations by contractors are listed in Appendix VI.D.2. In Appendix VI.E those for innovative operations are given and in Appendix VI.C.3. those for the new crops.

Fixed charges

For the standard part of the equipment the fixed costs amount to NLG 25 486 in the basic situation. Fixed costs of additional machinery are given in Appendix VI.D.1. Further differences in total fixed costs charges connected with differences in farm size result from the costs of land, buildings, field roads, farmyard surfacing and drains. It was assumed that seed potato, ware potato and bulbs are put in storage on the farm. The annual costs of a store, per square metre, were set at NLG 62. The total m^2 of storage capacity available on the representative farm types was assessed from the cropping pattern in the base year. One hectare seed potato requires 18 m^2 storage capacity. Potatoes and bulbs require 21 and 35 m^2 per hectare respectively. It was assumed that onions are not stored on the farm. The additional costs of a sorting place are NLG 1 820 per annum. See Appendix VI.D.3.

The costs of labour were set at NLG 60 000 per annum per full-time farm worker.

3.2 Environmental component[8]

3.2.1 Nutrients

The plant nutrients which are of current concern because of their threat to the environment are nitrogen (N), phosphate (P) and potassium (K). The emission of the nutrients was analysed starting with a balance sheet approach. Because the first application of the LP model was to crop production in the North East Polder, the emission figures relate to the conditions of this region. For each crop specified for the representative farm type, a nitrogen balance was assessed. Phosphate and potassium are not applied to individual crops but

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[8] For a detailed description of data collecting and processing and a listing of the sources used see De Koeijer and Wossink, 1990.

as a rotational application. So, for these minerals a balance sheet was derived for the cropping pattern. The method of completing the balance sheet for nitrogen is described below, for phosphate and potassium only the main results are given.

The nitrogen balance sheet covers the following items[9]:

N-balance sheet

supply	discharge
fertilizing	export in harvested products
mineralization	immobilization
atmospheric deposition	leaching
biological N-fixation	denitrification
	evotranspiration

The level of mineral fertilizer dressing was tuned to the nitrogen available from animal manure. The nitrogen in animal manure can be separated into: (a) 50% Nm: the mineral fraction directly available for the crop, (b) 25% Ne: the fraction becoming available during the second year by means of mineralization; (c) 25% Nr: the part becoming available in subsequent years.

In the North East Polder organic manure is given by means of general fertilization in autumn before growing potato, as application on this crop has the highest returns/costs ratio for this specific input. It was assumed that once every three year 9 tons of dried chicken manure is applied per hectare. In total 220 kg N/ha is brought on the farm land via organic manure. In the basic situation the land is not cultivated in winter. The mineral fraction of the organic manure is not taken up by any crop and leaches out in important amounts. The fraction available in the second year, assuming an efficiency of 20 % and an N content of 2.43 %, offers 44 kg N/ha to the potato crop. The fraction available in later years was disregarded.

For the next item on the N-balance sheet, *i.e.* atmospheric deposition of ammonia (NH_4^+) and nitrate (NO_3^-) on the soil the data from the national rainwater survey were used. The N-deposition in the region was computed from this source at 30 kg N/ha/year.

[9] Runoff is not included here, though the emission into surface water by drainage has received recently attention (Doorenbosch, 1991)

Papilionaceous plants, such as peas, are able to fix nitrogen by means of root-nodules. In the N-balance sheet for peas a fixation of 250 kg N/ha is assumed, of which 12 kg N/ha is delivered to the next crop.

For the export of N in harvested products the figures for each crop were taken from the Mineralenboekhouding voor het akkerbouwbedrijf (Mineral accounting system for arable farms) (CLM *et al.*, 1989).

The most important item on the N-balance sheet is nitrogen leaching (mainly as NO_3^- and hardly as NH_4^+ or organic N) to soil horizons more than 1 m below the surface. The extent of this loss depends on various factors, such as: N-supply, soil type, soil use, organic matter content of the soil, ground water level, precipitation *etc.*. Leaching and denitrification are the final entries in the calculation. Denitrification is the process of nitrate conversion into nitrogen gas (and a small amount of laughing gas) by bacterial activity. As 80 per cent of the atmosphere consists of gaseous nitrogen it is harmless for the environment. The bacterial activity only takes place in anaerobic conditions. The most important factors in the denitrification process are the level of groundwater and the organic matter content of the soil. Hence for wet, humous soils the denitrification percentage is relatively high and emission via percolation is less compared with dry soils containing little organic matter.

The evotranspiration of fertilizer N depends on the pH value of the soil. For an alkaline soil, as in the North East Polder about 5 % of fertilizer N is transformed into ammonia by means of evotranspiration. In the case of organic manure the extent of evotranspiration is much more important; when applied in autumn and ploughed in, about 35 % of the mineral fraction (Nm) volatilizes as ammonia. If a cover crop is grown subsequently the ammonia emmision will be up to 95 % of Nm. The dried chicken manure which is standard in the basic situation, contains about 24.3 kg N per ton, of which 50 % is mineral fraction. Evotranspiration comes to $0.5 * 0.35 * 24.3 = 4.25$ kg N per ton manure. If the manure is spread on a cover crop the evotranspiration amounts to 11.54 kg N per ton.

With some crops the discharge of nitrogen exceeds the supply, because of net mineralization, *i.e.* mobilization of N and uptake by the crops. This item was added to the balance sheets of the relevant crops (chicory, for instance). In the case of net mineralization the preceding crops in the rotation must have resulted in net immobilization of nitrogen. This, however, is ignored in the calculations.

To assess the N leaching the difference between N supply from fertilizer and atmospheric deposition and the discharge by means of crop uptake and evotranspiration was calculated as described above. According to the information sources used 80 % of this surplus is denitrified in the conditions prevailing in the North East Polder (Breeuwsma *et al.*, 1987). The remainder, *i.e.* 20 % was assumed to be discharged into the groundwater where it enhanced the nitrate concentration. The resulting figures on nitrate leaching figures for the standard cropping activities are presented in Appendix VI.C.1. In formula:

N leaching to groundwater below 1 metre depth = 0.2 * (atmospheric deposition + N-input by fertilizer and manure - crop uptake - evotranspiration)

$$NO3^- \text{ in g/l} = \frac{62}{14} * \frac{\text{kg N leaching to groundwater}}{10 * \text{precipitation surplus in mm/year}}$$

where:

atmospheric deposition	= 30 kg N per ha/year
evotranspiration: N fertilizer	= 5 %
N manure	= 35 % of Nm without cover crop 95 % of Nm with cover crop
precipitation surplus	= 400 mm /year

For the next nutrient, phosphate, the balance sheets covers the following figures in kg per hectare:

Phosphate balance

supply			discharge	
fertilizing	chemical	13	export by harvested products	60
	manure	85	leaching	2
atmospheric deposition		2	surface run off	-
			addition to soil stocks	38
		100		100

The natural leaching of phosphate for farmland in the Netherlands is 2 kg P_2O_5 per ha per annum independent of the supply level. This amount results in a concentration of 0.6 mg P_2O_5 per liter percolation water. The extent of additional leaching depends on the phosphate saturation level of the farmland in question. As indicated by the completed balance sheet above, each year about 38 kg P_2O_5 is added to the stocks of phosphate in the soil. For the North East Polder the amount that can still be added to the soil stock without exceeding the buffer capacity has been estimated to range from 1.4 to 10.4 tonnes P_2O_5 per hectare depending on the information source used. Additional leaching because of soil saturation is therefore not expected within at least the next 40 years. Moreover as fertilization practices become more sophisticated the moment of the saturation will be postponed. For this reason the phosphate emission was not considered in the model calculations.

In a comparable manner the balance sheet concerning potassium (K) was retrieved:

K-balance

supply			discharge	
fertilizing	chemical	83	export in harvested	
	organic	67	products	60
atmospheric deposition		4	leaching	-
discharge from soil			surface runoff	-
stock		6		
		160		160

Difference between soil types have important implications for the leaching of potassium. In the case of a clay soil, potassium can be adsorbed by the clay minerals. As long as the binding capacity of the clay soil is not exceeded, leaching will be of minor importance. In part of the region considered the soil is of a less heavy sandy clay type. This means that for K fertilization in autumn, leaching will amount to about 10 %. At this leaching percentage, applying organic manure which contains 67 kg K_2O results in a concentration of 1.9 mg K_2O/l in the groundwater. This is so far below the limit for drinking water (14.4 mg K_2O/l) that the emission of potassium was omitted in further calculations.

After examining the balance sheets for nitrogen, phosphorus and potassium, only the nitrogen emission to the groundwater was explicitly considered in modelling. In Appendix VI.C.1 the N surplus is given for the standard cropping activities, with the nitrate concentration in the upper groundwater.

3.2.2 Pesticides

The emission of pesticides can be subdivided into emission into the groundwater, surface water (drift) and into the air (evaporation). Apart from the environmental damage caused by the actual agricultural use, additional harm can be caused by cleansing the spraying equipment and by passing residues and packing materials. None of these additional pollution sources were analysed in the present study. Further, evaporation was not considered in the model calculations, though it is known that (especially with gaseous nematicides) the content of the pesticides in the air can be considerable and they can diffuse widely. More research on this topic is needed. So far there is not enough consistent information available on the subject to enable a quantification (De Koeijer and Wossink, 1990).

The extent of the emission of pesticides by percolation depends mainly on soil adsorption and the time taken for the pesticide to break down. The latter is related to temperature, percentage of moisture in the soil and micro bacterial activity, for instance. We used the model approach developed by Van der Linden and Boesten (1989) to quantify the emission from percolation into the upper groundwater (*i.e.* between 1 and 2 metres depth). The input variables of this model are the adsorption coefficient per weight unit of organic matter (the so-called K_{om}) and the half life of a biocide (DT_{50}). The K_{om} and DT_{50} values of the biocides were derived from a report of "De Werkgroep Bestrijdingsmiddelen in grondwater naar aanleiding van de notitie Milieucriteria" (Van den Berg, 1990; Brouwer, 1990). The input data for biocides in the various model crops were taken from the Handbook for Farm Calculations (PAGV, 1989).

In line with the tenets of environmental policy, assuming the worst circumstances, the emission value for a sandy, wet non-humous soil was used when running the model, even though on clay soil the real emission via percolation of pesticides will be less. See Appendix V.C.1 for the emission figures of the standard cropping variants for both a sandy and a clay soil.

3.2.3 Integration into the LP model

In the LP model each production activity was ascribed specific quantities and types of pesticides and a certain N-dressing. The concentration in the groundwater that results from these inputs was added to every cropping activity as quasi-external data. Emission limits could not be added as additional restrictions to the RHS colums because in this study the maximum concentrations for nitrate and pesticides (see tables IV.3 and IV.4) were assumed to refer to the upper groundwater. The emmision limits were accounted for per hectare of every crop, therefore. Hence, additional activities were formulated, that offer a specific maximum discharge, and linked to each cropping activity. See Scheme VI.1.

3.3 Cropping variants and alternative operation methods

Pesticide and mineral use depends not only on the crops grown, but also on the cultivation method. Therefore in the extended LP model, environmental economic cropping variants and fallow land were added to the standard production activities. With reference to section VI.3.1 it can be said that the cropping variants form an extension to the "technology set", representing the latest findings of cropping research. In the following an overview is presented of the variants for potato[10], sugarbeet, winter wheat, onion, peas and carrots.

The cropping variants range from the intensive to the ecological production system, representing a discrete set of production alternatives per crop which cover both: (a) successive points on non-linear production functions (the variants for winterwheat), and (b) points on different production functions using different technology, *i.e.* another mix of process variables such as N dressing, variety *etc.*. By means of these alternatives it is possible to assess the possibilities of adapting to price changes and environmental restrictions.

3.3.1 Potato

Potato is considered to be the main crop in Dutch arable farming because of its contribution to farmers' income. An analysis of the environmental quality of current farming practice (see De Koeijer and Wossink, 1990) showed, however, that the input and emission of nitrogen and pesticides is particularly high for this crop. Hence, in assessing alternatives for cropping practice the crop potato was given special attention.

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[10]An extended overview of the approach in deriving the cropping variants for potato is given in De Koeijer and Wossink (1992).

Scheme VI.1 Structure of limits to N discharge in the LP model[1]

	POT1	POT2	POT3_BI	POT3_PSR	POT4_BI	POT4_PRS	.. ..	[UITS1-3]	POT7	POT8	.. ..	[UITS1-4]	.. ..	NPOT1	NPOT3	NPOT3	Right-hand Side MAX	MIN	FIX
..																			
..																			
cUITSL_POT								1.00				1.00							1.00
cROT1-3	1.0	1.0	1.0	1.0	1.0	1.0		-99.00									0.00		
cROT1-4									1.0	1.0	.. ..	-99.00					0.00		
..																			
..																			
..																			
..																			
cPOT3			1.0	-1.0													0.00		
cPOT4					1.0	-1.0											0.00		
..																			
..																			
cNF_POT	1.0	1.0	1.0	1.0	1.0	1.0			1.0	1.0				-1.0	-1.0	-1.0	0.00		
NLE_POTeg								-476.00[2]				-413.00[2]		50.00[3]	9.00[3]	10.00[3]	0.00		

[1] For the crop potato the 1/0 rotation selection activities, *i.e.* [UITS1-3] and [UITS1-4] in this scheme, were used to limit N discharge. Note that only the activities POT1 to POT8 are given. An overview of all cropping variants is given in Appendix VI.C.2.

[2] The N discharge limit formulated by the EC translated into kg N in the case of 10 ha potato (1:3 rotation) and 7.5 ha potato (1:4 rotation).

[3] The nitrate leaching in kg N per ha of the optional N dressing methods for potato (see Appendix VI.C.2).

cUITSL_POT = rotation selection constraint
cROT1-3 = cropping variant selection constraint
cNF_POT = N dressing potato selection constraint
NLE_POTeg = N discharge limit European Community 50 milligram NO_3^-/l or 47.6 kg N per ha in the case of a potato crop.

The cropping variants for potato were developed in close collaboration with CABO-DLO (DLO-Centre for Agrobiological Research) in Wageningen. In this analysis seven process variables were considered (De Buck, 1991; Schans, 1990):

Process variables for potato and number of alternatives

-rotation	4*
-variety	2*
-nematode control (fumigation)	5*
-N-dressing method	3*
-late blight control	2*
-haulm killing	2*
-weed control	3*

With these process variables it is possible to create 4*2*3*5*2*2*3 = 1440 cropping variants for potatoes alone. Putting all those variants in the model would make it much too unwieldy, the more so because the other crops have many variants too. To reduce this number, a selected number of combinations of the first three process variables were chosen. Some of the possible combinations are not logical; for instance soil fumigation and a rotation of 5 years, so the number of combinations could be limited further. Eventually 23 cropping variants for potatoes were defined using the first three process variables (see Appendix VI.C.2).

The alternatives to the process variables: method of N-dressing, haulm killing, late blight control and weed control were assumed to have no influence on the yield of potatoes. In consequence of this, these variables were built into the model as separate activities that are coupled to the cropping variants (see table VI.1). In total there were 23+3+2+2+3 = 33 activities which means that 23*3*2*2*3 = 828 combinations for potato can be chosen by the model. Hence, the extended model is considerably smaller than it would have been if all process variables had been put into cropping variants.

3.3.2 Other crops

Integrated cropping variants for wheat, sugarbeet, onion, peas and carrots were subsequently retrieved from information of the OBS experimental station at Nagele, where conventional and environmentally-friendlier farming systems have been compared since 1979. The data obtained had to be modified; the output prices and the input prices were translated into base year (1989) values (PAGV, 1989) and the costs of rotation manuring was divided over the crops. The yields in kilograms were related to 1985-1989 averages (Janssens, 1991), thus adjusting for weather influences. Since yields in practice are usually inferior to those from an experimental farm, they were multiplied by the fraction obtained by dividing the figure from "Handbook for Farm Calculation 89-90" by the figure "conventional farming system OBS". The data from OBS were used for the quantities of inputs; prices were obtained from the Handbook. Note that by following this method, the pesticide use of the integrated variants was related to the expertise and knowledge prevalent on an experimental farm. Table VI.2 presents a summary of the main characteristics of the resulting integrated cropping variants per crop.

For the ecological variants the report on "Sustainable farming in Flevoland" (Van Hall, 1991) was the main source[11]. Here too, the yields and costs had to be translated into 1989 values. The time requirements of the ecological practices were not available. They were estimated by replacing the tractor hours for pesticide crop care by those for mechanical methods and additional manual work. The results are in line with other information (Antuma *et al.*, 1990 and sources mentioned). Table VI.2 gives an overview.

For winter wheat several extra variants in addition to the integrated and ecological ones were distinguished at different stages of fertilization, both with and without using fungicides and the growth regulating pesticide CCC (Besseling *et al.*, 1988, and sources mentioned). Table VI.3 presents an overview.

In the case of sugarbeet, herbicide use can be cut down. Variants with different spraying techniques and mechanical weed control were formulated for this purpose, see table VI.4 (Marcelis, 1987; Van Schaijik *et al.*, 1986).

3.3.3 Additional investments and contract work operations

To account for the operation methods of the environmentally-friendlier cropping variants usually being different, a number of new machines and some new contract work activities were added to the model. The new machinery is listed in Appendix VI.E with the annual costs for the base year.

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[11] Information from the OBS experimental station was not used here. The BD (or anthroposophic) farming system that is being analysed there, is also based on the principle of not using any pesticides or fertilizers. This system, however, combines arable farming with animal husbandry.

The innovations considered provide for a reduction in the input quantities and costs of biocides. On the other hand, labour and tractor hours increase when the new machinery is adopted. Both effects were accounted for by linking the investments to specific cropping variants using the machinery. Some of the variable operations in the innovative variants can also be done by means of contractors. The costs of these optional activities are also given in Appendix VI.E.

3.4 New crops

One of the technical innovations presented in Chapter IV was the introduction of new crops. Four crops were selected: (1) hemp (*Cannabis sativa*) for paper and rope production, (2) oilflax (*Linum usitassimum*) for the production of erucic acid, (3) Corn Cob Mix (*Zea mays*) for fodder and (4) chicory (*Cichorium intybus*) for the extraction of liquid sweeteners. For each of these crops the main model input is given in table VI.5, details are given in Appendix VI.C.3. Lack of data ruled out formulation of other, environmentally-friendlier, cropping variants. Note that the information used for table VI.5 is provisional. The gross margins in particular must be seen as indicative.

Table VI.1 Variable operations for N-dressing, weed control, haulm killing and late blight control in potato[1]

Operation	Method	Pesticides kg a.i./ha	Labour hours/ha[2]
N-dressing			
option 1	Standard: 210 kg N fertilizer and 44 kg N with organic manure per ha		0.6
option 2	"Neeteson": fertilizer only[3] 185 kg N per ha		0.6
option 3	Split fertilization supported by petiole analysis: 188 kg N per ha		0.8
Weed control			
option 1	Standard: 1 kg/ha metribuzin total field	0.7	2.5
option 2	Under leaf spraying[4]: 0.5 kg/ha metribuzin	0.35	3.0
option 3	Late ridging + hoeing: 0.125 kg/ha metribuzin[5]	0.0875	3.0
Haulm killing			
option 1	Standard: 5 l/ha diquat	1.0	0.5
option 2	Mechanical[6]		2.8
Late blight control			
option 1	Standard: Bintje 27 l/ha maneb+fentin	11.88	6.0
	PSR variety 20.25 l/ha maneb+fentin	8.91	4.5
option 2	Bintje: 14 l/ha maneb 80 % + 4.5 l/ha maneb+fentin	13.18	4.5
	PSR variety:10 l/ha maneb 80 % + 2.25 l maneb+fentin	8.99	3.0

[1] See Appendix VI.C.2 for a specification of the costs.
[2] Excl. the operations by contractors.
[3] Yield reduction of 750 kg/ha compared with option 1; this is accounted for in the costs.
[4] In the case of own mechanization row spraying accessories are required: annual costs NLG 612, the option of contract labour is also offered at NLG 70 per ha.
[5] The 0.125 kg metribuzin reflect the risk of unsuccessful mechanical weed control; it is assumed that over four years a pesticide treatment is required once. Investment in earther/ridge hoe, annual costs NLG 756.
[6] Investment in potato haulm shredder, annual costs NLG 2 415.

Source: De Buck (1991) based on information from the Centre for Agrobiological Research (CABO-DLO) in Wageningen. See also Schans (1990).

Table VI.2 Standard, integrated and ecological cropping variants for wheat, sugarbeet, onion, peas and carrots, base year values

Crop	yield tons/ha	Gross margin[1] NLG/ha	Pesticides in kg a.i. per ha F	H	I	D	Total	Labour hours[2]	N kg/ha
Standard:									
Wheat	7.5	2769/2358	2.47	3.14	0.12	-	5.74	14.1	160
Sugarbeet	61.0	4961/4616	3.36	-	0.38	-	4.01	29.2	140
Onion	51.0	5060/4143	10.05	5.60	0.75	2.25	18.65	48.3	360
Peas	4.9	2618/2351	0.50	2.47	0.75	-	3.72	14.1	20
Carrots	75.0	6371/4641	1.50	2.40	7.09	0.20	11.10	16.6	16
Chicory	..[3]	8283/7932	-	1.50	0.60	-	2.10	35.0	-
Integrated:									
Wheat	6.6	2446/2293	1.53	-	-	-	1.53	12.5	140
Sugarbeet	53.5	4295/4018	-	1.80	-	-	1.80	37.7	93
Onion	38.8	3477/2663	3.42	2.50	-	2.25	8.17	63.9	32
Peas	4.2	2142/1811	0.15	2.15	0.21	-	2.50	16.4	-
Carrots	68.3	5807/5483	-	0.77	1.64	-	2.38	20.8	-
Ecological:									
Wheat	5.5	1866	-	-	-	-	-	8.1	-
Sugarbeet	50.0	3942	-	-	-	-	-	77.7	142.5
Onions	25.0	2158	-	-	-	-	-	113.3	-
Peas	3.5	1862	-	-	-	-	-	23.9	-
Carrots	45.0	4050	-	-	-	-	-	96.3	-
Chicory	..[3]	5640	-	-	-	-	-	99.5	-

[1] The first figure indicates the gross margin in model excl. the costs of pesticides. The second figure was calculated accounting for the costs of pesticides.

[2] Excl. the operations by contractors.

[3] The yield of chicory is measured in chicons per ha not in tons.

F = Fungicides; H = Herbicides, incl. products for haulm killing and growth regulation;
I = Insecticides, D = Others

Source: Verschueren, 1991

Table VI.3 Overview of the additional wheat cropping variants, base year values

Variant	N-dose kg/ha	Freq. of N-dressing	Yield in tons/ha cereal	straw	Gross margins in model NLG/ha per ha	Labour hours per ha
With fungicides and pesticide growth control[1]						
WT160 =standard	160	3 times	7.5	4.7	2769	14.1
WT130	130	3 times	7.43	4.7	2776	14.1
WT100	100	2 times	7.29	4.	2774	13.5
WT50	50	1 time	6.76	4.2	2569	12.9
WT20	20	1 time	6.27	3.9	2390	12.9
WT0	0	-	5.88	3.7	2245	12.3
Without fungicides and pesticide growth control[2]						
WTF160	160	3 times	6.48	4.1	2327	13.1
WTF130	130	3 times	6.72	4.2	2462	13.1
WTF100	100	2 times	6.88	4.3	2566	12.5
WTF50	50	1 time	6.60	4.1	2499	11.9
WTF20	20	1 time	6.11	3.8	2320	11.9
WTF0	0	-	5.74	3.6	2183	11.3

[1] Pesticide use 7.74 kg a.i. per ha
[2] Pesticide use 4.36 kg a.i. per ha

Source: Verschueren, 1991

Table VI.4 Overview of alternatives for weed control in sugarbeet, base year values[1]

Variant	Pesticide weed control pre emergence	post emergence	Freq. of weed hoeing mechanical	Manual weeding hours/ha	Herbicides per hectare NLG	kg a.i.
SB1	total	total	2 times	15	520	5.6
SB2= standard	total	row	2 times	15	345	4.0
SB3	row	row	3 times	15	230	2.4
SB4	total	---	3 times	30	229	3.0
SB5	---	row	3 times	30	153	1.4
SB6	50 %	LD	2 times	15	347	3.2

total = spraying total field (0.5 hours/ha)
row = row spraying (1.0 hours/ha)
LD = low dosage system, treatments repeated (2 to 3 times) with a reduced dose of herbicides plus mineral oil

[1] The gross margin in model is NLG 4 961 and the N-dose is 140 kg/ha for all of these sugarbeet variants.

Source: Verschueren, 1991

Table VI.5 Cropping variants for new crops, base year values

Crop	yield tons/ha	Gross margins[1] NLG/ha	Pesticides in kg a.i. per ha F	H	I	D	Total	Labour hours/ha[2]
Hemp	9.6	1129/1044	0.50	-	-	-	0.50	7.40
Oilflax	2.0	1422/1105	-	1.73	0.75	2.08	4.55	11.20
Chicory (inulin)	55.0	4724/4474	-	2.70	-	-	2.70	42.90
Corn Cob Mix (CCM)	10.0 d.m.	1670/1560	-	2.20	-	1.98	4.18	7.40

[1] The first figure indicates the gross margin in model excl. the costs of pesticides.
The second figure is calculated accounting for the costs of pesticides.
[2] Excl. the operations by contractors.

Source: Wolters, 1991

3.5 The software

The software selected for the LP model in the MIMOSA system is XA-87, developed for solving linear programming problems on a personal computer. The XA system derives the LP problem formulation from LOTUS 123 files. This enables the advantages of the spreadsheet program (such as formulas, cell references) to be used. Furthermore, LOTUS was selected for its databank management function.

XA-87 includes a matrix generator option, called LTS (Look To Spreadsheet). An LTS program reads and combines spreadsheet files, covering all or part of the problem to be solved. By using LOTUS to provide the input the normal step of translating the LP solver input into MPS files can be omitted, as the XA system can read a problem formulation directly from LOTUS 123[12]. The XA program was run on a 80386 PC with co-processor.

Separate files were constructed for: (a) the production component as described in section 3.1, (b) the cropping variants for potato, (c) the cropping variants for the other crops, (d) the new crops, (e) the environmental component (the range of pesticides and coupling restrictions) and (f) the integration of the price policy variants and yield increase. Additional investments and contract operations were included for the files b to d. File f consists of

[12] This only applies to LOTUS 123, Symphony or compatible spreadsheets

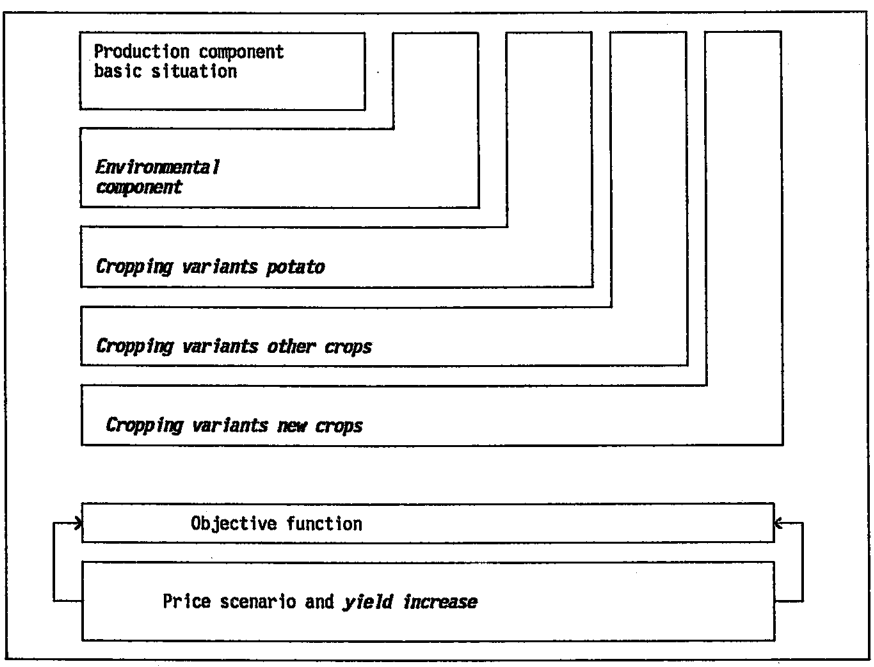
spreadsheet formulas and was added below the objective function in the LP matrix. For a market-oriented price policy and t = 2005 the formula for the gross margin of the cropping variants of wheat, for example, is as follows (see tables IV.2A and 2.B):

$$\text{gross margin year 2005} = \{\text{gross output base year} * \{[100 - (4.5\text{-}0.9)]/100\}^{(2005-1989)}\} - \{\text{variable costs base year} * [(100 - 0.4)/100]^{(2005-1989)}\}$$

Note that the variable costs in this formula cover only seed material, fertilization and sundries. The other variable costs such as contract work, tractor hours and pesticides are specified separately in the LP model.

Scheme VI.2 represents the combination of the different files by the LTS program. The parts indicated in bold italics represent technical change.

Scheme VI.2 Combining the different files by the LTS programm



4. Model validation

4.1 General concept

Validation is an important stage in model developing and may be described as corroborating the model with the part of real world it is intended to represent. Dent and Blackie (1979) prefer the term evaluation instead of validation as they distinguish between a verification process and a validation process. Verification then covers checking the simulation model for logical consistency and checking the data input to the model for validity. After verification, the validation procedure involves comparing the performance of the model either with recorded data for the system under study or with a subjective judgement of what the output should be. In case of the LP model presented here, validation by empirical testing was only possible for the base year situation. According to Hazell and Norton (1986) validation of an LP model involves: (a) comparing the model's outcome with the actual situation, (b) improving the LP model in the light of this comparison and (c) judging the LP model's reliability for its stated purposes, including its limitations. Rijk (1989) follows Hazell and Norton but stresses the importance of data verification before model testing.

Validation of the LP model in the present study combined the aspects mentioned above, and included: (a) verification of data and model structure and (b) matching the model outcomes for the base year situation against the actual situation (explicatory testing).

4.2 Verification

Verification and reconciliation of model structure and of the data used are important prior to testing the model's practical use. This process started during the development of the LP model and through the assessment of the representative farm types (Chapter V).

As the LP model combines a production and an environmental component, the data verification and the review of the variables and parameters of the model were done by consulting two types of experts: (a) extension officers in the North East Polder and (b) agronomists, soil scientists and environmental experts.

As indicated in Chapter V the information gathered from cluster analysis on farm survey data of the farms in the population, was subjected to an evaluation by the first category of experts. The cropping patterns and fixed labour supply of the representative farm types were modified in the light of this.

Data on the fixed costs of the farm types could not be retrieved from the farm survey. The inventory given in Appendix VI.D.3 resulted from other studies (Groot, 1989) and experts' insights. The standards for the replacement values of machinery given in the Handbook for Farm Calculations (PAGV, 1989) were judged as too high. According to the experts, in the North East Polder the replacement value of many machines will be the second-hand value (Noordam, 1991). Hence, the annual costs of the machines were reduced as these are formulated in percentages of the replacement value. Note that this is discutable because the maintenance costs of the second hand machinery might be higher. Note further that the values of the components of the fixed costs such as the farm machinery are less important than the data used in assessing the gross margin figures and the other objective function coefficients. The items of equipment the farm owns, determine which operations are performed by contractors and are therefore more relevant than the costs of the own machinery. The computations in Chapter VII focus on the cropping plan, cropping technique selected and on the relative changes in net farm result. Hence, consistency of data input for the fixed costs was emphasized rather than the absolute values.

Verification of variables and parameters was particularly important for the environmental part of the model because this is a new element in modelling of farm economics. We found an ongoing dialogue with agronomists and environmental experts to be very important when developing this part of the model. The detailed information required for the determination of the emission figures and in particular for the assessment of the cropping variants was obtainable only by consulting the researcher(s) concerned. In this manner variables and data were implicitly verified before being integrated in the LP model.

4.3 Explicatory testing

In the next step in the validation of the LP model, farm type IV was selected for comparing the model outcomes of the base year run with the actual situation. The values of the input data are presented in Appendix VI.B. In the first run the cropping pattern was defined by fixing the numbers of hectares of the different crops according to Appendix VI.B. In later calculations these constraints were replaced by the rotation restrictions described in section VI.3.1.2, allowing for optimization of the cropping pattern. In both instances only standard cropping activities were included. In table VI.5 the main model results for the fixed cropping pattern and for the optimal cropping pattern are compared.

The optimal cropping pattern differs from the fixed cropping pattern as follows. The maximal acceptable area under potato is chosen, namely 10 hectares (the total area available for arable crops in farm type IV is 30 hectares). And the maximum area sugarbeet is chosen (25 % of the total area). The number of hectares of cereals remaines unchanged, but wheat substitutes for barley. This change can be explained by the fact that wheat has a higher gross margin and barley is usually only sown if to replace wheat killed by frost. Among the other crops chicory is chosen instead of seedgrass, peas and carrots. The fixed cropping pattern was based on cluster averages and therefore included more crops. The practical farmer will make a selection as in the optimal cropping pattern. For seedgrass the change is also due to lower gross margins as the EC premium decreased between 1988 and 1989/'90.

The change in the cropping pattern influences the total amount of pesticide used. The input of both nematicides and fungicides increases because of the extra hectare of potato. The reduction in the input of herbicides can be ascribed mainly to the share of sugarbeet which is reduced in the optimal plan. In total a larger amount of pesticides is used.

Further there is an increase in hours of labour required to realize the optimal plan. Seasonal labour, however, is not needed; in neither period is the fixed labour a limiting factor. The net farm result increased by NLG 5 441 by the optimization.

The model outcomes regarding cropping pattern and labour use match the statistical information and experts' views well. It is generally accepted, for instance, that there is a significant oversupply of fixed labour on an arable farm of type IV in the North East Polder. The net farm result could not be compared directly with other statistical information, because in the statistical reviews the North East Polder is part of the larger central clay region. The average net farm result of the larger farms in that region (45 ha on average) was minus NLG 39 600 over 1985/'86 to 1988/'89 (LEI, 1990). For Farm type IV (30 ha) it can be expected to be lower due to scale disadvantages. Further the results were in line with the information of the major regional agricultural

Table VI.6 Main model outcomes farm type IV, base year situation

Farm type IV	Only standard cropping variants included	
	Fixed cropping pattern	Optimal cropping pattern
Cropping pattern (ha)		
Wheat	6.0	7.5
Summerbarly	1.5	-
Sugarbeet	9.0	7.5
Potato	9.0	10.0
Onions	3.0	3.0
Carrots	0.3	-
Chicory (chicons)	0.45	2.0
Peas	0.3	-
Seedgrass	0.45	-
Total	30.0	30.0
Labour used (hours/year)		
Fixed	895	919
Seasonal	0	0
Tractor hours	555	571
Net farm result (NLG/year)	- 64 170	- 58 729
Input of pesticides (kg a.i.)[a]		
Nematicides	1 566.00	1 740.00
Herbicides	98.72	95.84
Fungicides	152.71	167.51
Insecticides	13.58	12.20
Other	12.21	13.50
Total	1 843.22	2 029.05

[a] See Appendix VI.B for a listing per crop

Source: Verschueren, 1991

bookkeeping organization (Stormink, 1992) and with the LP outcomes[13] in Bos and Krikke (1991) for arable farms in the North Eastern Polder. These LP outcomes show net farms results of - NLG 65 000 to - NLG 94 400 for the 24 ha farm and - NLG 20 500 to - NLG 55 000 for the 36 ha farm. Note finally that the model computations in Chapter VII aim at assessing the relative changes in financial results. For the model applications the net farm result of the basic situation does not have to agree completely with the statistics. Regarding the difference, the fixed costs are important. As pointed out before the fixed costs were not analysed thoroughly.

Regarding pesticide use the data from LEI for the central clay region only cover the total costs. An analysis of inputs in kg a.i. was started recently but no results are available yet (Kavelaars, 1992).

5. Discussion

Here we will discuss construction of the model and its data use, *i.e.* the components presented in Scheme VI.2 and their contents. The model's potential for application and priorities for further research are discussed in Chapter VII.

Regarding the basic situation, the most striking is the supply of family labour. As shown by the first model computations only part of this labour is used (see table VI.6). In general there is a tendency for farmers to overestimate labour input when questioned for the annual farm Survey (Noordam, 1991). This is why the cluster results on labour supply were corrected inline with experts' advice before inputting the results into the model. When reducing family labour input further, the net farm result will improve. Family income associated with the model results, however, remains unchanged. The model result that only part of the labour supply is used can have different explanations: (a) the assumption that 1 full-time worker works 2030 hours per year is incorrect, (b) general work on the farms requires more than the 400 hours/year assumed in the model, (c) too many operations are assigned to contractors in the model and in reality more work is done in cooperation with neighbours.

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[13] For 1:4 potato cropping with zero or low yield pressure from the eelworm *Paratrichorus teres.*

The fixed costs of machinery, buildings *etc.* are important with regard to family income. As the present study focused on relative changes in income these costs were not analysed in detail and should be seen as indicative.

A further explanation of the low net farm result is in the relative extensive cropping pattern. As shown in Chapter V, however, farms of 30 hectares that grow more intensive crops such as bulbs and seed potato account for just 12 % of the population (farm category III) whereas farm category IV covers 27 %. Further the basic situation assumes 1:3 potato growing by cropping variant 1, *i.e.* 100 % Bintje and soil fumigation every rotation. In reality a small part of the 239 units represented by farm type IV had another situation in 1988/'89. They might have grown cropping variant 2, which implies soil fumigation every second rotation, and the most innovative farmers might have used one of the other new cropping variants for potato (see Appendix VI.C.2). This issue will be discussed in Chapter VIII on innovation adoption. In further research attention should be given to differences in gross margin levels between farmers. Those specialized in growing ware potato might realize higher physical output levels and higher prices than assumed in the present study.

The most important fact to emerge from the implementation of the model components of Scheme VI.2 is the requirement for collaboration between different disciplines. To complete the LOTUS files of the cropping variants and the environmental component it was necessary to consult research agronomists, extension officers and environmental experts.

With regard to defining the cropping variants for potato there was a difficulty in selecting one PSR variety, because we do not know which of the varieties currently available will be common in future. The varieties with the highest gross margins are licensed and are not available to all farmers. To overcome the problem an average PSR variety was made up. This drastically reduced the number of cropping variants considered and the results became more generally interpretable (Van Loon, 1991). The use of an average, however, may result in some degree of overestimation of the performance of PSR varieties.

Further the price of seed material of PSR varieties and for the crop as such were difficult to assess. This market is still small and controlled by specific traders, moreover the potato processing industry prefers cv. Bintje. It is assumed that both effects will become less important in future. Experts agreed that NLG 0.16 per kg should be used as the product price for Bintje and NLG 0.15 for the PSR variety. Note that for the other crops the same product price was selected for all cropping variants on the assumption that the higher market prices prevailing for ecological products will disappear rapidly as soon as the ecological variants become common practice.

Not accounted for in the assessment of the cropping variants for potato is the development of new pathotypes from the present population in the soil. It was assumed that the current status can be safeguarded by growing 50 % Bintje and 50 % PSR variety in combination with intensive soil sampling and treatment of infected spots if necessary. However, *Rhizoctonia solani* and *Verticilium dahliae* might become important (Struik, 1992). A 1:4 rotation of potato would give better opportunities to control these soilborne diseases. Other comparable problems arising from abstining from soil fumigation might be caused by *Paratrichodorus teres* (an eelworm) and sugarbeet eelworms (Bos and Krikke, 1991).

Regarding the effect of rotation frequency on the yield of potato it is known that there are differences between the varieties. Information on the PSR variety was lacking as these are new varieties that have not been exhaustively tested. The influence of rotation frequency on Bintje is known to be high (Scholte, 1991). We used the Bintje figures so we made a conservative estimate for the effect of rotation frequency on the yield of the PSR variety.

In further research attention should be given to the relations between the different entries on the N balance sheet. The denitrification process has been insufficiently explored, but is of major importance for nitrate leaching.

Finally, it should be noted that the yield levels and market perspectives for the new crops are uncertain. The yield data used in this study were obtained from experimental stations and will be superior to those obtained on an ordinary farm. Further agronomic research will improve the yield potentials, on the other hand.

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CHAPTER VII

The LP model in the MIMOSA system: implications of the scenarios[1]

Abstract

Applications of the environmental economic LP model described in Chapter VI are presented. The computations performed are comparative static and indicate the implications for Farm IV of the scenarios established in Chapter IV. This allows the effects of (1) technical developments, (2) environmental policy and (3) price and market policy on future farm organization in arable farming to be assessed. In addition, the functioning of the LP model is evaluated and priorities for its further development are discussed.

1. Introduction

In Chapter VI the environmental economic LP model - the core of the MIMOSA system - was defined and implemented for specialized crop production farms in the North East Polder. This chapter presents the use of the LP model for planning, *i.e.* to ascertain the optimal farm organization in response to changes in external conditions.

The computations performed with the LP model are of a comparative static nature and enable the changes in farm organization resulting from the six scenarios developed in Chapter IV (see figure IV.2) to be ascertained. These scenarios represent combinations of (1) technical developments, (2) different environmental regulations, and (3) different forms of price and market policy.

Scenario I indicates the effects of technical changes. Comparing the results of Scenarios I and II shows the impacts of standard environmental policy regulations, whereas the effect of differences in price policy can be assessed from comparing Scenarios I and IV and Scenarios II and V, respectively. The computations for Scenario III and VI indicate the effects of a compulsory

[1] A summary of the LP model (see Chapter VI) and the experiments concerning a regulatory levy on pesticide use (section VII.4), was published in Agricultural Systems (Wossink, De Koeijer and Renkema, 1992). See also De Koeijer and Wossink (1992).

switch to ecological farming. All the series were run with the model for Farm type IV.

Note that "induced innovation" is not accounted for, though the choices made among the innovations offered will differ between the scenarios. Moreover, the model outcomes indicate the bottlenecks in farm organization which should be given attention in technical research.

After interpreting of the findings we will evaluate the environmental economic model and recommend how the model should be refined.

2. Assessment of the basic situation

As all the series were run with the model for Farm type IV the model outcomes presented in Chapter VI.4, concerning model validation, cover the information on the basic situation. Table VII.1 gives an overview and additional figures concerning the use of pesticides and nutrients.

Figure VII.1 and table VII.1 indicate that for the standard cropping of potato in the North East Polder the total use of pesticides is more than 180 kg a.i. per ha per year. All the other crops require less than 20 kg a.i. per ha (PAGV, 1989). Note that the high use of pesticides in the standard variant for potato is mainly because of soil fumigation with dichloropropene every rotation. This requires 174 kg a.i. per ha per application. Another pesticide used in large quantities is the fungicide maneb. It is applied at 8.91 kg a.i. per ha to control *Phytophthora infestans*. Figure VII.1 also indicates the extent of emission of pesticides to groundwater. Potato cropping produces the largest emissions[2]. Two of the pesticides used in this crop, namely dichloorpropene (nematicide) and metribuzin (herbicide), are known to cause problems because they are easily leachable. With regard to maneb, it is known that the emission to groundwater of a degradation product is important, but data on this is lacking (De Koeijer and Wossink, 1990).

Table VII.1 and figure VII.2 present the input of nitrogen and the nitrate emission to groundwater. Potato has the highest input because of the application of organic manure in the standard cropping pattern, and it results in the most pollution. The inefficient use of N in manure applied in autumn before growing potato is largely responsible for this nitrate leaching.

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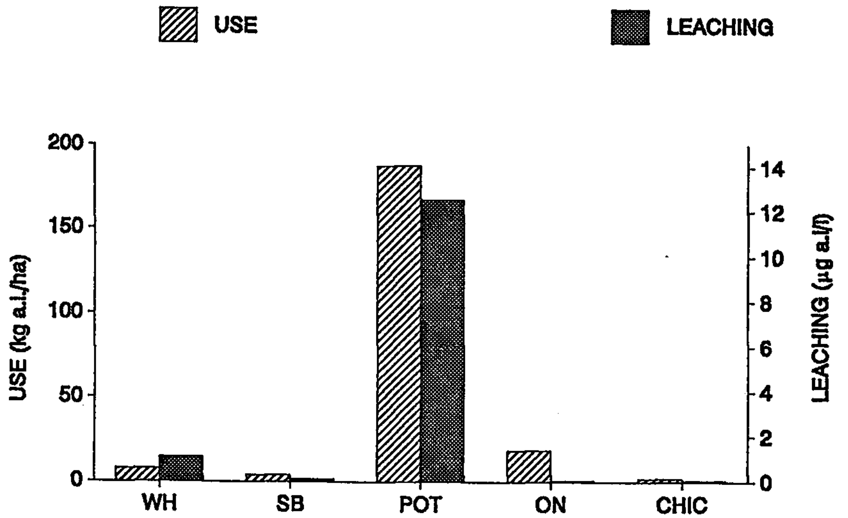
[2] It even exceeds the drinking water standards (0.5 μg/l groundwater) more than ten times.

Table VII.1 Main model outcomes Farm type IV, basic situation

	Standard cropping variants					
	Wheat	Sugarbeet	Potato	Onion	Chicory	Total
Ha in the cropping pattern	7.5	7.5	10.0	3.0	2.0	30.0
Gross margin in model[1]	2530	4610	5300	4242	7570	x
Costs of pesticides (NLG/ha)	411	345	1382	918	361	x
<u>Input of pesticides (kg a.i.)</u>						
Nematicides	-	-	174.00	-	-	1740.00
Herbicides	4.24	3.63	1.70	5.60	1.50	95.84
Insecticides	0.12	0.37	0.50	0.75	0.60	12.20
Fungicides	2.48	-	11.88	10.05	-	167.51
Other	0.90	-	-	2.25	-	13.50
Total	7.74	4.00	188.08	18.65	2.10	2029.05
<u>Emission of pesticides and nitrogen into groundwater</u>						
Nitrate mg/l	2.0	8.0	55.0	5.0	-	x
Pesticides µg/l	1.12	0.13	12.55	0.07	0.07	x

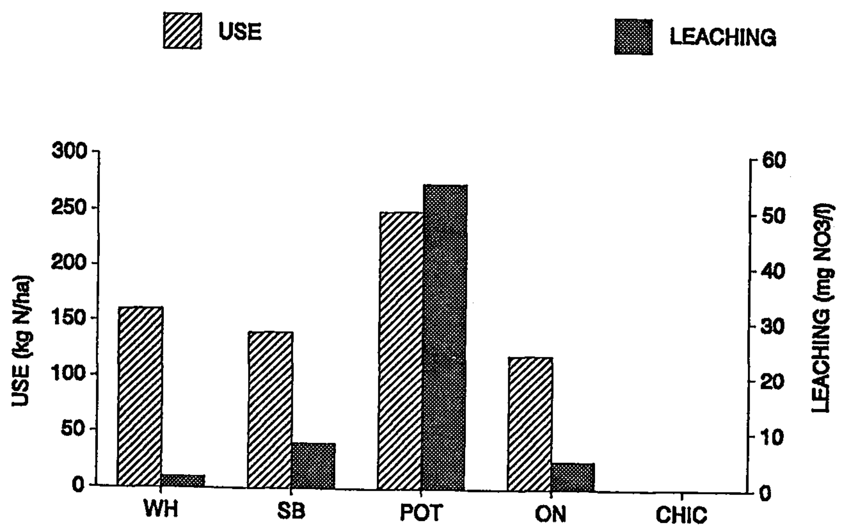
[1] Excl. the costs of pesticides.

Fig. VII.1 Use and emission of pesticides, standard cropping variants North East Polder



WH = wheat SB = sugarbeet POT = ware potato ON = onion CHIC = chicory

Fig. VII.2 Use and emission of nitrogen, standard cropping variants North East Polder



3. Scenario I: the effects of technical developments

3.1 Calculation procedure

In the computations the crop potato was given special attention, for two main reasons: it has the highest pollution figures per hectare and potato is the major crop in terms of farm income and has a large share in the cropping pattern. Cropping variants for potato were described in Chapter VI.3.3, together with cropping variants for the other crops and for the new crops. The aim of adding these cultivation alternatives to the LP is to indicate the trade-offs between yields (i.e. gross margins) and reduction of environmental pollution. The comparative static outcomes of the computations with the extended LP model express the potential for environmental economic improvements if the most modern techniques were to be introduced in the given farm type. In the next computation the increases in yields of the crops were added to the different cropping variants. The price changes of a market-oriented price policy were also considered and this finally resulted in the outcomes for Scenario I for t = 1995, 2000 and 2005.

3.2 Results

Effects of innovative cropping variants and new crops

When the LP model extended with all variants for potato, for the other crops and the new crops was optimized, it was found that the cropping pattern as such does not change. Compared with the basic situation, however, a different selection of cropping variants is made (see table VII.2, column Ia and Appendix VII.A for a detailed specification). There is a particularly important change-over regarding the potato variants. Instead of Bintje in a rotation of 1:3 with soil fumigation, a combination of 50 per cent Bintje and 50 per cent PSR variety is selected. For winter wheat a variant with a reduced N-input is chosen. Chicory and onions remain unchanged. Sugarbeet changes to two different variants. Both imply row spraying (in the case of variant 5 only after emergence). Because variant 5 requires additional manual work for weeding and the family labour supply in June I is limited a combination of variants 3 and 5 is selected.

Of the variable operations for N-dressing, weed control, haulm killing and late blight control in potato other (less polluting) alternatives are selected, as these have relative economic advantages. With regard to N-dressing the model opts for a reduced split fertilization supported by petiole analysis. Weed control changes over to the mechanical method using own machinery. Haulm killing is also mechanical and for late blight control a reduced treatment frequency is chosen. In connection with this the model opts for the following investments: (1) row spraying machine with accessories for spraying below the canopy for weed control in sugarbeet, (2) earther/ridge hoe for weed control in potato and (3) a potato haulm shredder. Total labour hours increases by circa 10 per cent for the total cropping plan. Casual labour is not required.

The "gap" between the outcomes with and without the new cropping variants mainly results from changes in the cropping technique selected for potato. The results of a sensitivity analysis[3] are given in Appendix VII.B.

Effects of yield increases

Considering changes in physical output from the basic year until 2005 (results Ib) gives only minor changes in cropping pattern compared with the basic situation. Moreover the resulting cropping patterns for t = 1995, t = 2000 and t = 2005 are the same. Part of the 7.5 ha of wheat is replaced by peas. Pesticide use shows a 6 per cent reduction to 233.77 kg a.i. for the total farm. Income changes resulting from the improvements of the yield levels total about NLG 1 900 annually.

Effects of a market-oriented price policy

Finally the price changes of a market-oriented price policy were added. This yields the implications of Scenario I for the model farm. The reduction in income is dramatic. Compared with the optimization with all cropping variants included, yield increases and constant prices (results Ib) the net farm result shows a decrease of NLG 40 031 for t = 1995 and of NLG 73 490 for t = 2000, for instance. Obviously, the yield increases cannot compensate for the price reduction according to price policy 1. Changes to even more environmen-

[3] It appeared that the difference in gross margin between Bintje and a Bintje/PSR combination has to be NLG 1 120 per ha to make soil fumigation profitable again in the base year situation. In the case of a 1:4, 1:5 and 1:6 rotation the model also opted for a Bintje/PSR combination.

tally-friendly cropping variants appear, except for potato. For the latter crop the model opts for chemical haulm-killing using diquat instead of the mechanical haulm-killing method, because the mechanical method becomes more expensive. Total pesticide use is 181.53 kg a.i. in t = 2005. This is a reduction of 27 per cent compared with the result for the basic period with all technical opportunities offered (results Ia).

3.3 Scenario I: discussion and conclusions

It must be stressed that the relationships and trends presented in the foregoing, are more important then the absolute figures, as the model is a simplified representation of the reality and covers only a specific group of farms. Note further that the conclusions depend on the price changes formulated for price policy 1 and in particular on the cropping variants and variable operations fed into the model.

Bearing in mind that farmers are well aware of the economic advantages of growing the common potato variety Bintje alternately with a variety resistant to nemathod pathotype A, instead of a rotation of Bintje 1 : 3 with soil fumigation, it is not unlikely that other factors prohibit new varieties being grown at a large scale. Both the availability of seed potatoes and the market prospects are unfavourable at the moment. Further the real-life farmer might prefer to wait before adopting the new cropping techniques (see Chapter VIII).

The way risk is handled also leads to a deviation between model results and practice. In the LP model risks are not taken into account. In practice, farmers try to reduce risk. Hence, unlike the model they may prefer a cropping variant with less profit above a crop with more profit but also with more risks. The linear programming method assumes instantaneous adjustments; switches occur according to changes in gross margin. The stability of the optimum solutions are important in this respect. Regarding potato, the model opts for a Bintje/PSR combination without nematicide use through all the calculations. The lowest reduced costs found in the computations with Scenario I for t = 1995, t = 2000 and t = 2005 were NLG 180 - 250 per ha for a Bintje/PSR combination with soil fumigation of infected patches and for Bintje 1:3 with soil fumigation every rotation. This sum can be considered as the "insurance premium" to avoid nematod infection, the real-life farmer is prepared to pay if he prefers the latter variants. The reduced costs of the most attractive variant for the 1:4

rotation, *i.e.* Bintje with soil fumigation every rotation, were NLG 160 per hectare for the t = 1995 situation and NLG 635 under the circumstances of both t = 1995 and 2000. Differences between the variants for wheat and sugar-beet are smaller and range between NLG 20 - NLG 40 and NLG 80 - NLG 100 respectively.

The changes in the cropping variants selected for wheat indicate that formulating intermediate cropping variants -- bridging the difference between standard, integrated and ecological variants -- for the other crops might be an interesting option. Regarding table VII.2 this would give insights into the substituting of wheat, peas and onion, for instance.

Considering these reservations the general conclusions regarding Scenario I can be summarized as follows:

- income decreases compared with the basic situation, hence technological change cannot compensate for the price reductions of a market-oriented price policy;
- there are significant reductions in the use of pesticides, because of innovations in cropping techniques;
- no new crops are selected.

Table VII.2 Results of the computations for Scenario I

FARM TYPE IV	(IO) Basic situation[1]	(Ia) Optimization with all cropping variants included	(Ib) Optimization with all cropping variants and yield increase	(Ic) Optimization with all cropping variants, yield increase and price policy 1		
			t=1995=2000=2005 [2]	t=1995	t=2000	t=2005
<u>Cropping pattern</u> (ha)						
Wheat standard	7.5					
WT 130 kg N		7.5	3.75			
WT 100 kg N no fungicides				7.5	3.75	
WT 50 kg N no fungicides						6.75
Potato standard Bintje	10.0					
variant5: Bintje +		5.0[a]	5.0[a]	5.0[b]	5.0[b]	5.0[b]
PSR variety		5.0[a]	5.0[a]	5.0[b]	5.0[b]	5.0[b]
Sugarbeet standard	7.5					
SB3-OM[3] 2.4 kg a.i. herb.		3.1	3.2			
SB5-OM 1.4 kg a.i. herb.		4.4	4.3			
SB5 1.4 kg a.i. herb.				5.3	5.1	7.5
SB-6 3.2 kg a.i. herb.				2.2	2.4	
Onion	3.0	3.0	3.0	3.0	3.0	
Chicory (vegetable)	2.0	2.0	2.0	2.0	2.0	2.0
Peas			3.75		3.75	2.85
Peas-ECO						0.9
<u>Use of pesticides</u> (kg a.i.)						
Nematicides	1740.00	0.00	0.00	0.00	0.00	0.00
Herbicides	95.84	63.49	56.95	74.30	68.04	57.27
Insecticide	12.20	12.20	14.54	12.20	14.54	11.99
Fungicides	167.51	159.56	152.16	141.00	142.54	112.27
Other	13.50	13.50	10.12	6.75	6.75	0.00
Total	2029.05	248.75	233.77	234.00	232.21	181.53
<u>Net farm result</u> (NLG/year)	-58 729	-42 923	-33 284/-23 941/-14020	-73315	- 97 431	- 119 540

[1] Optimization with only the standard cropping variants, for an overview of the variants see table VI.1-5 and Appendix VI.C

[2] The results for t= 1995, t= 2000 and t=2005 are the same except for the net farm result.

[3] OM indicates own mechanization, i.e. an investment in a row spraying machine.

[a] Haulm-killing mechanical, option2, [b] indicates option1 chemical (diquat).

4. Scenario II: the effects of environmental policy

4.1 Calculation procedure

The current regulatory context regarding the use of pesticides and nutrients in Dutch agriculture and the governmental proposals to call a halt to further environmental harm caused by these inputs were described in Chapter IV. The major policy objective in The Long-term Crop Protection Plan (Min LNV, 1990) is to reduce the total amount of pesticides used in agriculture in kg active ingredients to 50 % by the year 2000. Each sector of agricultural production has been given its detailed goals. Those for arable farming are given in table VII.3.

Table VII.3 Reduction goals for pesticide use in arable farming

Category	Reduction in % of kg a.i. in 2000 compared with 1984-88	
	1995	2000
Soil fumigants	46	70
Herbicides	30	45
Insecticides	15	25
Fungicides	15	25
Others	42	68
Total	39	60

To assess the implications of the reduction goals of the Long-term Crop Protection Plan these were translated[4] to the situation of Farm type IV. Note that in this way the reduction objectives formulated for the total arable farming sector are imposed to the single unit, which leads to an overestimation of the consequences.

Environmental policy instruments to realize the reduction goals were described in Chapter II. As a levy on pesticide use was suggested when the government unveiled the Long-term Plan, calculations were made for this specific economic incentive in addition to the assessment of the implications of the reduction goals by quantitative restrictions to the model. The goals considered in the computations were those for the year 2000 and the levy was assumed to be imposed in proportion to the weight of active ingredients.

[4] The base year results regarding pesticide use were taken as the 1984-88 situation.

Table VII.4 Translation of the Long-term Crop Protection Plan reduction goals to the Farm type IV situation

	Input of pesticides for the basic situation	Maximum quantities in kg a.i. per year 1995	2000
Nematicides	1740.00	939.60	522.00
Herbicides	95.48	66.84	52.69
Insecticides	12.20	10.37	9.15
Fungicides	167.51	142.38	125.63
Other	13.50	7.80	4.23
Total	2029.05	1237.72	811.62

The analysis of the implications of a levy started with an assessment of the amount currently used in the present farm organization and the level of income. This meant that the model was allowed to choose the standard cropping activities only. The results have already been presented (table VII.1), as have the effects of the Scenario I conditions on pesticide use (table VII.2, results Ic). Next, computations were made by imposing a levy of 0 to 200 guilders per kg active ingredients for all the individual pesticides included in the model.

In addition to the "volume" policy presented in table VII.3, the compound related "products" policy proposed in the Long-term Plan stresses the need to reorganize the list of pesticides currently authorized. It is difficult to assess the consequences of the interdiction policy, as this requires cropping variants to be defined that reflect the substitution opportunities of the specific products. There are no reliable data for these variants (*i.e.* information on new pesticides and their prices) available at the moment. Hence, the assessment is limited to indicating for which crops problems will occur. We also analysed whether problems are set by the pesticide concentration limits for groundwater, namely 0.1 μg/l per individual pesticide and 0.5 μg/l for the total leaching per crop.

With regard to minerals, the use of nitrogen is the central item in the calculations. The objective of the standard policy is to limit nitrate concentrations in groundwater to 50 mg/l (maximum according to EC regulations for drinking water).

4.2 Results

As indicated in section VII.3, technical innovations in cropping techniques can reduce the use of pesticides significantly. Nematicide input shows the most important change; the reduction is 100 per cent. Herbicides are reduced by 34 per cent and fungicides by 5 per cent (table VII.2). According to the normative LP procedure and the assumptions made, the reduction targets for total use in kg a.i. and for nematicides can be achieved by technical change.

The model outcomes of the computations with quantitative limits to pesticide input are presented in table VII.5 (column IIb) and should be compared with the results under the heading IIa. The comparison for t = 1995 shows that onions are almost completely replaced by wheat because of the reduction target for fungicides. Further, sugarbeet changes to a more environmentally-friendly variant. The constraint on insecticide use is limiting in the computation for t = 1995. In total the income loss is to NLG 1 328.

The more severe reduction targets for t = 2000 induce a further extensification. For wheat and sugarbeet the ecological variants become relevant and the number of hectares of wheat is increased because this crop replaces onion. Here too, insecticides appear to be the category most difficult to reduce, because of the relatively few alternatives for the control of pests.

Implications of a levy on pesticides

Optimization of the extended model for t = 2000, with an increasing levy in guilders per k.g. a.i. induced a change-over to other cropping variants and to other crops, accompanied by reductions in income (table VII.5, column IIc). The results:

- The share of sugarbeet and potato remains constant; sugarbeet changes over to a variant with less input of herbicides by row spraying;
- Set-aside becomes relevant in the case of a levy of NLG 50 and replaces wheat;
- A levy of NLG 60 must be imposed to achieve the reduction targets. Set-aside accounts for 5.9 hectares in this situation. The income reduction after restitution of the levies paid is NLG 2 360;
- To reduce fungicide use to the required level a levy of less than NLG 10 is sufficient; no levy is needed for nematicides. Insecticides appear to be the category determining the appropriate levy of NLG 60.

Implications of concentration limits and bans for pesticides

Emission restrictions for pesticides, *i.e.* 0.1 μg/l per individual pesticide and 0.5 μg/l for the total leaching into groundwater per crop, do not impose additional constraints in the situation t = 2000, price policy 1 and a levy of NLG 60. The exceeding of the 0.5 μg limit in the basic situation (see table VII.1) is caused by the use of dichloropropene (nematicide) and metribuzin (herbicide) in potato growing. The change-over to potato variant 5 (no soil fumigation) and mechanical weed control (option 3) instead of the chemical method implies that the leaching figure for potato is reduced to 0.04 μg/l[5].

The policy regarding banning of pesticides is not integrated into the environmental economic LP model. Using the "black" lists in the Long-term Crop Protection Plan an inventory was made of the products which are expected to be banned. Table VII.6 gives an overview. Alternatives to the herbicide metamitron in sugarbeet such as phenmedipham, are available (IKC-agv, 1991). The herbicide diquat applied in potato can be replaced by the mechanical method of haulm shredding[6].

For late blight control the fungicides maneb and maneb/fentin are required[7]. In the case of eschewing fungicide use the potato haulm is to be killed immediately and the crop harvested the moment late blight is detected, implying significant yield reductions. On average, the yields for an ecological variant are therefore not more than about 27.5 tons per hectare (Water, 1991; Antuma, *et al.*, 1990). For Bintje and the PSR variety this is 49.4 and 50.5 tons per hectare, respectively (see Appendix VI.C.2.). This would imply a yield reduction of 45 per cent according to present information with a wide variation from year to

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[5] This leaching results from the mechanical method of weed control which includes 0.5:4 = 0.125 kg metribuzin per ha, representing the risks of failure of the mechanical method. It is assumed that once every four year a treatment with metribuzin is needed in addition to the mechanical operation. In this situation 0.5 kg metribuzin will be applied and the leaching will be 4 * 0.04 = 0.16 μg/l. Note that this exceeds the emission restriction for individual pesticides.

[6] Investment in a shredder is not recouped, though the costs of the chemical method have grown to NLG 237 per ha under the conditions of t = 2000, price policy 1 and a levy of NLG 60. The contract work option of the mechanical operation was not included in the model. The costs of contract work can be expected not to exceed NLG 237 per hectare; the price in the basic period varies between NLG 140 to NLG 190 per hectare plus NLG 20 to NLG 30 standard costs per operation.

[7] An ecological variant for potato was not included in the model in a standard way. The reasons are given in Chapter VI.5.

year, depending on the weather. A general estimation of the average additional income loss per hectare for potato for t = 2000, price policy 1 and in case of a levy of NLG 60 for pesticides:

Bintje	yield reduction 45 %	NLG 3703
	pesticide costs saving	NLG 978
PSR variety	yield reduction 45 %	NLG 3648
	pesticide costs saving	NLG 480

For the 10 hectares of potato grown and after restitution of the levies paid, this totals more than NLG 23 000 annually. Incorporating a reduction of 45 per cent in the model for t = 2000, price policy 1 and a levy of NLG 60 shows that potato is reduced to a 1:6 rotation and set-aside is increased to 11.77 hectares. To restore the former cropping pattern the yield reduction has to be less than 33 per cent. In that case the income loss is still NLG 20 707. Not accounted for is the fact that infected potatoes cannot be stored. Immediate sales will usually yield lower prices.

Implications of regulations for mineral use

As pointed out in section VII.2 in the basic situation potato is characterized by high N input and leaching because organic manure is applied in autumn before growing this crop. The emission into the groundwater exceeds the drinking water limit of 50 mg NO_3^-/l. In model computations that include other options for N dressing (results Ia, Ib and Ic), the method of split fertilization supported by petiole analysis is selected, reducing the leaching to 10 kg N per ha or 10.5 mg NO_3^-/l. Hence, both the moderate limit of the EC and even the strict limit of 25 mg NO_3^-/l proposed by the Dutch Ministry of Environmental Affairs are fulfilled[8].

[8] Because of the problem of excess manure in the Netherlands it is interesting to assess under what conditions the use of organic manure will be attractive for the arable farmer. Just assessing the price reduction required for the manure to be included in the optimal plan is insufficient because in practice additional measures are required: (a) a green manure crop must be grown to fix N after manure has been spread and (b) the total amount of manure spread is to be reduced. The balance sheet approach (Appendix VI.C.1) allows for a maximum of 180 kg N from manure. Growing the green manure crop will give organizational problems because, for adequate N fixation, the crop must be sown in August. This, however, will not be possible for the total area intended to be put under potato the next year. For an environmental economic assessment additional research is required, *e.g.* on the effects of postponing the sowing and of the effects of the cover crop on the crops to follow. The latter topic relates to the organic matter balance sheet of the cropping pattern which is not included in the model.

Table VII.5 Results of the computations for Scenario II

FARM TYPE IV	Basic situation	(IIa=Ic) Optimization with all cropping variants, yield increase and price policy1		(IIb) Input limits for pesticides		(IIc) Fixed levy with set aside option				
						10	25	50	55	60
		t=1995	t=2000	t=1995	t=2000	t=2000				
Cropping pattern (ha)										
Wheat standard	7.5									
WT 100 kg N no fungicides		7.5	3.75	10.4	7.2	5.95	6.75			
WT-ECO					3.3			4.3	4.3	4.6
Potato standard Bintje	10.0									
Potato variant5: Bintje[b] +		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
PSR[b]		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Sugarbeet standard	7.5									
SB5 1.4 kg a.i. herb.		5.3	5.1	7.5	5.5	7.5	7.5	7.5	7.5	7.5
SB6 3.2 kg a.i. herb.		2.2	2.4		2.0					
Onion	3.0	3.0	3.0	0.1		0.8				
Chicory (vegetable)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Peas			3.75			3.75	2.84	3.75	3.75	
Peas-ECO							0.91			
Set-aside (with premium)								2.5	2.5	5.9
Use of pesticides (kg a.i.)										
Nematicides	1740.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Herbicides	95.84	74.30	68.04	66.26	49.99	60.61	57.28	30.90	30.90	21.64
Insecticides	12.20	12.20	14.54	10.37[c]	9.15	13.71	11.99	11.82	11.82	9.01
Fungicides	167.51	141.00	142.54	111.57	110.85	120.76	112.72	112.72	112.72	110.82
Other	13.50	6.75	6.75	0.16	0.00	1.80	0.00	0.00	0.00	0.00
Total	2029.05	234.00	232.21	188.36	169.99	196.34	181.53	155.45	155.45	141.50
Net farm result	- 58729	- 73315	- 97431	- 74663	- 99537	- 99636	- 102522	-106758	-107536	-108281
Change in income				- 1 328	- 2 106	- 2205	- 5091	- 9327	- 10105	- 10850
Change in income after restitution of the levies paid						- 234	- 553	- 1555	- 1555	- 2360

[b] Haulm-killing chemical (option1), weed control mechanical (option3), N dressing option3 and Late blight control option2.

[c] Shading indicates that the specific category of pesticides is limiting in the computations.

4.3 Scenario II: discussion and conclusions

The outcomes for Scenario II indicate the effects of standard environmental policy. It follows that the application of most modern cropping techniques results in the reduction targets for pesticide use being largely met and those for N leaching being completely met. N dressing in potato is most efficient (economically and environmentally) by means of a split fertilization supported by petiole analysis.

Note that in the computations for the scenarios no account was taken of the lower supply of organic matter when the model opts for refraining from manure, *i.e.* possible reduction in yield. A balance sheet to control the organic matter situation of the cropping pattern was not included in the model. Neither was the growing of green manure crops, under wheat and peas for example. Green manure crops are known to provide organic matter and to fix N. Furthermore, they improve the yield of the crops grown afterwards. Growing *Lolium perenne* as a green manure crop costs about NLG 214 per hectare. Other sources of organic matter are: chopping and ploughing in straw and sugarbeet haulm. By using these opportunities the organic matter can be kept at the required level (Noordam, 1992).

Comparison of the results of Ic and IIc indicates the effects of standard environmental policy. In conclusion:

- A levy on pesticide use has to be NLG 60 by weight of kg active ingredient to achieve the reduction targets of the different categories of pesticides given in the Long-term Crop Protection Plan for t = 2000;
- The emission limits for pesticides and nitrate do not lead to income reductions;
- The growing of sugarbeet and cichory is not affected by a levy on pesticide use or in the case the emission restrictions for pesticides or for nitrate are imposed;
- Onion and peas disappear from the cropping pattern, even the ecological variants of these crops do not pay when there is a levy of NLG 60;
- If a levy of NLG 60 is imposed on pesticide use in t = 2000, set-aside accounts for about 20 per cent of the farm land;
- Income losses due to quantitative restrictions or a levy are small and range between NLG 1 300 for t = 1995 and NLG 2 100 to NLG 2 360 for

t = 2000 in the case of a market-oriented price and after restitutions of levies paid;

- Refraining from late blight control in the case of bans on maneb and maneb/fentin will cause dramatic income reductions of up to more than NLG 20 000 annually.

Table VII.6 Scenario results and "problem" pesticides[1]

Crop	First priority	Before 1994	Before 2000
Result IIc (t=2000, price policy 1 and levy = 60) and Result Vb (t=2000, policy 2 and levy = 40)			
Potato:			
* Haulm killing			diquat
* Late blight control		maneb maneb\fentin	
Sugarbeet			
* Weed control	metamitron		
Additional for Results Vc (t=2000, price policy 2 and levy = 40)			
Wheat			
* Weed control of dicots	benazolin/MCPA		

[1] According to the "black" lists in the Long-term Crop Protection Plan (Min LNV, 1990), that cover 220 of the total of ca. 330 pesticides currently used. Hence, more products might become "problem" in future (see also: Oskam *et al.*, 1992, chapter 9).

5. Scenario IV and V: the effects of price policies

5.1 Calculation procedure

Two price policies were outlined in Chapter IV; a market-oriented policy and a restricted production policy with less severe price decreases and an obligatory set-aside of 15 per cent of the farm area. To consider the second price policy in the computations, set-aside was minimized at 4.5 hectares without a premium through all computations for Scenario IV and V. Further, the gross margin of the option "bait crop" for nematode control in potato was reformulated without a premium. This option is linked to the specific potato variants (see Appendix VI.C.2) and can also fulfil the obligation to have fallow land. Prices of outputs were modified according to table IV.2A. Prices of pesticides were raised by 3.0 per cent annually instead of 1.5 per cent in the case of price policy 1 (see table IV.2B). After replacing price policy 1 in this manner, the same computations were made as for Scenario I and II. Comparing the effects of Scenarios I and IV and Scenarios II and V enables the implications of the alternative price policy to be assessed.

5.2 Results

The results of the computations for Scenario IV are given in table VII.7 (column IVc). Comparison of these results with those of Scenario I for t = 1995 (Table VII.2, column Ic) indicates that set-aside replaces wheat in the cropping plan, as to be expected. Further, for sugarbeet the less environmentally-friendly variant number 3 is selected. The reduction in income brought about by price policy 2 is less and pesticide use decreases, mainly from a reduction in herbicide application. For t = 2000 there are more significant differences between the two price policies. Policy 2 induces the introduction of CCM in the cropping pattern instead of peas. Total pesticide use is about 8 per cent lower and the net farm result NLG 15 311 more compared with the results of Ic.

Next, the quantitative pesticide restrictions for t = 1995 and then for t = 2000 were included in the computations (Scenario V). Here again, insecticides appear to be the most limiting category of pesticide. Taking account of the set-aside obligation the differences between the results of IIb and Vb are small. As fallow land does not require pesticides, more (herbicides in particular) can be used on other crops. Sugarbeet variant SB5 requires relatively expensive herbicides, such as metamitron and fenmedipham. Some sugarbeet is replaced by the ecological variant in Vb. In price policy 1, with a less extreme increase in pesticide prices, it is obviously more interesting to grow wheat the ecological way, given the limitations to pesticide input.

Increasing levies were then imposed, as in the computations for Scenario II. A levy of 40 guilders by weight of active ingredients is required to achieve the quantitative reduction targets given in table VII.4. Compared with Va for t = 2000 the net reduction in income after restitution of the levies is NLG 1 931. The income effect is small, though the cropping patterns show quite different compositions. Without a levy on pesticide use CCM and onions are grown. Wheat is not a paying crop given the set-aside obligation. In the case of a levy of NLG 40 for pesticides this crop becomes interesting again, because the pesticide use of onion and CCM becomes very expensive.

Finally, the outcomes for t = 2000, price policy 2 and a levy of NLG 40 were analysed for the individual pesticides applied. As shown in table VII.6 an additional problem arises, namely for the control of dicot weeds in cereals because the integrated wheat variant is chosen in the cropping pattern. A total change-over to ecological wheat would imply an income reduction of NLG 515 per year.

The estimation of the income lost by refraining from late blight control was highlighted in section 4.2.2. Under the conditions of price policy 2 and a levy of NLG 40 the outcome per hectare is:

Bintje	yield reduction 45 %	NLG 3432
	pesticide costs saving	NLG 747
PSR variety	yield reduction 45 %	NLG 3380
	pesticide costs saving	NLG 501

For 10 hectares potato and on the premise that levies paid are restituted, the additional income loss is more than NLG 23 000. In this situation the model opts for a 1:6 rotation (POT23 Bintje/ PSR combination). To restore the former cropping pattern the yield reductions caused by late blight must be reduced to 33 per cent. This outcome is equal to those for the Scenario II situation in section 4.2.2.

5.3 Scenarios IV and V: discussion and conclusions

Compared with a market-oriented price policy the higher income levels and lower pesticide use figures for a restricted production policy are most significant (compare the results IIa and Va). Furthermore, a production restriction policy gives an opportunity for the new crop CCM. In the case of imposing limits to pesticide input the differences in cropping pattern are less distinct and if levies are imposed the differences disappear. The market-oriented price policy 1 induces set-aside. In the case of price policy 2 set-aside is compulsory. The result that the potato variants coupled with a bait crop are not competitive in the case of an obligation to have fallow land is interesting. According to the reduced costs the other options for nematode control, desinfection of infected areas particularly, are still preferable.

Because of the 15 per cent set-aside obligation the quantitative reduction objectives for pesticides are less restrictive on farm level, as the income reduction figures demonstrate. From the ecological point of view, however, the input in kg a.i. per ha is more relevant than total use per farm. In the situation of input limits for t = 2000 on average 6.48 kg a.i. is used per cultivated hectare, whereas price policy 1 results in 5.67 kg a.i. In the case levies are imposed set-aside is more important for price policy 1 and the input per hectare relatively higher. Further, the financial implications of the qualitative pesticide policy are more dramatic than those of the proposed policy of banning pesticides.

In conclusion:

- The main difference in the two price policies, given technical developments and standard environmental policy is in their implications to income;
- The composition of the cropping patterns in both instances is very similar;
- Because of the set-aside obligation according to price policy 2, quantitative input restrictions for pesticides are less limiting in case of price policy 2 and the income losses smaller;
- Interdictions for specific pesticides have comparable consequences in both cases.

Table VII.7 Results of the computations for Scenario IV and V

FARM TYPE IV	Basic situation	(IVc=Va) Optimization with all cropping variants, yield increase and price policy2			(Vb) Input limits for pesticides		(Vc) Fixed levy with set-aside option				
							10	25	30	35	40
		t=1995	t=2000	t=2005	t=1995	t=2000	t=2000				
Cropping pattern (ha)											
Wheat standard	7.5										
WT 100 kg N no fungicides		3.0			5.0	6.0					
WT Integrated							2.6	2.6	4.7	4.7	2.9
WT Ecological							0.4	0.4			3.1
Potato standard: Bintje	10.0										
Potato variant5: Bintje[b] +		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
PSR var[b]		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Sugarbeet standard	7.5										
SB3-OM 2.4 kg a.i. herb.		2.4					2.4	2.4			
SB5-OM 1.4 kg a.i. herb.		5.1					5.1	5.1			
SB3 2.4 kg a.i. herb.				2.2							
SB5 1.4 kg a.i. herb.			5.3	5.3	7.5	5.9			7.5	7.5	7.5
SB6 3.2 kg a.i. herb.			2.2								
SB-Ecological						1.6					
Onion	3.0	3.0	3.0	3.0	1.0		3.0	3.0	1.3	1.3	
Chicory (vegetable)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
CCM			3.0	3.0							
Set-aside (without premium)		4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
Use of pesticides (kg a.i.)											
Nematicides	1740.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Herbicides	95.84	53.64	47.30	45.51	48.40	45.39	44.78	47.78	36.23	36.23	26.12
Insecticides	12.20	11.64	11.26	11.26	10.37[c]	9.15	11.26	11.26	9.98	9.98	9.01
Fungicides	167.51	141.00	141.00	141.00	120.62	110.85	141.00	141.00	123.86	123.86	110.85
Other	13.50	6.75	14.49	14.49	2.19	0.00	6.75	6.75	2.91	2.91	0.00
Total	2029.05	213.00	214.06	212.27	181.58	165.39	203.99	203.99	172.99	172.99	145.99
Net farm result	-58729	- 67108	- 82120	- 96925	- 67972	- 83602	- 84246	- 87306	- 88251	- 89251	- 89891
Change in income					- 864	- 1482	- 2126	- 5186	- 6131	- 6995	- 7771
Change in income after restitution of the levies paid							- 86	- 86	- 942	- 942	- 1932

[b] Haulm-killing chemical (option1), weed control mechanical (option3), N dressing option3 and Late blight control option2.
[c] Shading indicates that the specific category of pesticides is limiting in the computations.

6. Scenarios III and VI: the effects of a compulsory switch to ecological farming

6.1. Calculation procedure

To complete the overview of the implications of the different scenarios, finally tentative[9] computations were made of the effects of Scenarios III and VI.

Ecological farming implies not using any pesticides or fertilizer and specific rotation rules (see Chapter VI.3.1.2). To enable the computations for Scenario III and VI ecological variants of potato cropping were derived and added to the LP model. Three ecological variants were formulated relating to the variants 22, 23 Bintje and 23 PSR, *i.e.* the 1:6 rotation (see Appendix VI.C.2). As described in section VII.4.2 the yield (tons per hectare) reduction of such variants is about 45 percent compared with variants not refraining from pesticides, mainly because of the risks of late blight. Further an adapted N-dressing method was formulated for the ecological potato variants. It was assumed that 180 kg N from manure is applied in autumn before potato growing. This quantity is the maximum the balance sheet approach allows for (see Appendix VI.C.1 and note 8 on page 134).

The new crops were excluded from the computations for Scenarios III and VI because no ecological variants could be ascertained. The growing of green manure crops (clover, *etc.*) which is crucial in ecological farming is represented by the set-aside option and was not explicitly modelled by means of LP activities. Further for Scenario III the market-oriented price policy 1 was used and for Scenario VI the production restriction price policy 2.

6.2. Results

The differences between the Scenarios III and VI are significant, particularly with respect to the resulting cropping patterns (table VII.8). It follows that a production restriction price policy matches the ecological rotation rules well. For a market oriented price policy this is not the case and the model opts for

[9] Assessment of ecological variants for potato was not included in the analyses of cropping variants described in Chapter VI. Therefore these variants have a less fundamental basis. Further a forced switch to ecological farming would influence the development of product prices formulated as price policy 1 and 2 which was not accounted for. These reservations make the computations tentative.

13.0 ha set-aside with premium. The reductions in net farm result are dramatic. Note, however, that the results IIIc and VIc include a 45 percent yield reduction for potato. In the case of the results IIc and Vc, an additional yield reduction (associated with an income loss of about NLG 23 000) would occur if the compound related pesticides policy is imposed in addition to the standard pesticides policy (see sections VII.4.2. and 5.2).

Ecological production systems are known for their higher labour requirements. Scenario VI asks for 1147 hours annually of which 116 hours is casual labour. Scenario III includes an important share of set-aside in the cropping pattern. Hence, the labour requirements are lower and sum to 950 hours, of which 21 hours is casual labour. The labour requirements of the basic situation, result IIc and result Vc are 919, 894 and 904 hours respectively.

6.3 Scenarios III and VI: discussion and conclusions

New crops were excluded from the computations for Scenarios III and VI because ecological variants were not available. In the case of Scenario III an important role of new crops is not to be expected, however, as indicated by the large share of set-aside instead of wheat[10]. Scenario II which also includes price policy 1 did neither stimulate the growing of new crops. In the case of Scenario VI ecological variants of new crops might be interesting. The intermediate outcomes for Scenario V (results Va, table VII.7) show that CCM offers good opportunities.

Comparing the results of Scenarios III and II and Scenarios V and VI indicates the effects of a switch to ecological farming related to standard environmental policy. The two major conclusions:

- A compulsory switch to ecological farming leads to further severe income losses;
- In the case of a market oriented price policy ecological farming implies a significant increase in set-aside (with premium); in the case of a production restriction price policy the changes in cropping pattern are small (peas is added).

[10] The gross margins of the new crops follow those of wheat, see Chapter IV.

Table VII.8 Results of the computations for Scenario III and VI

FARM TYPE IV	Basic situation	(IIc) Optimization with all cropping variants, yield increase, price policy1 and levy NLG 60 on pesticides	(Vc) Optimization with all cropping variants, yield increase, price policy2 and levy NLG 40 on pesticides	(IIIc) Compulsory switch to ecological farming and price policy1	(VIc) Compulsory switch to ecological farming and price policy2
			t=2000		
Cropping pattern (ha)					
Wheat standard	7.5				
Wheat Integrated			2.9		
Wheat Ecological		4.6	3.1	5.0	5.0
Barley Ecological					3.5
Potato standard: Bintje	10.0				
Potato variant5: Bintje[a] +		5.0	5.0		
PSR var[a]		5.0	5.0		
Potato variant23: Bintje[b] +				2.5	2.5
PSR varb[b]				2.5	2.5
Sugarbeet standard	7.5				
SB5-OM 1.4 kg a.i. herb.		7.5	7.5		
SB-Ecological				5.0	5.0
Onion	3.0				
Chicory (vegetable)	2.0	2.0	2.0		
Chicory Ecological				2.0	2.0
Peas Ecological					5.0
Set-aside (with premium)		5.9		13.0[c]	
Set-aside (without premium)			4.5		4.5[c]
Use of pesticides (kg a.i.)					
Nematicides	1740.00	0.00	0.00		
Herbicides	95.84	21.64	26.12		
Insecticides	12.20	9.01	9.01		
Fungicides	167.51	110.82	110.85		
Other	13.50	0.00	0.00		
Total	2029.05	141.50	145.99	0.00	0.00
Net farm result	-58729	- 99791[d]	- 98857[d]	- 138335	- 132157

[a] Haulm-killing chemical (option1), weed control mechanical (option3), N dressing option3 and Late blight control option2.

[b] Haulm-killing mechanical, weed control option3 (without additional metribuzin), no Late blight control (yield reduction 45 %) and N dressing 180 kg N from manure no fertilizer.

[c] Including the option of growing green manure crops such as clover etc.

[d] After restitution of the levies paid.

7. Comparison of the scenarios

This chapter describes how the LP model was used to assess the optimal farm organization considering the changes in external circumstances as indicated by the scenarios. The results can be interpreted from the viewpoints of the farmer and of the policy maker.

The main conclusion for the three most relevant scenarios (I, II and V) for t = 2000 are depicted in figure VII.3. The banning policy for pesticides is not accounted for in this presentation. It follows that Scenario II gives the greatest reduction in labour income[11], in total pesticide use and in cereal production. Scenario V yields the best farm income but the total output of cereals is significantly higher. Assessing the average yield per ha for t = 2000 results in 6.6 ton/ha for Scenario V (production restriction price policy) versus 5.9 ton/ha for Scenario II (market-oriented price policy). Compared with the basic situation, however, all scenarios lead to a considerable reduction of total cereal production[12]. Assuming that a reduction of 29 per cent is sufficient in view of the reorientation of the EC price and market policy, Scenario V gives the least worst prospects considering Farm type IV. Even in this case the income reduction compared with the basic situation is NLG 14 980.

The price policies appear to be most important for the scenario results for t = 2000. From the viewpoint of the farmer a production restriction price policy is preferable. The targets formulated for the reduction of pesticide use and the emission contraints for pesticides and for nitrogen are relatively easily met, *i.e.* with small losses in income. In the case of a regulatory levy on pesticide use the income loss totals NLG 1 932 for Scenario II and NLG 2 360 for Scenario V (after restitution of the levies paid).

In the case of Scenario I no environmental restrictions are imposed. Nevertheless pesticide use and nitrogen use decrease significantly because of the application of environmentally-friendlier techniques with relative economic advantages. The price changes stimulate some further extensification.

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[11] Labour income = Net Farm result + family labour costs.
For t = 2000 the family labour costs of Farm IV sum to 60 000 * $(1.01125)^{11}$ = 67 800.

[12] In the basic situation the cereal production is 7.5 ha times 7.5 tons/ha = 56.25 ton for Farm IV. Table VI.3 gives the yield of the wheat variants, the yield increase of 0.9 % annually was taken into account when composing fig.VII.3.

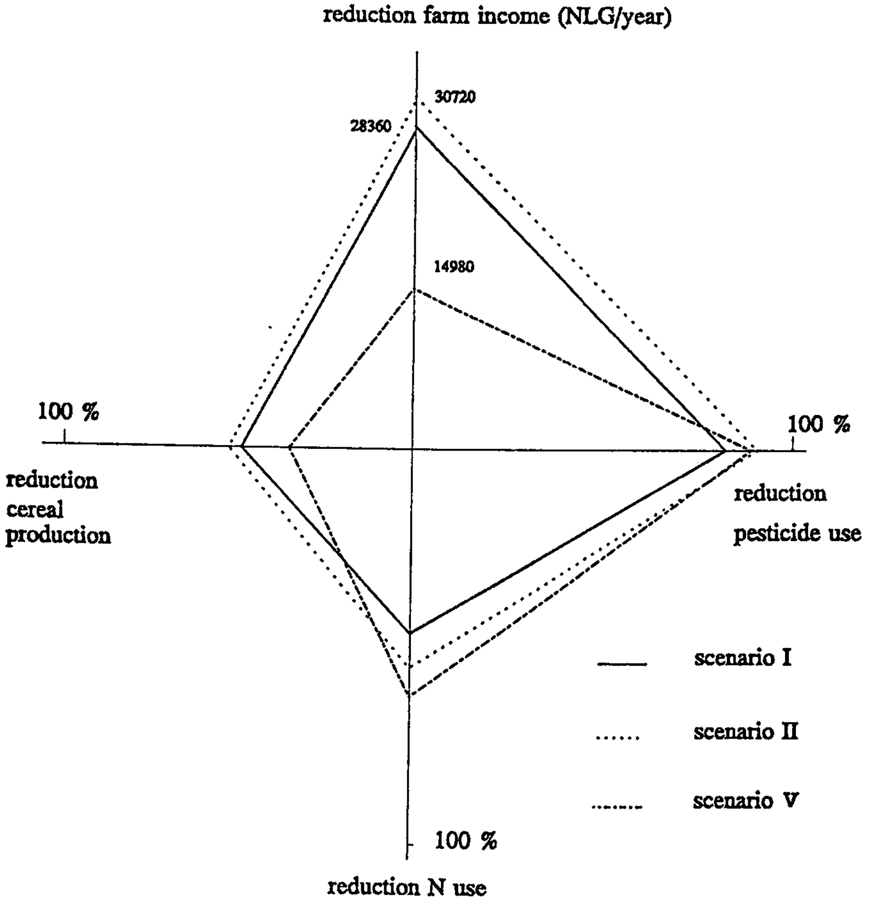
Note, as mentioned before, that the scenario results in this study are to a large extent determined by the price policies. For Scenarios III and VI the assumption of comparable price decreases for normal and for ecological products merits further research. Particularly interesting would be to analyse the price differences required[13] to offer better opportunities for ecological farming. Assessment of ecological variants for the new crops is another relevant item in this context.

Note further, as pointed at in Chapter IV, that induced technical innovations (and additional on-farm and off-farm activities) were not included in the scenarios. From the LP results, however, follow the bottlenecks in future farming and these bottlenecks can be expected to have major attention in research and extension, resulting in lower income losses than computed here.

Considering the severe income losses resulting from the scenarios the effects to income of additional farm land are interesting. In this context the marginal value of land was computed for the basis situation and for the three main scenarios. For the basic situation the LP procedure indicated a dual value for land of NLG 1775 per ha whereas for t = 2000 and Scenarios I, II and V this value was NLG 704, NLG 510 and NLG 919, respectively. Hence the marginal value of land, considering Farm type IV, decreases dramatically according to all three scenarios. Acreage enlargement is not an option to really improve the income perspectives is this situation.

[13] In relation to the prices of the "normal" products in t = 2000, for instance.

Fig. VII.3 Environmental economic results of the three main scenarios for t = 2000



8. Evaluation of the LP model

The strength of the environmental economic LP model lies in its flexibility, its easily understood mechanism and the relatively user-friendly software. The model provides an instrument for investigating and demonstrating the impact of policy options that consider the general economic trends that can be expected. As stressed in Chapter III it can either be used for planning, as shown in the present Chapter, or for conditional forecasting (policy analysis). In the former, final normative approach, the LP model is used to describe optimal future farm organization with special attention to environmental effects. For decision making at farm level the role of the model is particularly to elaborate precise technical specifications in the areas of environmental pollution and available technology. For further applications the study of these relations will require a continuous dialogue with experts from several disciplines so that the model can be updated to incorporate technical change and more restrictive or other environmental criteria. At the moment the model covers the leaching of nitrate and pesticides into the groundwater. There are, however, several other important environmental criteria, such as the emission into the air and toxicity to aquatic organisms and humans. Calculations for these other criteria make the approach even more valuable for research oriented on the future of arable farming.

With regard to the second orientation -- conditional forecasting -- the method presented is an instrument for encouraging and structuring the debate by enabling the efficiency of alternative environmental policy instruments and policy objectives to be evaluated by comparing the costs envolved and the reduction in pollution achieved. Moreover, the model quantifies the interplay between technical change, price and market policy and environmental policy. As follows from the computations in this chapter, innovation in cropping technique leads to an improvement of the aspects of environmental quality of agricultural production. So, in this instance a reorientation towards less strict environmental regulations would be obvious. Note that neither such induced institutional changes nor induced technical innovations are considered in the computations.

To be a real instrument for policy analysis the LP procedure needs to be extended with an adaptation analysis, *i.e.* whether and when the optimal solutions will be realized in practice. In Chapter VIII the modules of innovation adoption and farm contination of the MIMOSA system, covering this adaptation analysis, are elaborated.

In further research the gap between the outcomes of the normative LP model and actual farming practice should be given special attention. The extent of uncertainty of the technical relations and the risks involved are important in this respect; especially the risks resulting from refraining from late blight control in potato. The normative risks can be assessed by simulating weather conditions and coupling these to a potato growth model. The risks resulting from mechanical weed control can be incorporated in the same way.

Uncertainty with regard to the cropping variants needs special attention. The information used on several new techniques was incomplete or not entirely reliable. The model enables the assumptions made to be addressed in terms of their relative importance to profitability and to environmental effects of agricultural production.

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CHAPTER VIII

Innovation adoption and farm continuation in the MIMOSA system

Abstract
In this chapter the two modules of the MIMOSA system, covering feedback within the family farm, are defined for the arable farms in the North East Polder. The results of applying the modules are presented for one farm category (represented by farm type IV).

1. Introduction

As pointed out in Chapter VII.7 the outcomes of the normative LP procedure are useful for individual farm planning. They have to be extended with an analysis of adaptation in the case of conditional forecasting (policy analysis) for groups of farms. In the MIMOSA system the modules of feedback within family farms cover the adaptation process by indicating when and to what extent the normative LP results apply. These modules simulate the dynamic nature of the responses within different categories of farms by means of external information.

In section VIII.2 the consequences of the feedback within family farms for model formulation are discussed, that is whether additional representative farms have to be considered. Section VIII.3 focuses on the specification of the modules of innovation adoption and farm continuation and section VIII.4 presents a global application for one of the farm categories assessed in Chapter V. Note that in this manner phase 2 of the MIMOSA project, namely calculations to analyze the path of development of categories of farms was executed (see section III.2.3.4). Phase 3, extension to the aggregated level, was not implemented.

2. Feedback and the aggregation problem

In literature the term "adaptibility" is used to indicate the utilization of recent information on changing conditions in the decision making process. Generally there are two categories of adaptibility. Information can result in decisions without modification of the system concerned, as described by a specific model. Alternatively, the information can lead to such changes that the system changes and consequently the model has to be reformulated (Rausser and Hochman, 1979). As the core of the MIMOSA system is an LP model, reformulation is required if technical homogeneity is distorted, that is when the activities and constraints change. Because of its potential consequences for the number of representative farm types to be considered, feedback is part of the aggregation problem described in Chapter V.

The first element considered of feedback within the family farm was the decision on whether to continue the farm, representing the farm-family life cycle. Discontinuation of part of the farm population reduces the number of individual units represented by a specific farm type but does not reduce the number of representative farm types as such[1]. Hence, for this feedback element no additional representative farm models were required.

The most typical adaptive process in the MIMOSA system is innovation adoption behaviour. In Chapter VI.2.2 is was pointed out that a distinction has to be made between yield increase through biotechnological innovation and the other innovations, as the latter imply a change in farm organization. To reflect adoption from the latter category of innovations, the matrix of technical activities in the LP model alters over time. Simulating differences in adoption in this manner would have important consequences for the number of farm categories that have to be distinguished in modelling. In the case of differences in innovation adoption, an additional representative LP model is to be constructed because of the condition of technical homogeneity. Moreover, every possible combination of innovations is to be considered separately. So, in case of h innovations the maximal number of categories resulting from one representative farms may increase up to 2^h. This is a maximum as not all innovations or combinations of innovations may be adopted or some combinations might be irrelevant.

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[1] However, in the situation of the North East Polder, not even the number of individual units may change, namely when the farm is more than a certain number of hectares (see Chapter III.3.2.2).

To illustrate the foregoing the total number of new activities included in the LP model of the MIMOSA system is given in table VIII.1. The outcomes of the various experiments in Chapter VII for Farm type IV indicates which innovations have relative economic advantages and might be adopted by this particular farm category. In total 2^{19} model farms would be required to represented all possible innovation adoption combinations for category IV.

In conclusion: the number of model farms becomes unmanageable when adoption behaviour is considered as part of LP model feedback. Hence, in the present study an alternative approach was followed combining the LP outcomes with the innovation diffusion concept to establish rates of adaptation as suggested by Veeneklaas (1990, p.141).

Table VIII.1 Innovations selected by the LP model for Farm type IV

Crop	# Innovations[1]	# Selected in any model experiment[2]
Potato	22 new variants	1 (variant 5: Bintje + PSR)
	2 new methods for N dressing	1 (reduced N + petiole an.)
	2 new methods of Weed control	1 (mechanical)
	1 new method for Late blight control	1 (reduced application)
	1 new method for Haulm killing	1 (mechanical)
Wheat	13 new variants	4 (WT-130, WT-F100, WT-Eco and WT-integrated)
Sugarbeet	9 new variants	6 (SB3-OM, SB5-OM, SB3, SB5, SB6 and SB-Eco)
Onion/Peas Carrots	2 new variants for each crop	2 (Peas[3] and Peas-Eco)
New crops Set-aside	5 new LP activities	2 (CCM and Set-aside)
Total	55	19

[1] See table VI.3-5 and Appendix VI.C.2.
[2] See table VII.2,5 and 7.
Sensitivity analysis and the computations for Scenario III and VI are excluded.
[3] Peas are not included in the cropping pattern of the basic situation and are to be accounted for in the assessment of additional model farms.

3. Specification of feedback within family farms

3.1 Continuation module

Following Bouma (1988) two general conditions simulate the farm-family life-cycle in the MIMOSA system. A farm is wound up if: (a) the farmer reaches the age of 65 years[2] in period t + 1 and has no successor and if at the same time (b) the farm is less than a certain number of hectares. In the North East Polder this limit is set at 30 ha[3] which means that the continuation module applies to the farm categories I and II (24 hectare farms, see Chapter V). For the other categories the module is only used in ascertaining the number of potential adopters needed for the innovation adoption module.

The presence of a successor on farms with a manager of ≥ 55 years is simulated by (Bouma, 1988):

$$Psucc_{s,t,i} = d_0 + d_1 \ln (sfu_{s,t,i}) \qquad (1)$$

Where:

$Psucc_{s,t,i}$ = the probability that farms in category i with a manager ≥ 55 years in year t will be continued by a family member under the conditions of scenario s;

$sfu_{s,t,i}$ = standard farm units of the optimal cropping pattern for category i in year t under scenario s.

Using this function means that the probability of succession depends solely on the productive capacity of the farm.

Bankruptcy is a second reason for farm discontinuation. It is assumed that some of the entities in a farm category are liquidated each period when the level of own financial resources OC_{t+1} reaches a certain critical level. The development of the level of family capital is simulated by:

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[2] Reaching the age of 65 is a crucial factor in farm succession in the Nord East Polder. Almost all the land is state-owned and on normal or long lease. When the farmer reaches the age of 65 the lease contract will be terminated.

[3] In the North East Polder government interference strongly influences the reallocation process because the land is state-owned. According to specific allotment rules, liquidated farms of less than 30 hectares are used to enlarge neighbouring farms. Farms ≥ 30 hectares with no successor are leased to a new tenant without a change in size (Westhoff and Hazenberg, 1990). This means that in the foreseeable future the largest farms in the Nord East Polder will be 48 hectares, as is the situation at present (see Chapter V).

$$OC_{s,t+1,i} = OC_{s,t,i} + S_{s,t,i} \quad (2)$$

Where:
$OC_{s,t,i}$ = level of own capital of farm category i in year t under scenario s;
$S_{s,t,i}$ = family savings of farm category i in year t under scnario s.

The development of family savings is simulated by following Douma and Poppe (1987) who found a significant relationship between savings and farm labour income:

$$S_{s,t,i} = e_{o,i} + e_{1,i}\, Linc_{s,t\text{-}2,i} + e_{2,i}\, Linc_{s,t\text{-}1,i} + e_{3,i}\, Linc_{s,t,i} \quad (3a)$$

Where:
$Linc_{s,t,i}$ = farm labour income (net farm result + family labour costs) of farm category i in year t under scenario s;

Equation 3a has to be corrected to account for the fact that in the case of older farmers without a successor, usually only part of the replacement investments are carried out. For farmers older than 55 years and no successor, family savings are simulated by:

$$S_{s,t,i} = e_{o,i} + e_{1,i}\, Linc_{s,t\text{-}2,i} + e_{2,i}\, Linc_{s,t\text{-}1,i} + e_{3,i}\, Linc_{s,t,i} + e_{4,i}\, Charg\_fx_{s,t,i} \quad (3b)$$

Where:
$e_{4,i}$ = replacement investments omitted by farmers ≥ 55 years without a succesor in category i in per cent of total fixed charges;
$Charg\_fx_{s,t,i}$ = average of total fixed charges for farm category i in year t under scenario s.

The relative number of entities in a farm category for which equation (3b) is to be used instead of (3a) is derived by assuming a uniform distribution in both the group younger and the group older than the average age[4] in category i.

3.2 Innovation adoption module

In the MIMOSA system it is assumed that the diffusion of a particular innovation starts as soon as economic advantages result from the LP module. How rapidly the farmers in a specific category will respond to the new technique depends on the character of the innovation and the resistance to it among

[4] Distribution over 20 - 65 years. The average age of the farmers in a specific category i for the base year was derived from the results of the clustering (see table V.3).

these potential adopters. The innovation adoption module combines the concepts of economic constraints and diffusion concept with primary emphasis on the former, to simulate the time taken to adoption and the level of adoption (Hooks, Napier and Carter, 1983).

The first economic studies in the field of innovation diffusion were made by Griliches (agricultural innovations) and Mansfield (industrial innovations). Griliches's (1957 and 1960) well-known conclusion from empirical research was that the entire process of diffussion is largely guided by the profitability of the innovation. Mansfield is especially known for developing a diffusion model[5] and an explanatory theory which were very influential in subsquent economic research (Freeman, 1988). According to Mansfield (1961) the pattern of diffusion can be explained in terms of rational decision making by the potential adopters, taking into account: profit, scale of investment and learning processes based on communications between prior adopters and potential adopters. The rate at which the innovators are followed can be simulated by a linear function covering both the average relative economic advantage of the innovation and the size of the investment required (Mansfield, 1961). For the present study this implied:

$$q_{s,t,i,g} = f_{0,g} + f_1 \, prof_{s,t,i,g} + f_2 \, Inv_{s,t,g} \qquad (4)$$

Where:

g = 1,.....,h; h is the total number of innovations;
$q_{s,t,i,g}$ = coefficient of imitation for innovation g, category i, year t and scenario s;
$prof_{s,t,i,g}$ = the profitability of innovation g for farm type i for year t and scenario s;
$Inv_{s,t,g}$ = size of the investment required in the case of innovation g, year t and scenario s.

In equation (4) $f_{0,g}$ and f_2 are negative and f_1 is positive. The negative scale factor $f_{0,g}$ reflects the extent of uncertainty and differs from innovation to innovation. The extent of uncertainty includes three aspects: complexity, observability of results and the extent of consistency with existing beliefs and ideas, past experiences, skills and needs (Rogers, 1983). The imitation coefficient q relates to Mansfield's diffusion model. Equation 4 integrates the economic constraints concept into the diffusion concept. Changes in the

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[5] Defined as $\frac{Fdiff_t}{dt} = q \, Fdiff_t * (1 - Fdiff_t)$ which implies $Fdiff_t = \frac{1}{1 + e^{-(r+q)t}}$
where $Fdiff_t$ is the cumulative fraction of adopters at time t, r is a constant of integration and q is the rate of diffusion.

potential number of adopters and in $prof_{t,i,g}$ over time will lead to a modified distribution. This represents the slowing-down or speeding-up of the adoption process of the units that have not yet taken the plunge. In this manner "the dynamic nature of the responses" is accounted for (Upton and Haworth, 1987).

The classical diffusion process can be characterized in terms of three dimensions: the coefficient of imitation q, the pattern of diffusion (the shape of the diffusion curve) and the number of potential adopters. Rogers (1983) has articulated that because of the interpersonal interaction involved, the adoption curve should have a normal distribution and, consequently, the diffusion model should be logistic. In this case two basic statistical parameters of the normal distribution -- mean or average (μ) and standard deviation (σ) -- divide the adopter distribution curve into five fixed-sized categories: innovators, early adopters, early majority, late majority and laggards.

Information transfer on innovations, however, does not necessarily rely on interpersonal contacts, resulting in adoption by imitating or "learning". There is also an influence independent of adoption experiences by other farmers, the influence external to the population. Technical literature is an important source of information, particularly for the most innovative farmers (Kuiper and Van Woerkum, 1991). This means that the diffusion pattern might have another shape. Further Gatignon and Robertson (1985) suggest that the shape of the distribution of the initial opinions or beliefs about the attributes of an innovation may determine the diffusion pattern. In the case of a range of initial beliefs with equal probability an exponential curve would result, whereas a unimodal distribution produces a sigmoidal curve. Feder and O'Mara (1982) indicate that in agriculture experience and learning play an important role in innovation adoption and they propose a logistic model.

The innovator-imitator model of Bass (figure VIII.1) is widely used in marketing. This logistic model captures the spread of innovation resulting from interpersonal contacts and from mass media (Mahajan *et al.*, 1990b; and sources mentioned). The relative importance of the first information channel decreases during the diffusion process whereas the second becomes more important. As the Bass model distinguishes the two forces the size of the adopter categories is not assumed to be identical for all innovations as in Rogers's categorization. Groupings of adopters are unique to a particular innovation[6].

In this study the Bass model was selected for its theoretical superiority. Akinola (1986) statistically evaluated the Bass model for an agricultural innovation. He found a modest improvement over the classical diffusion model[7].

To be able to apply the Bass model for t,i, and g requires information on three items: (1) the adoption level p in the first time period; (2) the imitation rate q or the time-lag T^* and (3) the potential number of adopters $Fmax_{t,i}$.

4. Application to Farm type IV

Data from the 1984 Farm survey was used to estimate equation (1). That was the last census in which succession was included in the questionnaire. As indicated in table VIII.2 the succession rate in the North East Polder is above the national average. Regression analysis on the figures in table VIII.2 resulted in the following succession formula[8]:

$$Psucc_{t,i} = \underset{(0.06)}{-1.246} + \underset{(0.11)}{0.37} \ln sfu_{s,t,i} \qquad R^2 = 0.92 \tag{1}$$

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[6] The Bass model describes the diffusion process by the following cumulative frequency distribution ($p,q \geq 0$):

$$Fdiff_t = \frac{1 - e^{-(p+q)t}}{1 + q/p \; e^{-(p+q)t}}$$

Where:
- p = coefficient of external influence on the population (innovation);
- q = coefficient of internal influence on the population (imitation).

The peak of the non cumulative adoption curve f(t) at time T^* occurs when:

$$T^* = -\frac{1}{(p+q)} \ln(p/q), \text{ further } f_0 = f_{t=2T^*} = p.$$

[7] Akinola ascribes this to the nature and composition of data used (diffusion of spraying chemicals among Nigerian cacao farmers). A more important shortcoming might be in the ordinary least square procedure used to estimate the parameters of the Bass model instead of a nonlinear estimation procedure (Mahajan *et al.*, 1986).

[8] For another region in the Netherlands Bouma (1988) found: $Psucc = -1.0982 + 0.308 \ln sfu$, with t-values of -11.07 and 7.18 respectively and $R^2 = 0.93$.

In brackets the standard errors of the regression coefficients. As mentioned before for farm categories III to VIII equation (1) is only used to assess the number of potential adopters $Fmax_{s,t,i}$ required for the innovation adoption module. Furthermore, simulating bankruptcy is less relevant for farm categories III to VIII. It does not change $Fmax_{s,t,i}$, assuming that the reallotment of liquidated farms follows the institutional rules described in Chapter III.3.3 and that the new farmers have the same age distribution as the bankrupt farmers.

No data were available for equation (4). Parameter estimates are to be obtained from the diffusion history of analogous agricultural innovations. In addition expert judgments are needed to establish the similarity/dissimilarity between the new innovation g and previous innovations, so that the scale factor can be estimated. The research required for this was beyond the scope of the present study.

To demonstrate the application of the innovation adoption module the data required for the Bass model were estimated, thus omitting the use of the outcome of equation (4). Experts consulted yielded information for T^* and p of the different innovations. The year of first adoption follows from the LP computations. Note that in this way the base year used in the LP computations determines the possible start of the diffusion processes. Note further that direct estimation of the parameters of the Bass model approach does not account for any modifications of the adoption rate resulting from changes in relative economic advantages from period to period. In the case of using equation (4) this means modifying the average time lag for the farmers who have not yet adopted the specific innovation.

Table VIII.3 gives the values of T^* for the various innovations that have relative economic advantages for Farm type IV. For the innovation most important both in terms of reduction of environmental pollution and of income potential, *i.e.* potato variant 5, the value of T^* was particularly difficult to establish. The limited availability of seed tubers of PSR varieties and their market prospects are important restraining influences. So, the diffusion process is largely determined by the merchants involved in this specific market.

The total number of potential adopters $Fmax_{s,t,i}$ must be known so that the distribution in farm category i in absolute terms over the adopter classes can be assessed. This was determined as the total number in category i minus the number of farmers of $\geq$ 55 years without a successor in year t (resulting from equation (1)). For the base year: $Fmax_{0,IV}$ = 239 - 239 (1.00 - 0.69) = 202. This implies that 329 - 202 = 27 farmers in category IV are excluded from innovation adoption in the base year. The 202 other farmers are distributed over the adopter classes. Most of them (182 farmers) did not yet innovate in the base year. According to the p values of the different innovations, which reflect the share of adopters for the first year of diffusion, only 1 per cent of the potential adopters use all new techniques. Table VIII.4 presents the resulting diffusion.

Note that the approach assumes that the farmers who are most innovative regarding the methods for potato growing are also the first to adopt new wheat cropping variants, for instance. In practice this might be more dispersed as indicated in section VIII.2 when describing all possible combinations of innovations. As pointed out, the base year used for the LP computations, *i.e.* 1989, determined the start of the diffusion processes. Most innovations had economic advantages in the base year already. This suggests an earlier start (before 1989) of the diffusion of these innovations.

Tables VIII.5 to 7 give the distribution of farm category IV for the results of the runs with Scenarios I, II and V for the year 2000[9]. To establish the distributions, LP computations were done for the conditions of the three scenarios up to t = 2000 to assess the first year of adoption of the various innovations. In the case of Scenarios II and V it was assumed that levies are imposed as soon as t = 1996 and that the resulting cropping patterns in that year are the same as those of the Scenario II and V situations for t = 2000. So, the year of first adoption of WT-Ecological and Set-aside for Scenario II and of WT-Integrated and WT-Ecological for Scenario V was set at t = 1996 (see figure VIII.2.b and 2.c).

The relative impact of the application of the innovation adoption and the continuation module (adaptation analysis) on the outcomes of the three scenarios, measured in terms of income changes, is shown in figure VIII.3. The main scenario results after applying the innovation adoption module and the farm continuation module are depicted in figure VIII.4. For figure VIII.4 the outcomes of tables VIII.5 to 7 for t = 2000 were condensed to weighted (by

[9] As indicated in Chapter IV.3.3. and Chapter VII.7 these Scenarios were considered as the most relevant combinations of price policy and environmental policy variants.

the number of farms) averages for losses of farm income and reductions in pesticide use, nitrogen use and cereal production. In table VIII.8 these results are compared with their equivalent without application of the adaptation analysis. There are no important changes in the differences between the scenarios except for nitrogen use and for cereal production in Scenarios I and II.

Note that because a fixed value for q was used in the diffusion models of the innovations and because of the influence of the base year used in the LP computations the adaptation might be underestimated. Increases in the rate of imitation caused by price changes, for example, are ignored. These increases can be assumed to differ over the scenarios and thereby influence the impact of the procedure on the scenario outcomes.

In relation to the basic situation, all three scenarios lead to a significant reduction in pesticide use (83 to 90 %), nitrogen use (33 to 44 %) and cereal production (25 to 30 %) and to a dramatic income loss[10] (NLG 18 000 to NLG 30 000). In terms of "sustainable" agriculture the first three results can be evaluated as positive developments. A reduction of NLG 18 000 to 30 000 in the annual farm income for a main category of arable farms in the North East Polder indicates, however, that the economic sustainability is endangered. Acreage enlargement is not an option to improve the income situation substantially in the situation of Farm category IV (see Chapter VII.7). Considering the relatively low labour requirements of the farm organization in the basic situation which decrease further under the scenario conditions, off-farm and new on-farm activities might be optional sources of additional income.

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[10] Remember that the consequences of the compound related "product" policy for pesticide use are not taken into account in this income loss.

5. Discussion

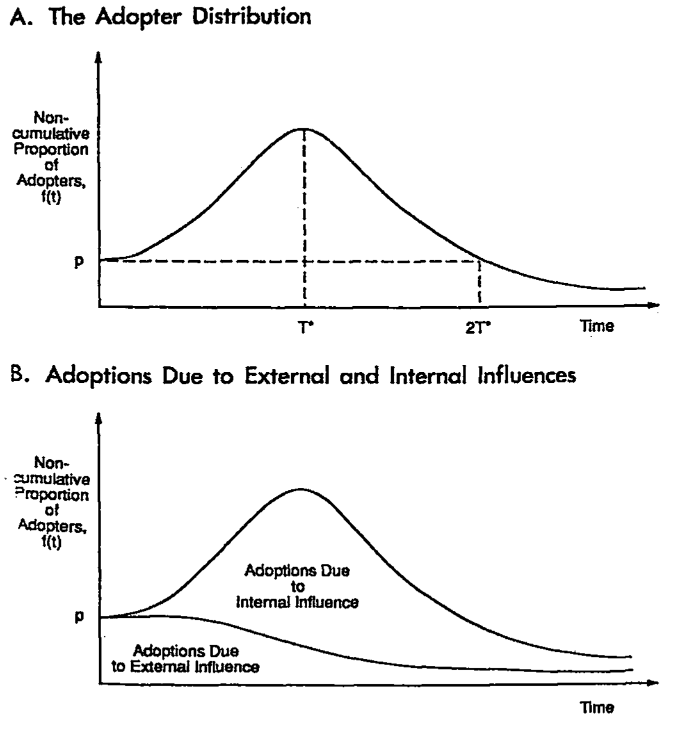
The analysis described in this chapter indicates that the provisional nature of the feedback modules in the MIMOSA system need to be re-emphasized. Nonetheless the exercise demonstrates a useful device for including feedback within family farms using external information. Including this feedback turned out to be particularly important in the case of the short term effects of the scenarios (see figure VIII.3). The outcomes of the Scenarios I, II and V for t = 2000 did not differ much before and after the adaptation analysis.

The modular set-up offers good opportunities for further investigation of the feedback within farm families in a step-wise manner. More research is required to establish the financial position of the farm, and further empirical analysis is needed to complete the innovation adoption module. With regard to the first item a pre-analysis (Van der Meulen, 1991) indicated that distinguishing classes of financial resistance in the basic situation and simulating changes in this distribution (Mulder, 1991) offers perspectives.

Aggregation to the regional level by summing results for the eight representative farm types assessed in Chapter V was not elaborated in this study because it would have meant an appreciable increase of the LP calculations as presented in Chapter VII and of the assessment of the feedback elements presented in this chapter.

Finally, note that omitting land transfer does not influence the results found in Chapters VII and VIII. According to the present institutional rules for reallocation, farm enlargement is only possible for farm categories I and II (24 ha farms, 23 % of the population). Before applying the transfer module to these categories it is advisable to pay attention to the financial status of the farms.

Fig.VIII.1 Adoption distribution in the Bass model



Source: Mahajan, Muller and Srivastava, 1990

Table VIII.2 Percentage of farm managers ≥ 50 years with a successor

sfu class	North East Polder	Netherlands
10 - 70	20	15
70 - 110	33	25
110 - 150	49	40
150 - 190	73	54
all farms	63	43

Source: Dir LNV Flevoland, 1987

Table VIII.3 Estimation of average time lags in adoption of relevant innovations by farm category IV

Innovation	p	T^* in years
Potato:		
- Bintje/ PSR combination	0.02	6.0
- method 3 of N dressing (no manure)	0.01	9.0
- method 3 of Weed control (mechanical)	0.02	6.0
- method 2 for Late blight control	0.01	6.0
- method 2 for Haulm killing (mechanical)	0.02	4.0
Wheat:		
WT-130, WT-F100, WT-Eco and WT-integrated	0.15	1.8
Sugarbeet:		
SB3 = SB3-OM, SB5 = SB5-OM, SB6 and SB-Eco	0.05	3.1
Onion, peas and carrots:		
Peas and Peas-Eco	0.15	1.8
New crops and set-aside:	0.05	3.1

p = coefficient of external influence on innovation, equal to the fraction of adopters in the first time period.
T*= average time lag

Source: Van Loon (1992) and Kloet (1992)

Fig.VIII.2a Diffusion of innovations selected in all scenarios, t = 2000

Diffusion	Innovation
94%	Bintje/PSR combination
67%	Method 3 N dressing potato
94%	Method 3 Weed control
94%	Method 2 Late blight control
100%	Method 2 Haulm killing
100%	WT-F100
100%	WT-130
100%	SB6
100%	SB5

Fig.VIII.2b Diffusion of additional innovations for Scenario I, t = 2000

Diffusion	Innovation
48%	Peas

Fig.VIII.2c Diffusion of additional innovations for Scenario II, t = 2000, levy = f60

Diffusion	Innovation
87%	WT-Eco
67%	Set-aside

Fig.VIII.2d Diffusion of additional innovations for Scenario V, t = 2000, levy = f40

Diffusion	Innovation
87%	WT-Integrated
87%	WT-Ecological

Table VIII.4 Outcomes of innovation adoption module, farm category IV, experiment Ia (t = base year)

$Fmax_{0,IV}$ = 214[a]	209 farmers (87%) (I0)	20 farmers (8%)	6 farmers (3%)	2 farmers (1%)	2 farmers (1%) (Ia)
<u>Cropping pattern</u> (ha)					
Wheat standard	7.5				
WT-130		7.5	7.5	7.5	7.5
Potato variant 1 Bintje	10.0[b]	10.0[b]	10.0[b]		
variant 5 Bintje +				5.0[c]	5.0[d]
PSR variety				5.0[c]	5.0[d]
Sugarbeet standard	7.5	7.5			
SB3-OM[3]			3.0	3.9	3.1
SB5-OM			4.5	3.6	4.4
Onion	3.0	3.0	4.5	3.0	3.0
Chicory (vegetable)	2.0	2.0	2.0	2.0	2.0
<u>Use of chemicals</u>					
Nematicides	1740.00	1740.00	1740.00	0.00	0.00
Herbicides	95.84	95.84	79.47	74.27	63.49
Insecticide	12.20	12.20	12.20	12.20	12.20
Fungicides	167.51	167.51	167.51	152.66	159.56
Other	13.50	13.50	13.50	13.50	13.50
Total	2029.05	2029.05	2012.68	252.63	248.75
<u>Net farm result</u> (NLG/year)	-58 729	-57 477	-56 435	-44 495	-42 923

[a] $Fmax_{0,IV}$ = Total number of farmers in category IV minus farmers ≥ 55 years without a successor in the base year: 239 - 7.97*10 (1.00 - 0.69) = 214.
[b] Without new variable operations for potato.
[c] With the new operation for weed control
[d] With new operations for N dressing, weed control, late blight control and haulm killing.

Table VIII.5 Outcomes of innovation adoption module, farm category IV, experiment Ic (t = 2000)

$Fmax_{o,IV}$ =223 [a]	30 farmers (13%)	60 farmers (25%)	42 farmers (17%)	107 farmers (45%) (Ic)
Cropping pattern (ha)				
WT-F100	10.0	7.5	7.5	3.75
Potato variant 16 Bintje	6.0[b]			
Potato variant5 Bintje +		5.0[c]	5.0[d]	5.0[d]
PSR variety		5.0[c]	5.0[d]	5.0[d]
SB5	5.1	6.1	5.1	5.1
SB6	2.4	1.4	2.4	2.4
Onion	4.5	3.0	3.0	3.0
Chicory (vegetable)	2.0	2.0	2.0	2.0
Peas				3.75
Use of chemicals				
Nematicides	0.00	0.00	0.00	0.00
Herbicides	92.99	72.82	74.67	68.04
Insecticide	11.63	12.20	12.20	14.54
Fungicides	116.50	140.60	140.60	142.54
Other	10.12	6.75	6.75	6.75
Total	231.26	232.37	234.22	232.21
Net farm result (NLG/year)	-108 887	-99 114	-98 504	-97 431

[a] $Fmax_{2000,IV}$ = Total number of farmers in category IV minus farmers ≥ 55 years without a successor: 239 - 5.19 *10 (1.00 - 0.69) = 223.
[b] Without new variable operations for potato.
[c] With method 3 for weed control and method 2 for late blight control, N dressing and haulm killing standard
[d] With N dressing method 3, method 3 for weed control, method 2 for late blight and haulm killing standard

Table VIII.6 Outcomes of innovation adoption module, farm category IV, experiment IIc (t = 2000 and levy = NLG 60)

$Fmax_{2000,IV}$ = 223 [a]	31 farmers (13%)	16 farmers (7%)	45 farmers (19%)	147 farmers (61%) (IIc)
<u>Cropping pattern</u> (ha)				
WT-F100	15.5	10.5	5.9	
WT-Eco			4.6	4.6
Potato variant 22 Bintje	5.0[b]			
variant5 Bintje		5.0[c]	5.0[c]	5.0[d]
variant5 PSR variety		5.0[c]	5.0[c]	5.0[d]
SB5	7.5	7.5	7.5	7.5
Chicory (vegetable)	2.0	2.0	2.0	2.0
Set aside				5.9
<u>Use of chemicals</u>				
Nematicides	0.00	0.00	0.00	0.00
Herbicides	84.96	66.16	46.71	21.64
Insecticide	8.45	10.32	9.75	9.01
Fungicides	59.40	110.85	110.85	110.82
Other	0.00	0.00	0.00	0.00
Total	152.81	187.33	167.31	141.50
<u>Net farm result after restitution</u> (NLG/year)[e]	-110 548	- 101 536	- 100 829	-99 791

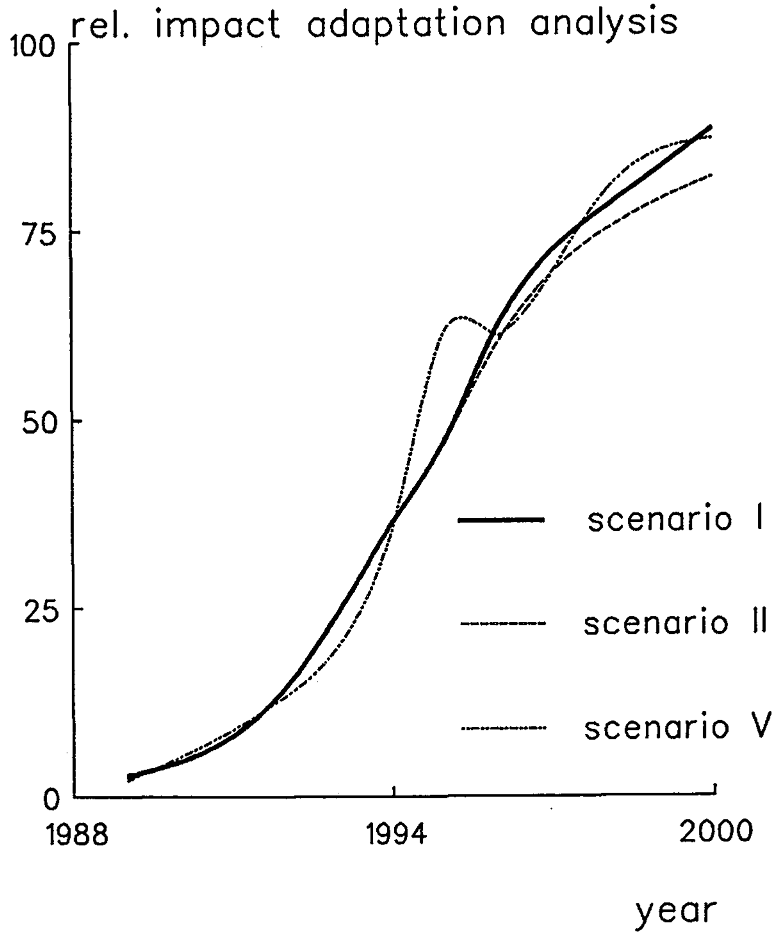
[a] $Fmax_{2000,IV}$ = Total number of farmers in category IV minus farmers ≥ 55 years without a successor: 239 - 5.19 *10 (1.00 - 0.69)= 223.
[b] Without new variable operations for potato.
[c] With method 3 for weed control, method 2 for late blight control, N dressing and haulm killing standard.
[d] With method 3 for weed control, method 2 for late blight control, N dressing method 3 and haulm killing standard.
[e] Restitution based on pesticide use of solution IIc (see last column).

Table VIII.7 Outcomes of innovation adoption module, farm category IV, experiment Vc (t = 2000 and levy = NLG 40)

$Fmax_{0,IV}$ = 223 [a]	29 farmers (12%)	15 farmers (7%)	45 farmers (19%)	150 farmers (63%) (Vc)
Cropping pattern (ha)				
WT-F100	8.25	4.0		
WT-Integrated			1.9	2.9
WT-Ecological			4.1	3.1
Potato variant 22 Bintje	10.0[b]			
variant 5 Bintje +		5.0[c]	5.0[c]	5.0[d]
PSR variety		5.0[c]	5.0[c]	5.0[d]
SB-5	7.5	7.5	7.5	7.5
Onion	2.75	2.0	2.0	
Chicory (vegetable)	2.0	2.0	2.0	2.0
Set aside	4.5	4.5	4.5	4.5
Use of chemicals				
Nematicides	0.00	0.00	0.00	0.00
Herbicides	69.62	49.81	24.56	26.12
Insecticides	9.60	11.02	9.01	9.01
Fungicides	87.03	131.04	110.85	110.85
Other	6.18	4.52	0.00	0.00
Total	172.45	196.39	144.43	145.99
Net farm result after restitution (NLG/year)[e]	- 97 086	- 85 559	- 84 691	- 84 051

[a] $Fmax_{2000,IV}$ = Total number of farmers in category IV minus farmers ≥ 55 years without a successor: 239 - 5.19 *10 (1.00 - 0.69) = 223.
[b] Without new variable operations for potato.
[c] With method 3 for weed control, method 2 for late blight control, N dressing and haulm killing standard.
[d] With method 3 for weed control, method 2 for late blight control, N dressing method 3 and haulm killing standard.
[e] Restitution based on pesticide use of solution Vc (see last column).

Fig. VIII.3 Relative impact (%) of the application of the innovation adoption and continuation modules on the scenarios results for Farm category IV[a]



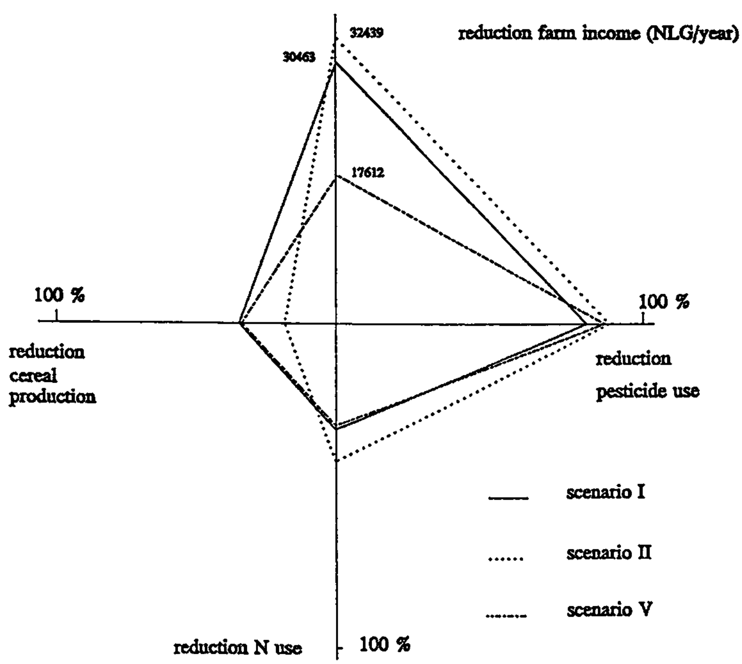
[a] Expressed by the ratio of the change in income (after restitution of the levies paid) after adaptation analysis of the scenario results of year t to the income change resulting from the LP computation (*i.e.* assuming instantaneous adjustment).

Table VIII.8 Environmental economic results scenarios for t = 2000, Farm category IV before and after adaptation analysis

Per farm	Scenario I before	I after	II before	II after	V before	V after	base year
Farm labour income[1] (NLG)	-29630	- 31733	-31990	-33709	-16250	-18882	- 1270
Pesticide use (kg a.i)	232	232	141	151	146	154	2029
Nitrogen use (kg N)	3740	4657	2930	3981	2336	4414	6910
Cereal production tons/year	28.3	38.9	27.8	48.4	37.3	38.8	56.2

[1] Net farm result + family labour costs, for t = 2000 the costs of family labour of Farm type IV sum to 60 000 * $(1.01125)^{11}$ = 67 800.

Fig. VIII.4 Summarized environmental economic results of the three scenarios for t = 2000, Farm category IV after adaptation analysis



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CHAPTER IX

General discussion

Abstract
The methodological issues of the research presented in this thesis and its applicability are discussed. The most basic results are reiterated and promising avenues for future research are indicated.

1. Introduction

In this final chapter it is discussed whether the method and system developed are suitable to be used to study agricultural change. This is done by re-examining the aims specified in Chapter I and comparing them with the results and experiences of this study. The two main themes of the study have to be distinguished for this, namely to provide a tool: (1) for farm planning and (2) for conditional forecasting for policy evaluation. Both the theoretical considerations in the literature on agricultural change and the results of comparable investigations were used as background material for the procedure selected to develop this tool (Chapter II and III). The discussion and demonstration of the working of part of the MIMOSA system, namely the construction of the scenarios, the assessment of the representative farms, the environmental economic LP module and the innovation adoption module (Chapters IV-VIII), provide the basis for assessing the applicability of MIMOSA and the topics that merit further research.

2. Methodological issues

Method used

There are basically two approaches to applied production analysis: econometric modelling and mathematical programming. As extensively described in Chapter II, linear programming at the farm level was chosen for the MIMOSA system as this facilitates (a) the selection from the technology set available and directly related to the latter (b) the change in the environmental aspects of agricultural production, to be assessed.

Apart from the approaches available for modelling changes in agricultural production over time, Orcutt *et al.* (1986) distinguish three methods of representing the state of the population concerned: (a) using of multivariate distribution, (b) using the cell frequency representation or (c) listing all the attribute values for each entity or for a sample of the population. As they state there is not necessarily a connection between the method used to represent the state of the population and the modelling technique used for the updating. In practice, however, the cell frequency approach is combined with the transitional matrix technique and the listing mode with micro-based simulation of changes in attribute values. As was discussed in Chapter VIII, the former combination is less attractive if the changes of attribute values are interrelated because then the Markov chain method leads to an unmanageable number of cells needed to classify the entities without loss of information.

In comparable studies of agricultural change at regional level in the Netherlands by Bouma (1988) and Boorsma (1990) the listing mode was applied. Bouma considered each entity (farm) in the region of investigation and applied Monte Carlo simulation to model the entities' behaviour. Boorsma worked with a sample and for the analysis of the process of structural change he used a dynamical micro simulation model. This model contains several farm level LP models with advancing planning horizon embedded in a regional LP model representing the market for agricultural land.

As in the present study Boorsma was particularly interested in the consequences of alternative technical and institutional changes at farm level. Next, he focessed on the regional developments again using the normative method of LP for the updating. The present study started in the same manner; normative assessment of the impact of the scenarios by LP for the individual (representative) farm. Next, however, the path of development of the category represented by the LP model was analysed. To this end the category represention and age distribution per category were combined with LP and external information for updating at the category level.

Combining the listing mode (for a sample) with LP and adoption simulation of the individual sample farms for updating would yield a micro simulation model accounting for the processes of adaptation. Whether such an approach has advantages compared with the one presented here is questionable. For planning, adaptation rates are not relevant, whereas conditional forecasting asks for insight into adaptation processes at the category or regional level and not at the farm level.

Potential and limitations of the farm economics approach

In this study the processes of adaptation of family farms in respons to changing circumstances were analysed, to provide a tool for farm planning and for conditional forecasting. We contended that a dynamic system combining a detailed LP model of normative individual farmer behaviour with modules for feedback within and between family farms based on the positive approach meets the model requirements and can be constructed.

The farm-based approach enables the impact of environmental and price policy instruments for farm organization to be considered. Moreover, different regulations can be considered simultaneously and their combined effects can be assessed. A second important aspect lies in assigning the resulting advantages and disadvantages to groups of farms. Such distributional effects are usually among the important design criteria of policies.

The difficulties of the farm-based approach start with the data. To start with, an initial data base of single observations of the population concerned must be available and accessible. As pointed out, the farm survey used for the determination of the farm categories in this study included very little socio-economic information. For a correct representation of the state of the population data on aspects such as the prospects for succession and on the financial position of the farms are also needed. Suitable data were available for the technical innovations and for part of the continuation module but not for innovation adoption. Therefore in the latter case external information had to be used. Finally it has to be added that a farm-based approach is time-consuming and demands a considerable degree of research organization.

The LP approach versus econometric models

LP models and econometric models are both capable of yielding projections of agricultural change under various assumptions. In fact the methods complement each other, as pointed out in Chapter III. Any comparison of the outcomes of both methods would be fraught with difficulty because of the problems of separating differences in results from differences in assumptions. No equivalent time series approach is on hand for the calculations made for the scenarios. However, both methods have been applied in one study of levies on pesticide use for Dutch agriculture (Oskam *et al.*, 1992). Comparative static computations were made in that study and price changes and yield increases were not considered. The resulting levies differed significantly for the two methods used. The aggregated LP approach indicated sums of less than NLG 25 whereas the time series model yielded a levy of NLG 100. The premises underlying the two methods determine these results; the LP model includes technical innovations and assumes instantaneous adjustments, the econometric approach reflects the adjustment as derived from historical time series with 'average' technical change. Hence, the time series model gave a maximum estimation of the levy and the LP approach a minimum estimation.

The data and organizational problems of the two approches are quite different: in econometric models the difficulty is finding a series of consistent and comparable observations, in the LP approach the problem is to find a consistent set of input-output coefficients. The major advantage of the LP approach over an econometric model is that it reflects the farm organization as a selection made from the different techniques that are open to a farmer. These techniques have to be established first; this is the most delicate and time-consuming part of the study.

Further, the integrated character of the work of building and using the environmental economic LP model imply that record keeping and a flexible structure of the LP model are crucial. The software used for the LP computation, which includes a matrix generator and is suitable to be fed from spreadsheet input, appeared to be very important in this respect.

Integration of environmental aspects in economic models

To be able to analyse whether an economic development is 'sustainable' its probable economic and environmental effects have to be compared. Fully integrated environmental economic models that demonstrate economic processes and processes in the natural environment with their interrelationships are rare. Integral coupling is said to impose high demands on interdisciplinarity and data availability and to result in large and complex models (Wossink, De Koeijer and Jarosch, 1990). Frequently a hierarchical approach is chosen, which means that from a complex economic model environmental parameters follow and not vice versa, or that input parameters of the economic model (N dose, for instance) are used as an indirect measure of the environmental effect of these inputs.

In the present study the environmental component was coupled to the economic component in the LP model. This meant that the ecological (emission) models used were not built into the model, but instead their output parameters are incorporated as quasi external data. Because the LP approach enables many activities producing the same agricultural product to be considered, the potential of the resulting environmental economic model is considered sufficient. The coupling approach involved extensive consultation with experts on environmental effects and plant protection, though actual interdisciplinairy research was not required (De Koeijer and Wossink, 1990). One advantage of the coupling approach is that it enabled the environmental component and the economic component to be developed more or less separately given the production activities. Moreover, the option to exchange one of the two parts (both in spreadsheet form), is still open. So the emission figures can easily be replaced by those resulting from another leaching model, because the LP software can be fed with separate spreadsheets. Finally, it is worth noting that the emission model can be integrated into the LP model in the case the leaching equations can be represented in spreadsheet formula and references.

Scenario technique

Technology plays an important role in this study of future agricultural change. It must be emphasized, however, that the study is not to be considered as an example of technological forecasting. The technical alternatives incorporated into the LP model are regarded as opportunities and stimuli for the environmental changes and production reductions required according to the different policy views.

What is called an integrative approach was followed in drawing up the scenarios and in assessing their implications for farm organization (Tuininga, 1981). Projections of technical developments were combined with a normative assessment of the adaptations in farm organization required to realize the environmental policy objectives. In this manner the interactions between the development of technological trajectories and the selection environment of farm firms were reflected on the basis of their theoretical background as described in Chapter II. According to Van Doorn and Van Vught (1981), although many methods are available for research oriented on the future there is still a lack of such theoretically underpinned approaches that cast light on the interactions mentioned.

The limitations of the scenario technique must also be stressed. The method does not outline forecasts of agricultural changes at farm or aggregated level. Its purpose is to identify a spectrum (*i.e.* scenarios) of possible future development paths and their likely consequences. However, the analysis provides relatively accurate assessments of the problem areas to be expected in future.

3. Applicability

In the study the emphasis was on the development of the MIMOSA system and the environmental economic LP model in particular. The results of the computations (experiments) in the first place serve as a basis for the discussion of how the LP model and the innovation adoption module work. The LP module, however, is a useful instrument for farm planning, *i.e.* to assess the optimal reactions at the farm level to changing conditions. It is a tool to shed light on the interactions of production intensity, environmental aspects and farm income and to compare the implications of different policy options at farm level. Before further application, however, the risks associated with the environmentally-friendlier cropping variants should be incorporated into the LP model. Note further that financing was not included in the application presented here.

Regarding conditional forecasting for policy analysis, the tendencies regarding the implications of the scenarios are the most interesting outcome. Relationships and trends are more important than the absolute figures, particularly because the application reported here covers only one specific group of family farms. Further the results of the innovation adoption module should be interpreted with caution, as this module was not tested for its functioning.

An evaluation of the model's practical use for policy evaluation also involves a comparison with the costs of other approaches. The farm-based approach produces a rapid output. The additional insights gained have to be judged in terms of the additional costs involved. Obviously, multiple use is preferable, though this requires additional efforts because of maintenance and possible modification.

To save costs and time the approach in the present study was simplified; computations were made for just one category of farms. Aggregation to the regional level was not implemented. When evaluating policy regulations in practice, simplifications such as reducing the number of representative farms and/or omitting the feedback modules reduce the competiveness of the farm-based approach.

As pointed out in Chapter III the only intermediate market to be considered at the regional level is that of agricultural land. In the North East Polder the reallocation of land is determined by governmental policy, as the land is state-owned. Simulating the current institutional reallocation rules would require the formulation of two additional farm models (for the two representative farm types of 24 ha) and the assessment of transitional probabilities for two of the initial farm categories.

4. Further research

Farm planning

Further refining of the LP model for normative research should give attention to four items: (1) risk and (2) an organic matter balance will have to be integrated, (3) the LP model will have to be continually updated to take account of new developments in technology and planned regulations and (4) the organization of model input will have to be adjusted so that farm specific constraints and price and yield figures can be modified in a more user-friendly way.

Risks have important implications for the potential to reduce the environmental pollution caused by agricultural production. Further research needs to focus on these risks, particularly those associated with crop care (Pannell, 1991). Our experiences in constructing the cropping variants suggests that the problems surrounding the data needed to establish the risks will be considerable.

Further, more effort needs be directed at identifying and quantifying the elements (and their relations) necessary for a deeper and more complete view of the cropping variants. This, however, lies beyond the scope of farm management research. The LP results thus far and in the future can be used as a support in drawing up the agenda for research on technology by indicating the relations that have been insufficiently investigated but that appear to be important regarding effiency (costs/returns relationship) and effectiveness (economic/environmental relationship). Examples of this for the potato crop include: the differences between the various PSR varieties, effects of rotation on yield, additional alternatives for late blight control and the relevance and problems of manure application.

The environmental economic LP model included a large number of pesticides. As indicated in Chapter VI two criteria were used to measure the environmental effects of the pesticides: (1) active ingredient expressed in kg/ha, irrespective of toxicity, persistence and mobility and (2) emission to groundwater. A further refinement of the LP model would have to pay attention to further aspects of the environmental impact of pesticides, as well as their metabolites[1].

Conditional forecasting

To improve the potential application of the MIMOSA system for conditional forecasting not only requires the implementation of the regional model but also the addition of risks to the LP model, testing of the innovation adoption module and the further fine-tuning of the outcomes of the normative LP results to actual farming practices. Attention should be given to differences in risks attitudes, in quality of management and in optimization objectives. To incorporate these differences requires a more extensive assessment of the representation of the family farms in the population. For realistic modelling at farm level the entities need to be distinguished in terms of their financial and

[1] A measure of general environmental impact is currently being developed by CLM (Centre for Agriculture and Environment), Utrecht. Such an environmental "yardstick" would be easy to incorporate into the LP model.

technical status as well as in terms of management objectives in relation to the farm family life-cycle. This requires the use of other or additional (for statistical matching) data. Further a sample approach, *i.e.* a random selection from the original units in the categories resulting from cluster analysis, seems more appropriate in this case because of the joint probability of changes in goals, values, situation (technical, financial, environmental) and the appreciation of this situation. Links with the sociological work on "styles of farming" might be useful (see for instance Van der Ploeg *et al.*, 1992). So far this field has not been involved in the project.

In the present study the scenario results were not reported back to policy makers nor did we reconsider/modify the scenarios. This needs be focused on in further research. For example, interesting for environmental policy assessment is the LP result that abstaining from soil fumigation will be brought about "automatically" by technological change and market forces, whereas banning fungicides for late blight control will lead to dramatic reductions in income.

Feedback to the agronomists took place as described in Chapters VI and VII. For further research the model outcomes could be used to indicate the bottlenecks in farm organization and/or institutional regulations that can be expected and should be focused on, such as the problems raised by the proposed pesticide policy related to compounds, for example.

Maintenance

Finally it should be noted that there is a continual need to revise and update the modules of the farm model (in particular the LP model) and also the scenarios. Further, as time passes, certain larger tasks must be attended to, such as redefinition of the base year, of the time horizon and of the representative farms. From the scientific point of view, empirical research on the behavioural aspects, an assessment of the risks of environmentally-friendlier cropping techniques with their consequences and refining of the structure of the MIMOSA system and its modules is more attrative than the maintenance work.

5. Major findings and conclusions

Against the above background of general propositions, the major findings and conclusions from the research project are:

- A farm-based methodology combining normative and positive analysis can contribute to give insights for both farm planning and conditional forecasting.
- Linear programming of the individual farm is a method well suited to indicate the trade offs between farm economic aspects and environmental aspects of arable farming for their whole traject of interaction.
- A modular set-up for a farm-based approach has major advantages both with respect to implementation and application. The problem of agricultural change can be studied in an outwardly spiralling manner, firstly at the farm level, and subsequently at the aggregate level.
- A farm based approach is time-consuming and labour-intensive. For conditional forecasting whether the method is preferable to other techniques such as the time series approach, will depend on the specific research question.
- The root causes of the present environmental problems result from failures in the system of economic incentives. In agriculture the economic incentives are largely determined by price and market regulations. As follows from the scenario results, a policy strategy of attuning environmental regulations to price policy regulations is preferable, further in policy implementation attention should be paid to the expected technical innovations.
- Price policies appear to be most important for the future of arable farming, the model results indicate that the targets formulated for the reduction of pesticide use and the emission constraints for pesticides and nitrogen according to the (proposed) Dutch environmental regulations are easily met; i.e. with low income losses.

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SUMMARY

This study of agricultural change deals simultaneously with: (a) farm planning, *i.e.* the constant adaptation to changing circumstances at the level of the individual farm firm and (b) conditional forecasting, *i.e.* the analysis of alternative agricultural and environmental policy views and their impact.

Chapter I gives a general introduction and sets out the objectives and scope of the study. The specific research objectives were: (1) to develop a model system based on farm economics to assess the impact at farm and regional level of different scenarios concerning technical developments, agricultural price policies and environmental regulations; (2) to ascertain and describe technical developments and alternative policy options for Dutch arable farming by means of a number of scenarios; (3) to apply the scenarios and part of the system to arable farming in the North East Polder, the region that served as a case study for implementing and testing the system. The North East Polder was selected because of its intensive cropping pattern, because it is a distinct geographical entity and, because of the availability of data in particular. The time horizon was set at 2005 because of the uncertainty of predicting technical and institutional developments over a longer span of time.

The attention paid to scenario development and integration of environmental quality aspects in particular, distinguishes the present study from other research on agricultural change at farm level in regions in the Netherlands. Because the analysis included an investigation of the alternative policy views it went beyond the field of regular farm management research. Furthermore it represents a shift from more practice-oriented research towards an exploration of possible and desirable long-term developments including problem perception and problem definition.

Chapter II reviews and assesses the relevance of a farm economics approach to research on agricultural change. It is contended that in any adjustment in agriculture the family farm is the central decision making unit and that agricultural change comes about by reactions to external forces, of which technical and institutional developments are to be the most influential. Also

involved are internal forces related to the technical and financial status of the farm and to behavioural and family-related factors. The Structure-Conduct-Performance framework was used to bring the elements together and draw up model requirements.

In *Chapter III* it is discussed that because of the orientations mentioned at the outset, namely assessing the optimal farm organization for different external conditions (farm planning) and analysis of the effects of policy measures (conditional forecasting) modelling had to combine the normative and the positive approach. The core of the modular system MIMOSA (MIcro MOdelling to Simulate changes in Agriculture), developed for the study, is a single period linear programming (LP) model. Apart from the usual farm activities, the LP model covers an environmental component representing input and leaching of nitrogen and pesticides. The next part of the MIMOSA system combines three modules for additional feedback within and between family farms, not accounted for in the optimization module. The continuation module accounts for changes in the number of entities within each category over time. By means of the innovation adoption module the results of the normative LP model, which indicates the optimal adaptation in farm organization, are finetuned to differences in adaptation behaviour and aggregated to the category level. With regard to feedback between family farms, only land transfer is considered in the MIMOSA system

The modular set-up of the MIMOSA system led to the research being divided into three phases: (1) comparative static model calculations for different representative farm types to assess the optimal farm organization for different external conditions and to elucidate the working of environmental economics models; (2) calculations for farm categories to analyse their path of development over time and (3) extension to the aggregated level by a weighted summing of the results from the different farm categories and by accounting for interfarm relationships.

In accordance with these phases building the MIMOSA system included: (a) scenario assessment to reduce the different policy views on future price policy and environmental policy, as well as the technical innovations to expect, to a restricted number of consistent, diverging variants; (b) the construction and implementation of an environmental economics model at the farm level; (c) the construction of modules of feedback within family farms to fine-tune the results of the normative linear programming procedure; and (d) the development of an aggregation procedure accounting for regional interdependence between individual farms. Part a, b and c were applied to arable farming in the North East Polder, part d of the MIMOSA system was not implemented in the present study.

Chapter IV presents the assessment of the scenarios. Variants were operationalized until 2005 for three main fields: technical development; environmental policy regulations; and agricultural price policy measures and general price changes. By combining the variants six scenarios were composed. Comparing the outcomes of Scenarios I and II and of Scenarios IV and V enabled the effects of environmental constraints to be assessed, whereas from Scenarios I and IV and Scenarios II and V the impact of the two price policy variants followed. Scenarios III and VI represented the impact of a compulsory switch to ecological farming. Scenarios I, II and V were considered as the combinations with the greatest practical relevance.

Chapter V deals with the identification of representative farm types for the population of 864 specialized crop production farms in the North East Polder. Cluster analysis by means of Ward's method was applied to the factor scores from principal components analysis of farm survey data on the 864 entities. This yielded 13 clusters, from which eight representative farm types resulted after combining several clusters according to size (ha) and type of soil without losing essential differences.

Chapter VI discusses the structure and data use of the environmental economics LP model. An inventory is given of the environmental effects incorporated into the LP model and of the methods used to assess these effects. Later in this chapter the technical innovations of Chapter IV are specified by LP activities. So, for every crop several cropping variants and new crop care methods were defined representing environmentally-friendlier farming techniques. Defining the cropping variants appeared to be time-consuming because no ready to use technical data were available. Information was collected from many sources and by consulting experts.

Chapter VII presents the results of LP computations for the most important farm type in the North East Polder (type IV), representing 239 of the 864 farms in the population. Compared to the basic situation (1989) all scenarios led to dramatic reductions in annual income. For t = 2000 this varied between circa NLG 28 000 for Scenario I, NLG 31 000 for Scenario II and NLG 15 000 for Scenario V, for example. Interestingly, in the case of Scenario I pesticide use was reduced by 89 per cent without imposing environmental regulation. This reduction was achieved mainly by technical innovation.

An analysis of adaptation, *i.e.* whether and when the optimal LP solutions would be realized by the entities in a specific farm category was added for conditional forecasting. *Chapter VIII* deals with this analysis of adaptation. Feedback within family farms was implemented and applied to farm category IV. Phase 2 (see above) of the MIMOSA project was executed, in this manner. Aggregation to the regional level was not elaborated; this would have meant an appreciable increase of LP computations and adaptation analyses for the seven other farm types in the North East Polder. Neither was the land transfer module implemented. Simulating the current institutional reallocation rules would require the formulation of two additional representative farm types and the assessment of transitional probabilities for two of the eight initial farm categories.

Regarding the application of feedback within family farms to farm category IV, firstly the continuation module accounts for changes in the number of entities by simulating succession. Secondly innovation adoption is simulated. It was assumed that the diffusion of a particular innovation over the entities in a farm category starts as soon as economic advantages result from the LP computations for the farm representative of the category. How rapidly the entities will respond depends on the characteristics of the innovation and on the resistance among the potental adopters. No empirical data were available on this rate of imitation. Instead, parameter estimates for the innovation diffusion model -- the Bass model was selected for this purpose -- were etablished by consulting experts. It appeared that considering farm discontinuation and differences in innovation adoption did not lead to important changes in the implication of the scenarios I, II and V for farm category IV in t = 2000.

Finally *Chapter IX* deals with the applicability of the farm economics approach for planning and conditional forecasting, with the most significant results and issues that merit further research. The LP module of the system MIMOSA is an useful instrument for planning, *i.e.* to assess the optimal reactions at the farm level to changing conditions. It is a tool to shed light on the interactions of production intensity, environmental aspects and farm income and to compare the implications of policy measures at farm level. Regarding conditional forecasting, the tendencies regarding the implications of the various scenarios are the most interesting outcome. Relationships and trends are more important than the absolute figures, particularly because the application reported covered only one specific group of family farms. It should be noted that the additional insights gained by a farm-based approach (rather than econometric research, for instance) have to be judged in terms of the additional costs involved.

Further refining of the LP model should focus on (a) the risks associated with the environmentally-friendlier cropping variants, (b) the incorporation of an organic matter balance, (c) integration of additional aspects of the environmental impact of pesticides, (d) new technical developments and planned policy regulations, (e) adjustment of the organization of the LP input so that farm-specific constraints and price and yield figures can be considered in a more user-friendly way and (f) a more extensive assessment of the representation of family farms with regard to their financial status and with regard to management objectives in relation to the farm family life-cycle.

To recap, the major findings and conclusions of the study are:

- A farm-based methodology combining normative and positive analysis can contribute to give insights for both farm planning and conditional forecasting;
- Linear programming of the individual farm is a method well suited to indicate the trade offs between farm economic aspects and environmental aspects of arable farming for their whole traject of interaction;
- A modular set-up for a farm-based approach has major advantages both with respect to implementation and application. The problem of agricultural change can be studied in an outwardly spiralling manner, firstly at the farm level, and subsequently at the aggregate level;

- A farm based approach is time-consuming and labour-intensive. For conditional forecasting whether the method is preferable to other techniques such as the time series approach, will depend on the specific research question;
- The root causes of the present environmental problems result from failures in the system of economic incentives. In agriculture the economic incentives are largely determined by price and market regulations. As follows from the scenario results, a policy strategy of attuning environmental regulations to price policy regulations is preferable, further in policy implementation attention should be paid to the expected technical innovations;
- Price policies appear to be most important for the future of arable farming, the model results indicate that the targets formulated for the reduction of pesticide use and the emission constraints for pesticides and nitrogen according to the (proposed) Dutch environmental regulations are easily met; *i.e.* with low income losses.

SAMENVATTING

Bij beleidsmakers, agrarische ondernemers en andere belanghebbenden bestaat een grote behoefte aan en belangstelling voor een beter inzicht in de aanpassingen die de agrarische sector de komende jaren te wachten staan. Deze studie betreft zowel: (a) planning, dat wil zeggen de normatieve bepaling van de aanpassing aan de voortdurend veranderende omstandigheden op het niveau van het individuele akkerbouwbedrijf als (b) de analyse van alternatieve visies ten aanzien van prijs- en milieubeleid voor de akkerbouw en hun gevolgen.

Hoofdstuk I geeft een algemene inleiding tot het onderzoek en presenteert de doelstellingen ervan. Deze waren: (1) het ontwikkelen van een modelsysteem, uitgaande van een bedrijfseconomische aanpak, om de gevolgen van verschillende scenarios ten aanzien van technische ontwikkeling en milieubeleid en prijs- en marktbeleid voor de landbouw aan te geven op bedrijfsniveau en op regionaal niveau, (2) het onderscheiden en beschrijven van technische vernieuwingen en van alternatieve beleidsvisies voor de Nederlandse akkerbouw door middel van een aantal scenarios en (3) het toepassen van een gedeelte van het genoemde modelsysteem en van de scenarios op de akkerbouw in de Noordoostpolder, het gebied dat dienst deed als voorbeeld in dit onderzoek. De keuze voor de Noordoostpolder werd ingegeven door het intensieve bouwplan, de duidelijke geografische begrenzing en met name door de beschikbaarheid van gegevens voor dit gebied. De tijdshorizon in het onderzoek was gesteld op 2005 omdat technische en institutionele[1] veranderingen daarna zeker niet meer in te schatten zijn.

Hoofdstuk II geeft een overzicht en vaststelling van de betekenis van een bedrijfseconomische aanpak voor onderzoek van agrarische veranderingen. Er wordt gesteld dat elke verandering in de Nederlandse landbouw teruggaat naar beslissingen van het gezinsbedrijf en dat deze veranderingen ontstaan als

[1] Met institutionele ontwikkelingen wordt in het onderzoek het geheel aangeduid van overheidsmaatregelen op het gebied van markt- en prijsbeleid en milieubeleid voor de landbouw.

reacties op externe determinanten, met technische en institutionele ontwikkelingen als de belangrijkste. Ook van belang zijn interne determinanten die verband houden met de technische en financiële toestand van het bedrijf en met de gezinssituatie. Het Structure-Conduct-Performance raamwerk brengt al deze elementen samen.

In *Hoofdstuk III* wordt besproken dat vanwege de doelstellingen van het onderzoek, namelijk zowel planning als beleidsanalyse, voor de modellering een combinatie nodig was van de normatieve en de positieve aanpak. Centraal in het MIMOSA (MIcro Modelling to Simulate changes in Agriculture) systeem staat een lineair programmerings (LP) model van het individuele (representatieve) bedrijf. Dit LP model omvat naast de gebruikelijke onderdelen van de bedrijfsvoering, een milieucomponent die de input en uitspoeling van stikstof en bestrijdingsmiddelen aangeeft. Het tweede gedeelte van het MIMOSA systeem bestaat uit een module voor de feedback binnen het gezinsbedrijf (continuïteit van het bedrijf en adoptiegedrag) en een voor de feedback tussen de verschillende bedrijven (grondmarkt).

Door de modulaire opzet van het MIMOSA systeem werd het onderzoek in drie fasen verdeeld: (1) comparatief-statische berekeningen op het niveau van het representatieve bedrijf om de optimale aanpassing in de bedrijfsvoering aan te geven en om inzicht te krijgen in de werking van een milieu-economisch LP model, (2) berekeningen op groepsniveau om het ontwikkelingspad per categorie aan te geven en (3) aggregatie tot regionaal niveau door een gewogen optelling van de resultaten per categorie rekening houdend met de feedback tussen bedrijven.

In overeenstemming hiermee omvatte het ontwikkelen van het MIMOSA systeem: (a) vaststelling van de scenarios, (b) het ontwikkelen van een milieu-economisch LP model op bedrijfsniveau, (c) het ontwikkelen van een innovatie adoptie module en een continuïteitsmodule om de LP resultaten te vertalen naar categorieniveau en (d) het ontwikkelen van een aggregatieprocedure rekening houdend met regionale samenhangen. Onderdeel d van het MIMOSA systeem werd niet toegepast voor het voorbeeld gebied de Noordoostpolder.

In *Hoofdstuk IV* is de constructie van de scenarios beschreven. Er werden alternatieven geformuleerd voor drie gebieden: technische ontwikkeling, regelingen in het kader van het milieubeleid en prijsveranderingen in het kader van het EG markt- en prijsbeleid en algemene prijsveranderingen. Door de combinatie van alternatieven ontstonden zes scenarios. Scenario I, II en III veronderstellen een marktgericht prijsbeleid terwijl Scenario IV, V en VI produktiebeperking omvatten en minder scherpe prijsdalingen. Verder omvatten Scenario I en IV geen milieurestricties; is in Scenario II en V het standaard milieubeleid opgenomen en veronderstellen Scenario III en VI een verplichting tot ecologische akkerbouw. Van de verschillende scenarios is de practische betekenis het grootst van I, II en V.

Hoofdstuk V betreft het vaststellen van representatieve bedrijven voor de populatie van 864 gespecialiseerde akkerbouwbedrijven in de Noordoostpolder. Hiertoe werd principale componenten analyse toegepast op gegevens uit de Landbouwtelling van 1988 en vervolgens clusteranalyse volgens de methode van Ward. Dit leverde 13 clusters op welke na verdere samenvoeging resulteerden in acht representatieve bedrijven.

Hoofdstuk VI geeft een overzicht van de ontwikkeling van het milieu-economisch LP model voor de akkerbouw in de Noordoostpolder. Er is vooral aandacht gegeven aan de keuze van de milieucriteria en aan de methoden om de benodigde milieuparameters te verkrijgen. Verder zijn in dit hoofdstuk de in Hoofdstuk IV gesignaleerde technische ontwikkelingen gepreciseerd en vertaald naar LP input. Zo zijn voor elk gewas een reeks van zogenaamde gewasvarianten opgesteld die verschillen naar milieutechnische en bedrijfeconomische LP coefficienten. Ook zijn diverse LP activiteiten opgesteld die nieuwe technieken met betrekking tot de gewasbescherming vertegenwoordigen. Het opstellen van de teeltvarianten bleek tijdrovend omdat geen rechtstreeks bruikbare technische gegevens aanwezig waren. De informatie werd uit vele bronnen verkregen, met name door het raadplegen van de betreffende technische onderzoekers.

In *Hoofdstuk VII* zijn de uitkomsten van de LP berekeningen voor het belangrijkste bedrijfstype (Type IV, dat 239 van de 864 bedrijven in de populatie omvat en is te karakteriseren als een 30 hectare bedrijf met een accent op consumptieaardappelen) in de Noordoostpolder beschreven. De berekeningen geven de gevolgen aan van de verschillende scenarios. In vergelijking met de uitgangssituatie hebben alle scenarios grote dalingen van het jaarlijkse inkomen tot gevolg. Voor t = 2000 liep dit bijvoorbeeld uiteen van circa f 28 000 voor Scenario I, f 31 000 voor Scenario II en f 15 000 voor Scenario V. Een interessante uitkomst was dat bij Scenario I -- dus zonder milieurestricties -- het bestrijdingsmiddelenverbruik met 89 procent kon worden teruggebracht, met name door toepassing van nieuwe technische mogelijkheden.

In *Hoofdstuk VII* is de optimale aanpassing in de bedrijfsvoering beschreven voor de verschillende scenarios. Met het oog op beleidsondersteuning is vervolgens een aanpassingsanalyse uitgevoerd, dat wil zeggen of, en wanneer, de optimale aanpassingen zoals die volgen uit de berekeningen gerealiseerd worden door de bedrijven gerepresenteerd door het LP model. *Hoofdstuk VIII* beschrijft de uitkomsten van deze aanpassingsanalyse voor bedrijfstype IV. De modules voor innovatie adoptie en bedrijfscontinuïteit simuleren de feedback binnen de gezinsbedrijven op basis van externe informatie. Voor de innovatie adoptie werd gebruik gemaakt van het diffusiemodel van Bass. De aanpassingsanalyse bleek op de scenario resultaten voor t = 2000 weinig effect te hebben.

Op de beschreven wijze werd fase 2 (zie hiervoor) van het MIMOSA onderzoek uitgevoerd. Aggregatie naar regionaal niveau werd niet uitgewerkt omdat dit een herhaling van de berekeningen (LP en aanpassingsanalyse) betekende voor de andere zeven bedrijfstypen. Ook werd, zoals reeds opgemerkt, de module voor land transfer niet toegepast. In het geval van de akkkerbouw in de Noordoostpolder is dit, uitgaande van het vigerende heruitgiftebeleid in dit gebied, evenwel eenvoudig te doen. Hiervoor zijn twee extra representatieve bedrijven nodig en de kans op bedrijfsvergroting voor twee van de acht representatieve bedrijven (namelijk die van 24 hectare). Er dient te worden opgemerkt dat het weglaten van de land transfer module geen gevolgen heeft voor de scenario uitkomsten. De berekeningen betreffen een bedrijfstype van 30 ha dat derhalve bij het huidige heruitgiftebeleid niet in aanmerking komt voor bedrijfsvergroting.

Hoofdstuk IX tenslotte bespreekt de bruikbaarheid van het MIMOSA systeem, de belangrijkste resultaten van de toepassing voor de Noordoostpolder en geeft tevens punten voor verder onderzoek. Benadrukt wordt dat het belangrijkste doel van het onderzoek het ontwikkelen van een milieu-economisch LP model was en het nagaan hoe deze normatieve aanpak te combineren met de positieve onderzoeksaanpak. Het LP model is te zien als een zeer bruikbaar instrument voor normatief onderzoek op bedrijfsniveau, dat wil zeggen om inzicht te verkrijgen in de samenhang van bedrijfsvoering, milieukwaliteit en bedrijfssaldo. Vanuit het standpunt van de beleidsondersteuning zijn de tendensen in de scenario uitkomsten het meest interessant. De modules voor de aanpassingsanalyse werden niet op hun werking getest, bij de interpretatie van de uitkomsten dient daarmee rekening te worden gehouden.

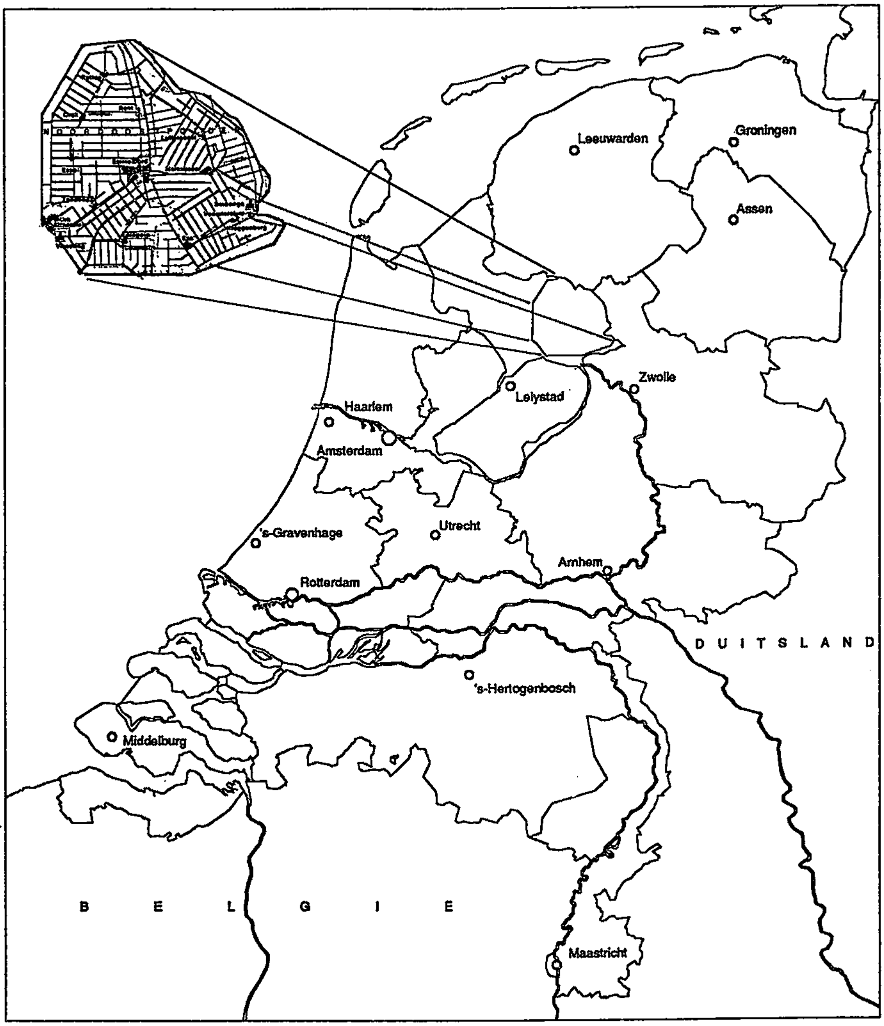
Verder onderzoek zou met name aandacht moeten geven aan (a) de risico's verbonden met de verschillende teeltvarianten, (b) het opnemen van een organische stof balans in het LP model, (b) het inbouwen in het LP model van andere milieuaspecten van bestrijdingsmiddelen en hun afbraakprodukten, (c) nieuwe technische mogelijkheden en beleidsmaatregelen, (d) aanpassen van de LP invoer zodat bedrijfsspecifieke gegevens makkelijker beschouwd kunnen worden en (f) de representatie van gezinsbedrijven met name voor de financiele situatie en met betrekking tot de doelstellingen van de bedrijfsvoering in relatie tot de gezins-bedrijfslevenscyclus.

De conclusies van het onderzoek zijn als volgt samen te vatten:

- Een bedrijfseconomische aanpak waarbij de normatieve analyse (LP) wordt gecombineerd met de positieve kan van dienst zijn bij zowel planning op bedrijfsniveau als bij ondersteuning van het overheidsbeleid met betrekking tot de landbouw;
- Lineaire programmering is een geschikte methode om de uitruil aan te geven tussen de bedrijfseconomische aspecten en de milieu-aspecten van de agrarische bedrijfsvoering;
- Een modulaire opzet bij een bedrijfseconomische aanpak biedt de mogelijkheid het complexe aanpassingsproces in de landbouw te onderzoeken op een concentrische wijze. Bovendien heeft het voordelen voor implementatie, toepassing, validatie en voor verder modelonderzoek;
- Een bedrijfseconomische aanpak is arbeidsintensief; met betrekking tot beleidsanalyse zal het van de specifieke onderzoeksvraag afhangen of de aanpak te preferen is boven andere technieken zoals tijdreeksstudie;

- Zoals blijkt uit de scenario resultaten is afstemming van milieubeleid en markt-en prijsbeleid van groot belang, verder dient men bij de beleids--invulling expliciet aandacht te geven aan de verwachte technische vernieuwingen;
- Het EG prijsbeleid heeft voor de toekomst van de akkerbouw veel ingrijpender gevolgen dan het milieubeleid; de doelstellingen van het (voorgenomen) beleid ten aanzien van de vermindering van het bestrijdingsmiddelengebruik en van de uitspoeling van deze middelen en van stikstof naar het grondwater zijn met een gering inkomenverlies te realiseren.

MAP OF THE NORTH EAST POLDER



Appendix VI.A Structure of the LP model

ACTIVITIES	Production activities 1,.......k	Seasonal labour 1,.......... l	Variable operations: methods of control and own mechanization or contract work 1,.......................m	New machinery for crop care 0/1 a	 b	 c	Pesticides 1,....n	Fixed charges	Right-hand Side
CONSTRAINTS									
Max. hectares	+1								Total land
Rotation restrictions	+1								Max. ha of each crop or group of crops
Fixed labour in periods of 14 days	$+a_{ij}$	-1	$+a_{ij}$						Available fixed labour in hours
Casual labour in periods of 14 days		+1							Available casual labour in hours
Coupling production activities and variable operations	+1		-1						<= 0
Coupling production activities and new mach.	+1			-999					<= 0
	+1				-999				<= 0
	+1					-999			<= 0
Coupling production activities and chemicals	$+a_{ij}$		$+a_{ij}$				-1		<= 0
Discharges of chemicals and nitrogen to groundwater	$-a_{ij}$		$-a_{ij}$						
Fixed charges								1	= 1
OBJECTIVE FUNCTION	Gross margins excl. costs of chemicals	Costs per hour	Costs per hectare	Annual costs a	 b	 c	Costs per kg a.i.		

Appendix VI.B Factor endowments and other characteristics of the representative farm types

Characteristic	FARM TYPE I	II	III	IV	V	VI	VII	VIII
1. Average farm size in ha	24	24	30	30	30	36	42	48
2. Labour available (hours/year)								
. Fixed labour[1]	1.2	1.3	1.3	1.0	1.1	1.1	1.1	1.1
. Casual labour								
- max hours/year	2352	578	846	224	486	558	436	850
- max hours per fortnight	780	190	280	80	160	180	145	280
5. Standard cropping activities in ha								
. winter wheat	3.0	4.0	2.75	6.0	3.5	6.5	7.5	10.0
. summer barley	0.5	1.0	0.75	1.5	1.0	1.0	1.0	3.0
. sugarbeet	5.0	5.5	7.5	9.0	7.5	9.0	11.0	11.0
. potato	7.8	8.0	10.0	9.0	10.0	10.0	12.0	14.0
. onions	2.6	2.0	3.0	3.0	3.5	6.0	4.5	5.0
. carrots	1.0	1.0	-	0.3	1.0	-	1.0	1.0
. chicory	3.6	2.0	1.0	0.45	2.0	2.0	3.0	3.0
. green peas	0.5	0.5	1.0	0.3	1.0	1.5	2.0	1.0
. seedgrass	-	-	2.5	0.45	0.5	-	-	-
. tulips	-	-	1.5	-	-	-	-	-
7. Mechanization status[2]	I	I	I	I	I	II	II	II
8. Fixed costs NLG/year[3]	158110	164140	174155	156035	160175	187861	195456	205761

[1] Full-time equivalent
[2] See table VI.D.1
[3] See table VI.D.3

Appendix VI.C.1 Input and emission of nutrients and pesticides standard cropping variants

WINTER WHEAT

Pesticide use

Pesticide name	Type	Quantity active ingredients kg/ha	DT50 in weeks	Conc. groundwater in µg/l sand	clay
Mecoprop	H	2.24	2	1.10	0.20
MCPA	H/G	2.00	2	0.02	0.00
Chlormequat	G	0.90	10	0.00	0.00
Fenpropimorph	F	0.75	0	0.00	0.00
Propiconazole	F	0.13	8	0.00	0.00
Maneb 80 %	F	1.60	7	0.00	0.00
Pirimicarb 50%	I	0.10	15	0.00	0.00
Total		7.74		0.20	0.05

H = herbicide; G = growth regulator; N = nematicide; F = fungicide; I = insecticide; D = other

N balance

Supply (kg/ha/year)			Discharge (kg/ha/year)			Leaching N kg/ha/year	NO_3^-
Deposition	Fertilization	Mineralization	Uptake product[1]	Evaporation	Denitrification		mg/l
30	160	-	170	8	10	2	2

[1] Straw included

SUMMER BARLEY

Pesticide use

Pesticide name	Type	Quantity active ingredients kg/ha	DT50 in weeks	Conc. groundwater in µg/l sand	clay
MCPA/Mecoprop	H	2.6	2		
Propiconazole	F	0.125	8	0.00	0.00
Total		2.725			

N balance

Supply (kg/ha/year)			Discharge (kg/ha/year)			Leaching N kg/ha/year	NO_3^-
Deposition	Fertilization	Mineralization	Uptake product[1]	Evaporation	Denitrification		mg/l
30	50	-	80	-	-	-	-

[1] Straw included

SUGARBEET

Pesticide use

Pesticide name	Type	Quantity active ingredients kg/ha	DT50 in weeks	Conc. groundwater in $\mu g/l$ sand	clay
Fenmedipham	H	0.19	8	0.00	0.00
Chloridazon	H	2.60	24	0.13	0.00
Metamitron	H	0.84	4	0.00	0.00
Parathion 25 %	I	0.25	7	0.00	0.00
Pirimicarb 50%	I	0.25	15	0.00	0.00
Total		3.83		0.13	0.00

N balance

Supply (kg/ha/year)			Discharge (kg/ha/year)			Leaching N kg/ha/year	NO_3^-
Deposition	Fertilization	Mineralization	Uptake product	Evaporation	Denitrification		mg/l
30	140	-	125	7	30	8	8

POTATO[2]

Pesticide use

Pesticide name	Type	Quantity active ingredients kg/ha	DT50 in weeks	Conc. groundwater in $\mu g/l$ sand	clay
Metribuzin	H	0.70	5	0.00	0.00
Dichloropropene	N	174.00	2	12.2	0.60
Maneb	F	8.91	7	0.00	0.00
Fentin-acetate	F	2.97	20	0.00	0.00
Parathion 25 %	I	0.25	7	0.00	0.00
Pirimicarb 50 %	I	0.25	15	0.00	0.00
Diquat	H	1.00		?	?
Total		188.08		12.55	0.64

[2] Rotation frequency 1:3, soil fumigation every rotation

N balance

Supply (kg/ha/year)				Discharge (kg/ha/year)				Leaching N kg/ha/year	NO_3^-
Deposition	Fertilization manure	Fertilization fertilizer	Mineralization	Uptake product	Evaporation manure	Evaporation fertilizer	Denitrification		mg/l
30	220[a]	210	-	160	38	13	199	50	55

[a] Of which 44 kg N effective for the potato crop

ONION

Pesticide use

Pesticide name	Type	Quantity active ingredients kg/ha	DT50 in weeks	Conc. groundwater in µg/l sand	clay
Propachlor 480 g/l	H	4.20	1	0.00	0.00
Pendimethalin	H	2.58	24	0.05	0.00
Paraquat/	H	0.36		0.00	0.00
Diquat	H	0.24		0.00	0.00
Difenoxuron	H	0.50	3	0.00	0.00
Maneb/	F	7.80	7	0.00	0.00
Chlorothalonil	F	1.50	3	0.00	0.00
Vinclozonil	F	0.75	3	0.00	0.00
Parathion 25 %	I	0.70	7	0.00	0.00
Maleic hydrazide	G	2.25	2	0.02	0.02
Total		18.65		0.07	0.02

N balance

Supply (kg/ha/year)			Discharge (kg/ha/year)			Leaching N kg/ha/year	NO_3^-
Deposition	Fertilization	Mineralization	Uptake product	Evaporation	Denitrification		mg/l
30	120	-	120	6	19	5	5

PEAS

Pesticide use

Pesticide name	Type	Quantity active ingredients kg/ha	DT50 in weeks	Conc. groundwater in µg/l sand	clay
Bentazone	H	0.72	6	7.00	7.00
Simazine 50 %	H	0.35	8	0.02	0.01
Methabenthiazuron	H	1.40	19	0.00	0.00
Vinclozolin	F	0.50	3	0.00	0.00
Parathion 25 %	I	0.75	7	0.00	0.00
Total		3.72		7.02	7.01

N balance

Supply (kg/ha/year)			Discharge (kg/ha/year)			Leaching N kg/ha/year	NO_3^-
Deposition	Fertilization	Mineralization	Uptake product[1]	Evaporation	Denitrification		mg/l
30	20	-	225	1	50	12	2

[1] Straw included

CARROTS

Pesticide use

Pesticide name	Type	Quantity active ingredients kg/ha	DT50 in weeks	Conc. groundwater in µg/l sand	clay
Metoxuron	H	2.40	3	0.00	0.00
Linuron	H	0.40	31	0.04	0.00
Chlorofenvinphos	I	2.00	5	0.00	0.00
Bromophos	I	5.00	1	0,05	0.00
Iprodion	F	4.50	6	0.00	0.00
Maneltra-borium fertilizer		0.20		?	?
Total		14.50		0.09	0.00

N balance

Supply (kg/ha/year)			Discharge (kg/ha/year)			Leaching N kg/ha/year	NO_3^-
Deposition	Fertilization	Mineralization	Uptake product	Evaporation	Denitrification		mg/l
30	16	55	100	1	-	-	-

CHICORY

Pesticide use

Pesticide name	Type	Quantity active ingredients kg/ha	DT50 in weeks	Conc. groundwater in µg/l sand	clay
Propyzamide	H	1.50	?	?	?
Dimethoate	I	0.60	2	0.07	0.05
Total		2.10		0.07	0.05

N balance

Supply (kg/ha/year)			Discharge (kg/ha/year)			Leaching N kg/ha/year	NO_3^-
Deposition	Fertilization	Mineralization	Uptake product	Evaporation	Denitrification		mg/l
30	-	40	70	-	-	-	-

Appendix VI.C.2 Potato cropping variants

no.	Rotation frequency	Percentage Bintje/PSR[1]	Nematode control[2]	Yield[3] ton/ha	Nematicides kg a.i./ha	Contract work costs[4]	Gross margin/ha[5]
1	1:3	100	1	49.4	174	1 025	6 600
2	1:3	100	1*	47.0	87	885	6 211
3	1:3	50	1*	Bintje: 51.0	174	1 025	6 852
				PSR var: 53.5	-	745	6 674
4	1:3	50	2*	Bintje: 50.7	34.8	887	6 806
				PSR var: 53.2	-	745	6 629
5	1:3	50	4	Bintje: 50.5	-	745	6 774
				PSR var: 53.0	-	745	6 598
6	1:3	50	3*	Bintje: 50.8	-	745	6 819
		50		PSR var: 53.3	-	745	6 643
7	1:4	100	1	53.0	174	1 025	7 175
8	1:4	100	1*	51.3	87	885	6 907
9	1:4	100	3	50.3	-	745	6 742
10	1:4	50	1*	Bintje: 54.1	174	885	7 348
				PSR var: 56.8	-	745	7 163
11	1:4	50	2*	Bintje: 53.9	34.8	887	7 317
				PSR var: 56.6	-	745	7 132
12	1:4	50	4	Bintje: 53.8	-	745	7 294
				PSR var: 56.4	-	745	7 111
13	1:4	50	3*	Bintje: 54.0	-	745	7 326
				PSR var: 56.6	-	745	7 174
14	1:5	100	1	56.4	174	1 025	7 719
15	1:5	100	1*	55.3	87	885	7 535
16	1:5	100	4	52.7	-	745	7 125
17	1:5	100	3*	54.2	-	745	7 526
18	1:5	100	3	55.2	-	745	7 526
19	1:5	50	2*	Bintje: 57.0	34.8	887	7 810
				PSR var: 59.9	-	745	7 624
20	1:5	50	4	Bintje: 56.9	-	745	7 801
				PSR var: 59.8	-	745	8 609
21	1:5	50	3*	Bintje: 57.1	-	745	7 822
				PSR var: 59.9		745	7 613
22	1:6	100	4	56.6		745	7 746
23	1:6	50	4	Bintje: 59.5	-	745	8 203
				PSR var: 62.4	-	745	8 006

[1] PSR: resistant to potato nematodes (pathotype A)
A fixed combination of 50 % Bintje and 50 % PSR variety was chosen, as it is expected that growing more of the PSR variety will stimulate the development of new pathotypes from the present nematode population in the soil.

[2] Nematode control:
- 1 = soil fumigation, every rotation and soil sampling 0.5 treatment at NLG 169 per ha for Bintje
- 1* = soil fumigation, every second rotation and soil sampling 0.5 treatment for Bintje
- 2* = soil fumigation infected patches, every second rotation and intensive soil sampling 1.78 treatments for Bintje
- 3 = bait crop, every rotation and soil sampling 0.5 treatments for Bintje
- 3* = bait crop, every second rotation and soil sampling 0.5 treatments for Bintje
- 4 = no method applied and soil sampling 0.5 treatments for Bintje

[3] Price for Bintje NLG 0.16 per kg and NLG 0.15 for the PSR variety. For each variant the value of the by-product is NLG 200 per hectare.

[4] Contract work costs for harvesting and soil fumigation.

[5] Excl. costs of pesticides

For the costs of the bait crop see optional operation for potato

Source: De Buck (1991) based on information from DLO-Centre for Agrobiological Research (CABO Wageningen) and on KWIN 89/90 (PAGV, 1989).

Optional operations for Potato

Activity: N dressing option 1 (= standard incl. manure)

		Quantity/ha	Price (NLG)	NLG/ha
Yield	main product	..	0.16 per kg	..
Gross output (a)				..
Fertilizer	N	210 kg	1.14 per kg	239
	organic	9 tons	0.09 per kg	81
Total variable costs (b)				320
Gross margin per (a-b)				-320

Of the organic manure 44 kg N is effective, see section VI.3.2.1
Contract work organic manure NLG 85 per ha
N leaching 50 kg/ha

Activity: N dressing option 2 ("Neeteson")

		Quantity/ha	Price (NLG)	NLG/ha
Yield	main product	-750	0.16 per kg	-120
Gross output (a)				-120
Fertilizer	N	185 kg	1.14 per kg	211
Total variable costs (b)				211
Gross margin per (a-b)				-331

N leaching 9 kg/ha

Activity: N dressing option 3 (Split fertilization supported by petiole analysis)

		Quantity/ha	Price (NLG)	NLG/ha
Yield	main product	..	0.16 per kg	..
Gross output (a)				..
Fertilizer	N	188 kg	1.14 per kg	214
	petiole analysis	1	95 per analysis	95
Total variable costs (b)				309
Gross margin per (a-b)				-309

N leaching 10 kg/ha

Activity: Weed control option 1 (Metribuzin total field spraying)

	Quantity/ha	Price (NLG)	NLG/ha
Herbicides Metribuzin	1 l	133	133
Gross margin per ha			-133

Activity: Weed control option 2 (spraying with Metribuzin under leafs)

	Quantity/ha	Price (NLG)	NLG/ha
Herbicides Metribuzin	0.5 l	133 per l	67
Gross margin per ha			-67

Required: row spraying accessories see Appendix VI.E or contract work NLG 70 per ha

Activity: Weed control option 3 (Late ridging)

	Quantity/ha	Price (NLG)	NLG/ha
Herbicides Metribuzin	0.125 l	133 per l	17
Gross margin per ha			-17

Required: investment in earther and ridge hoe, see Appendix VI.E

Activity: Late Blight control option 1 Bintje

	Quantity/ha	Price (NLG)	NLG/ha
Fungicides Maneb 80 %	0	7.50 per l	0
Maneb/Fentin (12 applications)	27 l	12.00 per l	324
Gross margin per ha			-324

Activity: Late Blight control option 1 AM-variety

	Quantity/ha	Price (NLG)	NLG/ha
Fungicides Maneb 80 %	0	7.50 per l	0
Maneb/Fentin (9 applications)	20.25 l	12.00 per l	243
Gross margin per ha			- 243

Activity: Late Blight control option 2 Bintje

	Quantity/ha	Price (NLG)	NLG/ha
Fungicides Maneb 80 % (7 applications)	14 l	7.50 per l	105
Maneb/Fentin (2 applications)	4.50 l	12.00 per l	54
Gross margin per ha			- 159

Activity: Late Blight control option 2 AM-variety

	Quantity/ha	Price (NLG)	NLG/ha
Fungicides Maneb 80 % (5 applications)	10.00 l	7.50 per l	75
Maneb/Fentin (1 application)	2.25 l	12.00 per l	27
Gross margin per ha			- 102

Activity: Haulm killing option 1

	Quantity/ha	Price (NLG)	NLG/ha
Herbicides Diquat	1.00 l	120.00 per l	120
Gross margin per ha			- 120

Activity: Haulm killing option 2

	Quantity/ha	Price (NLG)	NLG/ha
Herbicides Diquat	0.00 l	120.00 per l	0
Gross margin per ha			0

Required: Haulm shredder, see Appendix VI.E

Nematode control: Bait crop

		Quantity/ha	Price (NLG)	NLG/ha
Yield	set-aside premium		1500	1500
Gross output (a)				1500
Planting material		1500 kg	0.05 per kg	75
Herbicides		4 l	62.00 per l	248
Sundries	interest	NLG 1500	7 percent	105
	insurance	NLG 1500	0.3 percent	5
	marketing board			40
	sorting			210
	storage			200
Total variable costs (b)				883
Gross margin per ha O.M. (a-b)				618
Costs pesticides				248
Gross margin in model				866

Appendix VI.C3 New crops

HEMP

Gross margin calculation base year values

		quantity per ha	price (NLG)	NLG/ha	kg a.i. per ha
Yield	main product	9.6 t	300 per ton	2 880	
	EC ha premium			895	
Gross output (a)				3 775	
Sowing seed		20 kg	8.00 per kg	160	
Fertilization:					
	N	200 kg	1.14 per kg	228	
	P_2O_5	90 kg	1.04 per kg	94	
	K_2O	250 kg	0.57 per kg	143	
Biocides:					
	Vinchlozolin F	0.50 l	83.00 per l	42	0.25
	Ipropion F	0.50 l	87.00 per l	44	0.25
Sundries:					
	Interest			40	
	Insurance			27	
Total variable costs (b)				776	
Gross margin ha O.M. (a-b)				2 999	
Costs biocides				85	
Contract work standard					
Heading				176	
Mowing/chopping				1 084	
Transport (farm)				79	
Storage				246	
Transport				370	
Gross margin in model				1 129	

Source: Wolters, 1991

OIL FLAX

Gross margin calculation base year values

			quantity per ha	price (NLG)	NLG/ha	kg a.i. per ha
Yield	main product		1800 - 2200 kg	0.60 per kg	1 200	
	by-product				-	
	EC ha premium				1 426	
Gross output (a)					2 626	
Sowing seed			85 kg	2.90 per kg	247	
Fertilization:						
	N		85 kg	1.14 per kg	97	
	P_2O_5		70 kg	1.04 per kg	73	
	K_2O		80 kg	0.57 per kg	46	
Biocides:						
	Bentazon	H	3 l	57.00 per l	171	1.44
	Sethoxydim	H	1.5 l	70.00 per l	105	0.29
	Mineral oil	D	1.5 l	4.25 per l	11	2.08
	Parathion 25 %	I	3.0 l	9.50 per l	28	0.75
Sundries:						
	Interest				10	
	Insurance				22	
	Drying and cleansing				75	
Total variable costs (b)					884	
Gross margin ha O.M. (a-b)					1 742	
Costs biocides					315	
Contract work standard						
Mowing					235	
Threshing					400	
Gross margin in model					1 422	

Source: Wolters, 1991

CHICORY INULUN

Gross margin calculation base year values

		quantity per ha	price (NLG)	NLG/ha	kg a.i. per ha
Yield	main product	55 t	0.12 per kg	6 600	
Gross output (a)				6 600	
Sowing seed		4 kg	285 per kg	1 140	
Fertilization:					
	N	140 kg	1.14 per kg	160	
	P_2O_5	100 kg	1.04 per kg	104	
	K_2O	145 kg	0.57 per kg	83	
Biocides:					
	Carbetamide H	7.0 l	33.00 per l	231	2.10
	Chlorprofam H	1.5 l	12.75 per l	19	0.60
Sundries:					
	Interest			350	
	Insurance			40	
Total variable costs (b)				2 126	
Gross margin ha O.M. (a-b)				4 474	
Costs biocides				250	
Contract work standard					
Sowing				150	
Harvesting				670	
Earthing\rolling				270	
Gross margin in model				4 724	

Source: Wolters, 1991

CORN COB MIX (CCM)

Gross margin calculations base year values

		quantity per ha	price (NLG)	NLG/ha	kg a.i. per ha
Yield	main product	10 ton d.m.	0.25 per kg	2 500	
Gross output (a)				2 500	
Sowing seed		0.96 kg	285 per kg	274	
Fertilization:					
	N	200 kg	1.14 per kg	228	
	P_2O_5	90 kg	1.04 per kg	94	
	K_2O	300 kg	0.57 per kg	171	
Biocides:					
	Atrazin/bentazon H	4.0 l	24.00 per l	96	1.60
	Mineral oil D	3.0 l	4.25 per l	13	2.58
Sundries:					
	Interest			33	
	Insurance			30	
Total variable costs (b)				938	
Gross margin ha O.M. (a-b)				1 562	
Costs biocides				109	
Contract work for account of buyer					
Gross margin in model				1 670	

Source: Wolters, 1991

Appendix VI.D1 Inventory and costs of machinery in the base year

Type of machinery	Number	Replacement value	Annual costs in % of replacement value	Total annual costs (NLG) base year value
<u>Fixed machinery</u>				
Tractor 40-60 kW	1	25 000	15.5	3 875
Dumping cart 8 t	1	18 000	11.7	2 106
Cart 4 t	2	4 000	10.6	424
Plough 2.0 m (stubble)	1	7 000	10.9	763
Roller cambridge	1	1 000	9.3	93
Cultivator (fixed tine) 3 m	1	4 000	10.8	432
Weed harrow 4.5 m	1	3 000	11.7	351
Rotor harrow 3 m	0.5	7 500	15.3	1 147
Sowing machine 3 m	0.5	4 000	11.7	468
Fertilizer dispenser 12 m	1	3 000	15.4	462
Spraying machine 21 m	0.5	10 000	13.6	1 360
Hoeing machine 3 m	1	8 000	13.5	1 080
Row miller	0.5	10 000	19.9	1 990
Cutter bar	1.0	6 500	19.6	1 274
Potato setting machine 4 lines	0.5	11 000	15.9	1 749
Box filler, transporter, dumper *etc.*	0.5	25 000	14.9	3 725
Front loader	1	7 000	13.9	937
Shovel	1	1 500	12.1	181
Steamcleaner	1	5 000	16.5	825
Draincleaner	1	12 000	15.2	1 824
Airheater	1	3 000	14.0	420
Total				25 486
<u>Variable machinery I</u>				
Tractor 60-90 kW	1	70 000	15.5	10 850
Plough (reversible) 1.2 m	1	16 000	16.6	2 656
Cultivator spring tine 3 m	1	3 000	12.6	378
Total				13 884
<u>Variable machinery II</u>				
Tractor 90-120 kW	1	110 000	15.5	17 050
Cart 6 t	1	6 000	10.6	636
Plough (reversible) 1.6 m	1	20 000	16.6	3 320
Cultivator spring tine 5 m	1	4 000	12.6	504
Acrobat rake 3 m	1	2 500	10.4	410
Bale clencher	1	4 000	14.0	560
Bale sled	1	3 000	13.2	396
Additional costs for not sharing fixed machinery				10 439
Total				33 315

Source: PAGV, 1989; Groot, 1989; Noordam, 1991

Appendix VI.D.2 Contract work operations and tariffs[a]

Operation		Tariff NLG per ha
Soil fumigation (excl. costs of nematicides)		280
Precision sowing	sugarbeet onion chicory vegetable carrots	380
Ridging/rolling	chicory vegetable	150
	carrots	270
Row spraying (excl. costs of chemicals)		85
Combine harvesting	cereals	450
	peas	375
	seedgrass	680
Straw baling (per ton)	cereals, peas and seedgrass	40
Harvesting	sugarbeet	620
	potato	745
	onion	370
	chicory vegetable	1 230
	carrots	1 300
Haulm shredding potato		120
Haulm mowing onion		270
Loading onion		460

[a] For a specification of the contract work operations for the new crops see Appendix C.3

Source: PAGV, 1989

Appendix VI.D.3 Fixed costs of the representative farm types in the base year

Specification of costs	FARM TYPE							
NLG per year	I	II	III	IV	V	VI	VII	VIII
Standard machinery[a]	25 486	25 486	25 486	25 486	25 486	25 486	25 486	25 486
Additional machinery[a]	13 884	13 884	13 884	13 884	13 884	33 315	33 315	33 315
Land NLG 750 per ha	18 000	18 000	22 500	22 500	22 500	27 000	31 500	36 000
Buildings NLG 170 per ha	4 080	4 080	5 100	5 100	5 100	6 120	7 140	8 160
Parcel roads and pavement NLG 55 per ha	1 320	1 320	1 650	1 650	1 650	1 980	2 310	2 640
Drains NLG 82,50 per ha	1 980	1 980	2 475	2 475	2 475	2 970	3 465	3 960
Storage NLG 62 per m^2 plus NLG 1820 for sorting place	11 680	11 710	14 960	14 840	12 980	14 470	15 300	18 840
Overhead NLG 8000 plus NLG 70 per ha	9 680	9 680	10 100	10 100	10 100	10 520	10 940	11 360
Labour NLG 60 000 per full-time farm worker	72 000	78 000	78 000	60 000	66 000	66 000	66 000	66 000
Total	158 110	164 140	174 155	156 035	160 175	187 861	195 456	205 761

[a] See Appendix VI.D1

Sources used: Groot, 1989; PAGV, 1989; Noordam, 1991

Appendix VI.E Innovations in chemical and mechanical crop care

Investments	Replacement value in NLG	Annual costs in % of the replacement value	Annual costs in NLG base year value
a. Row spraying accessories 4.5 m	4 500	13.6	612
b. Haulm shredder[1] 2 rows	11 500	21	2 415
c. Earther/ridge hoe	6 000	12.6	756

1 Incl. accessories for tractor montage

Source: see Appendix VI.D.1

Contract work operations	Costs in NLG per ha base year value
Insect killing in onions (integrated cropping variant) by biological method (greenfly)	250
Weed control in carrots (integrated variant)	180
Weed control and haulm burning in onion, carrots and chicory (ecological variants)	350

Source: Vereijken, 1983; Van Hall, 1991

Appendix VII.A Specification of the effects of technical change

The major part of the difference between the outcomes of the computations I0 and Ia is realized by the innovation in potato cropping. The total area potato is the same in both plans, hence the "gap" is due to a change in variants and/or other optional operations. With regard to the change in variants, the preliminary gross margin (*i.e.* before costs of the optional operations) is higher for the new potato cropping variant. The physical outputs of Bintje for the standard variant and for the optimal cropping variant are respectively 49 400 kg/ha and 50 490 kg/ha, or NLG 7 904 and NLG 8 078. In the first case the costs of soil fumigation amount to NLG 993 per ha (NLG 713 per ha for dichlorpropene and NLG 280 per ha for contract work). In the optimal system the reduction of yields caused by nematodes is controlled by growing 50 % PSR variety, which gives a gross margin of NLG 7 950 per ha.

The second major difference with regard to the increase of net farm result, is in the method of N dressing. In the standard variant, organic manure is applied (NLG 166 per ha incl. contract work) as well as N fertilizer (NLG 239 per ha). In the optimal system (split fertilization: 188 kg N with petiole analysis) the costs are reduced to NLG 309 per ha.

Wheat and sugarbeet are the other crops that show differences. In the case of wheat the change-over to a variant with reduced N leads to an increase of NLG 53 in total net farm result. In sugarbeet, innovations in weed control are important. The costs of herbicides are reduced from NLG 2588 to NLG 1386 for the 7.5 ha of this crop.

Table App.VII.A Specification of the financial effects of technical change in guilders per year, for Farm type IV

	Basic situation	All variants included	Difference
<u>Differences in variants</u>[1]			
Potato standard: Bintje	79040		
variant5: Bintje +		40390	
PSR variety		39750	
Winter wheat standard	20767		
Winter wheat 130 kg N		20820	
Total			1153
<u>Differences in operations</u>[2]			
Sugarbeet			
Herbicides	2588	1386	
Row spraying (contract work)	638	0	
Row spraying machine (investment)	0	612	
Potato			
Nematicides	7130	0	
Soil fumigation (contract work)	2800	0	
N fertilization	4050	3090	
Fungicides (late blight control)	3240	1305	
Herbicides	1330	0	
Earther (investment)	0	756	
Haulm-killing (chemical)	2700	0	
Haulm-shredding (investment req.)	0	2415	
Additional tractor hours		259	
Total	24476	9823	14653
Total difference in net farm result			15806

[1] Gross margins in model
[2] Costs of chemicals/investments/contract work

Appendix VII.B Sensitivity analysis Potato

When growing potato the soil is fumigated in order to prevent serious decreases in yield being caused by nematodes[1]. Soil fumigation is only needed if the frequency of the Bintje cultivation exceeds 1:4. In the case of a combination of 50/50 per cent Bintje and a PSR variety in a rotation of 1:3 the nematode pupolation remains stable and soil fumigation is unnecessary. In order to determine the influence of the price differences between Bintje and PSR varieties on soil fumigation, several calculations were done. In the regular optimizations the price for Bintje was fixed at NLG 0.16 per kg and for the PSR variety at NLG 0.15. The critical price level for Bintje appeared to be NLG 0.21 per kg (see column Id in table App.VII.B). The variable operations selected remained unchanged. This means that the difference in gross margin between Bintje and a Bintje/PSR combination has to be NLG 1 120 per hectare to make soil fumigation profitable in the base year situation.

The following sensitivity calculations pertained to the rotation frequency of potato (see table App.VII.B). As the high yielding crops onion and chicory are limited to a specific number of hectares, the area of winter wheat is extended if the model is forced to select lower fequencies of potato growing. Other changes relate to haulm killing and weed control in potato. The mechanical methods require additional investments, which are no longer profitable when the area of potato is reduced to less than 10 ha in the case of haulm killing and 7.5 ha for weed control. Further, the income loss of an 1:5 rotation is smaller than that of a 1:4 rotation.

With regard to soil fumigation it has to be added that the assumptions made for the nematode-killing effects of the innovative control methods (infected patches or bait crop (methods 2* and 3 respectively in Appendix VI.C.2) might be too conservative. This might be why the traditional method is selected when the price of Bintje is raised to NLG 0.21 per kg. More technical research is required on the new methods and on the risks associated with the Bintje/PSR combination, see also Chapter VI.5.

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[1] The premise is that the nematicides applied in the North East Polder control nematode pathotype A. The PSR variety is not attacked by this pathotype.

Results sensitivity analysis potato

FARM TYPE IV	(I0) Basic situation[1]	(Ia) Optimization with all cropping variants included[1]	(Id) Sensitivity analysis potato Bintje f0.21/kg PSR variety f0.15/kg	Rotation[1] 1:4	1:5	1:6
Cropping pattern (ha)[2]						
Wheat standard	7.5					
WT-130		7.5	7.5	8.5	10.0	11.0
Potato Bintje	10.0 var1	5.0 var5	10.0 var1	3.75 var12	3.0 var20	2.5 var23
PSR variety		5.0 var5		3.75 var12	3.0 var20	2.5 var23
Sugarbeet standard	7.5					
SB3-OM[2]		3.1	3.75	4.4	4.1	3.9
SB5-OM		4.4	3.75	3.1	3.4	3.6
Onion	3.0	3.0	3.0	4.5	4.5	4.5
Chicory (vegetable)	2.0	2.0	2.0	2.0	2.0	2.0
Variable operations potato[3]						
-Soil fumigation	100 %	-	100 %	-	-	-
-N dressing	1	3	3	3	3	3
-Weed control	1	3	3	3	2	2
-Late blight control	1	2	2	2	2	2
-Haulm killing	1	2	2	1	1	1
Pesticide use potato						
Total in kg a.i. per ha	188.08 Bintje	13.76 Bintje 9.57 PSR	187.77 Bintje	14.76 Bintje 10.57 PSR	15.02 Bintje 10.83 PSR	idem ..
Total leaching in µg/l	12.55	0.04[4]	12.39[4]	0.04[4]	0.18	..
Leaching dichlorpropene µg/l	12.35	-	12.35	-	-	..
Leaching metribuzin µg/l	0.35	0.04[4]	0.04[4]	0.04[4]	0.18	..
Net farm result NLG/year)	-58 729	-42 923	-29 839	-45 719	-45 088	-50 133

[1] Bintje NLG 0.16 per kg and PSR variety NLG 0.15 per kg.
[2] OM indicates own mechanization, *i.e.* investment in a row spraying machine
[3] The number of the method selected is given, see Table VI.1 and Appendix VI.C.2.
[4] Note that the use of 0.125 kg metribuzin per ha in the case of unsuccessful mechanical weed control leads to an underestimate of the leaching; it is assumed that once every four years an additional chemical treatment is required. In this particular situation the leaching is 4 times higher.

CURRICULUM VITAE

Grada Antonia Arendina Wossink werd op 19 januari 1958 geboren te Varsseveld (Gelderland). In 1976 behaalde zij het Gymnasium-diploma aan de Gemeentelijke Scholengemeenschap te Doetinchem. In september van dat jaar begon zij met de studie Agrarische Economie aan de toenmalige Landbouwhogeschool te Wageningen. In februari 1983 werd het doctoraal examen afgelegd met als hoofdvak de Algemene Agrarische Economie en als bijvakken Agrarische Bedrijfseconomie, Informatica een Staathuishoudkunde.

Van maart 1983 tot juli 1986 was zij als wetenschappelijk medewerkster werkzaam bij de studiedienst van de Hoofdafdeling Landbouwstatistieken van het Centraal Bureau voor de Statistiek te Voorburg. Het belangrijkste onderzoek aldaar betrof een input-out analyse naar de bijdrage van de agrarische export aan de Nederlandse economie en een studie naar de nevenverdiensten in de landbouw i.o.v. de Europese Commissie.

Sinds augustus 1986 is zij als universitair docent verbonden aan de vakgroep Agrarische Bedrijfseconomie van de Landbouwuniversiteit. De onderwijstaak betreft met name de verslaggeving en financiering van land- en tuinbouwbedrijven. Haar onderzoek is gericht op het thema Bedrijfseconomische aspecten van technische en institutionele ontwikkelingen in de landbouw, waarbij vooral de milieuaspecten de aandacht hebben. Sinds juni 1992 maakt zij tevens deel uit van de Universiteitsraad van de Landbouwuniversiteit.