VEGINECO
EU. FAIR PROGRAM

Integrated and ecological nutrient management

VEGINECO Project Report No. 3

The Netherlands Italy Spain Switzerland

Integrated and ecological nutrient management

VEGINECO Project Report No. 3

J.J. de Haan (ed.)

VEGINECO, FAIR 3CT 96-2056
"Integrated and ecological vegetable production, development of sustainable farming systems focusing on high quality production and minimum environmental impact",
VEGINECO was a shared cost research project sponsored by the European Union
from 01-01-1997 until 31-3-2001 (53 months).

Co-ordinator
ir. F.G. Wijnands,
Applied Plant Research BV
Research Unit: Arable Farming and Field Production of Vegetables,
Address : Edelhertweg 1, PO Box 430, 8200 AK Lelystad, the Netherlands
Phone : (31) 320 291 111
Fax : (31) 320 230 479

Partners:
dr. Vanni Tisselli
Centro Ricerche Produzioni Vegetali (C.R.P.V.) soc. coop. a.r.l.
Address : Via Vicinale Monticino, 1969 47020 Diegaro di Cesena (FO), Italy
Phone : (39) 547 347 164
Fax : (39) 547 346 142

dr. Fernando Pomares
Instituto Valencia de Investigationes Agrarias (IVIA)
Address : Apartado Oficial, 46113 Moncada (Valencia), Spain
Phone : (34) 6 1391 000
Fax : (34) 6 1390 240

dr. Christian Gysi
Swiss Federal Research Station for Fruit-Growing, Viticulture and Horticulture (FAW)
Address : 8820 Wädenswil, Switzerland,
Phone : (41) 1 783 61 11
Fax : (41) 1 780 63 41

Publisher: Applied Plant Research BV
Address : Edelhertweg 1, Lelystad, The Netherlands
: P.O. Box 430, 8200 AK Lelystad, The Netherlands
Tel. : +31 320 29 11 11
Fax : +31 320 23 04 79
E-mail : infoagv@ppo.dlo.nl
Internet : www.ppo.dlo.nl

Table of contents

Introduction

F.G. Wijnands
Applied Plant Research (PPO), Lelystad, The Netherlands

1.1 Vegetable production in Europe: shortcomings and new farming systems

Although vegetables cannot be said to be a key issue within European Union market policy or political discussion, they are, nevertheless, a major constituent of the daily diet of hundreds of millions of European citizens. Consequently, it is very important to ensure the availability of a wide variety of relatively cheap, high-quality, fresh vegetables on a daily basis.
The farms throughout Europe producing field-grown vegetables are relatively small, and are mostly concentrated in certain regions (for practical market-oriented reasons). These farms are characterised by very intensive land use (all-year-round soil utilisation) and high (external) labour requirements per hectare. Thus, there is almost no 'space' to incorporate nature and landscape elements. Since the range of crops on a farm is limited, crop rotations are short and host crops are present all year round in a very small geographical area. Crops are thus under the constant risk of being decimated by pests and disease. This situation provokes the intensive, but increasingly ineffective, use of pesticides. Another contributory factor to the high use of pesticides and also of nutrients is the need to realise high yields and ever-increasing 'cosmetic' quality demands, forced on the industry externally by very highly competitive international markets.
Since the costs of nutrient en pesticide inputs are relatively low compared to market value of the crops in production, there is little economic incentive to reduce these costs and thus the inputs. The high inputs are seen as 'insurance' costs. At present, vegetable-growing enterprises are experiencing very strongly fluctuating, generally low, profitability. Viewed against a background of necessary (socially acceptable) wage increases for hired labour (field workers) and increasing overproduction (due to free market competition), future prospects are even gloomier. Consumers are worried about health risks related to agricultural products, and, in particular, to the nitrate content, pesticide residues, contaminants, etc. in fresh vegetables. They are also concerned about the adverse effects on the environment of high nutrient inputs and the growing lack of concern for nature and landscape. There is a growing public demand for production methods, which have an 'ecological content'. The dilemma is that, simultaneously, consumers are also demanding high quality products, and not only consumers. Government authorities, in their policies and efforts, are addressing exactly the same issues, and, finally, retailers and other market parties are increasingly searching for 'certified environmentally friendly products'.
Farmers are thus no longer being asked to produce cheap food in large quantities, but are currently being challenged to be responsible managers of rural areas, of their green space. At the same time, they are also required to produce high- quality (even speciality) products. The repercussions of these demands are influencing the entire depth and scale of farm management.
There is an urgent need for new multi-objective farming systems that integrate into the old objectives 'new' aims such as product quality coupled with quality in production methods, quality in the a-biotic environment, higher landscape and nature values, and agronomic sustainability. For this to take place, the old one-sided (mainly agrochemical-based) methods have to be reconsidered, redesigned, and replaced by new multi-objective methods that are able to meet these new objectives. In redesigning these methods, the key issues of farming are involved, such as crop rotation, crop protection and nutrient management. In addition, new strategies for nature and landscape development are urgently required. All these different aspects need to be integrated in safe, efficient, acceptable and manageable strategies. At the farm level, this can only be done within the context of a farming system.
At present, there are two major visions with respect to integral approaches towards agriculture: integrated and organic farming systems (I/OFS). Integrated production is slowly growing in importance, and integrated labels have been introduced in a number of European regions and countries. The development of these labels is still in progress, but, too often, it is only based on single factor research. A consistent research base on comprehensive farming systems, and on the potential and possibilities for integrated production, is mostly lacking. Switzerland is possibly the only exception. Here, as early as the end of the eighties, large-scale pilot projects were carried out, which resulted in detailed production guidelines.
For organic production, national labels have long been available and have recently been harmonised with the European directive on organic farming (EU 91/2092). The current objectives of organic farming are to use no pesticides or chemical fertilisers at all. The emphasis is on what should not be done, rather than on stressing explicit (positive) objectives for protecting the environment or caring for nature and landscape.
Both systems have not yet been fully explored and exploited and need to be developed further before a proper evaluation can be made of their potential contribution to the future of European agriculture.

1.2 VEGINECO: Farming systems research on field grown vegetables

Objectives and research method

Within the framework of the EU FAIR programme, a project was set up to develop integrated and ecological farming systems for outdoor vegetable farming systems.

The overall objective of this project was:
'to develop integrated and ecological outdoor horticultural farming systems that are more sustainable in agronomic, environmental, ecological and economic terms, and that ensure high quality products that minimise environmental and health risks, thereby meeting market demands'.

This EU project focused on research into farming systems to develop, test, evaluate and compare prototypes of integrated and ecological vegetable farming systems in four important vegetable-producing regions in Europe, selected to represent different socio/economic, soil and climatic conditions. These regions were: the clay region in the South-western area of the Netherlands, Emilia-Romagna in Italy, and the Valencia region in Spain. Additionally in Switzerland, organic and integrated pilot farms were compare and improved.

In this project, the prototyping methodology of designing, testing, improving and disseminating new 'farming systems' (Vereijken 1994, 1995) was applied and improved. It was a combined research/development effort, taking as its starting point a profile of agronomic, environmental and economic demands (objectives) for more sustainable, future-oriented farming systems.The end product was a number of tested prototypes, ready and available for widespread application.

Participants in this farming systems research

Applied Plant Research (P.P.O., formerly P.A.V.), Lelystad, the Netherlands (project co-ordinator)
PPO has been involved in farming systems research since 1978. For the VEGINECO project, PPO tested integrated and organic vegetable systems in the South-western clay region of the Netherlands. The integrated systems consisted of eight variants of integrated vegetable systems in which arable and intensively or extensively grown vegetable crops were combined. The integrated system variants were aimed at direct practical implementation to achieve optimal economic results, whilst the organic system was focused more on experimental freedom to explore the environmental and agronomic potential of the system.

Centro Ricerche Produzioni Vegetali (C.R.P.V.) soc. coop. a.r.l. Cesena, Italy (Emilia-Romagna)
C.R.P.V developed and tested two types of integrated systems and one type of an organic system for this project. All the systems were located in the Emilia-Romagna region. To reflect the situation of small farmers accurately, the organic system and one of the integrated systems were based on fresh vegetables. The other integrated system, aimed at larger farms, focused on integrating arable and horticultural activities.

Instituto Valenciano de Investigaciones Agrarias (IVIA), Moncada (Valencia), Spain
I.V.I.A. developed and tested five integrated systems and one organic system for this project, based on the small-scale production of fresh vegetables. To form a representative sample, the integrated systems included enterprises spread over the entire Valencia region. The location (Paiporta) and rotation system of the organic system was identical to one of the integrated systems.

Eidg. Forschungsanstalt fur Obst-, Wein- und Gartenbau, Wädenswil (F.A.W.), Switserland
F.A.W. performed 'on-farm research' at 14 private pilot farms scattered over the country – seven integrated farms and seven organic farms. By monitoring the practices and results at these selected farms, a clear picture emerged of their differences. This made it possible to target specific elements in need of further development and to introduce improvements in these areas into farm practice.

VEGINECO publications
This VEGINECO method manual is one of a series of publications resulting from the VEGINECO project. VEGINECO specialises in producing tested and improved multi-objective farming methods for key farming practices – e.g. crop rotation, fertilisation and crop protection – to facilitate the integration of potentially conflicting objectives like economy and ecology. In addition to improving 'old' practices, new methods have been developed to integrate environmental concerns in the field of nature and landscape management with current farming practices.
A manual deals with each method in depth. An extensive description of prototyping methodology is included in the manual on crop rotation. In addition to these methodological manuals, other publications include workshop proceedings and a final report on the VEGINECO project. The workshop proceedings focus on project results in general and their implications for policy and certification. The final project report concentrates on the results of the prototyping methodology, in terms of application and development, and how well the tested systems performed.
This report describes a methodology for developing nutrient management strategies. In addition, examples of its application under different conditions in Europe are presented.

1.3 Prototyping methodology

For the development of these sustainable vegetable-farming systems, a standardised methodology called "prototyping" was used. The methodology is a combined research/development effort beginning with a profile of agronomic, environmental and economic demands (objectives) for more sustainable, future-oriented farming and ending with tested, ready-to-use prototypes, designed for widespread use.
The prototyping methodology was examined for arable farming in a four-year European Union Concerted Action (Vereijken, 1994 and 1995). For vegetable farming,

however, this type of research is limited.
The methodology of prototyping is still young, dynamic and developing. However, it can be described as an innovative process in 4 steps: analysis and diagnosis, design, testing and improving and dissemination (Figure 1.1) .
The process of prototyping starts with a regionally based *analysis and diagnostic* phase that includes the following aspects: sectorial statistics, farm structure, agro-ecological state-of-the-art, ecological–environmental impact, the socio-economic situation, trends in structural changes and current political conditions.
Based on an analysis of shortcomings in current farming methods and of future perspectives, the design phase starts by establishing a hierarchy of objectives for all-round sustainable farming systems.
In the VEGINECO prototyping practice, these rather abstract objectives are translated into five directional themes: quality production, clean environment, attractive landscape and diversified nature, the sustainable management of resources, and farm continuity.
In order to quantify the objectives of a theme, each one is fixed within a number of farm-level parameters. Each parameter is given a target value so that a well-defined, documented and clear framework can be established to design, test and improve farming systems. The target levels are future oriented and are derived from legislation, scientific evidence or expert knowledge.

The next step is to design a suitable set of farming methods (methods are defined here as coherent strategies on the major aspects of farming). In most cases, these methods need further development if they are to realise their objectives.
To create a basic framework for interpreting the results, the next step in the methodology is to design a theoretical prototype to link the parameters with the methods.
It then becomes possible to check the links. The last part of the theoretical exercise ends with detailed cropping programmes, allowing for adjustments that might be necessary for specific crops, weather and soil conditions.
The next phase is *testing and improving* the farming system that has been designed. For the test phase to be successful, a farming system has to be laid out in time and space. Important here is the choice, not only of a multi-functional crop rotation, but also of the agro-ecological identity of the farm.
When the prototype shows stable results at the level of the parameter targets, the next logical step is *dissemination.* The perspectives of a new prototype can only be evaluated in practice. Management is the key factor for the success and feasibility of these new approaches. Therefore a region-specific prototype, developed on experimental farms, is first tested on a small number of pilot farms. This is considered an indispensable step before new prototypes are introduced on a large scale.

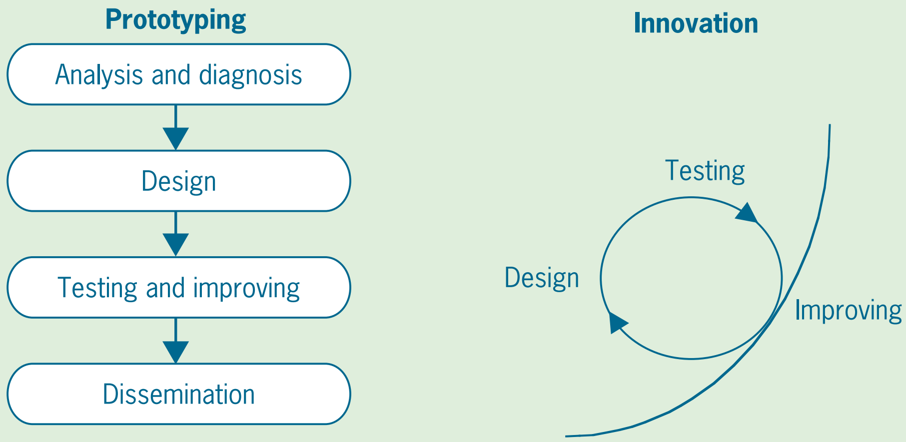


Figure 1.1 Prototyping methodology and the innovation cycle

2 Integrated and Ecological Nutrient Management

J.J. de Haan & F.G. Wijnands
Applied Plant Research (PPO), Lelystad, The Netherlands

2.1 Problems in nutrient management

2.1.1 Environmental and health/well-being problems

The overloading of seas, lakes, rivers and streams with nutrients (nitrogen and phosphorus) can result in a series of adverse effects known as eutrophication. Phosphorus is the important nutrient for eutrophication in fresh waters and nitrate is the important substance for salt waters. In addition, nitrate contaminates groundwater sources that are used for drinking water. Ammonia is an important source of acidification. High nitrate levels in drinking water causes high costs to purify the water. Finally, high fertilisation levels cause an increase in hardness of groundwater.

In the European Union, one can see these adverse effects in many regions. Agriculture is one of the main sources of these pollution problems. Although in the past ten years, nitrogen and phosphate emissions have been reduced and surpluses of nitrogen and phosphate have dropped by 25%, less than half of the fertiliser inputs are utilised by the products. The remainder, the mineral residue, remains behind somewhere in the environment. Agriculture is not the main source of phosphorus pollution in Europe. Households and industry are the largest contributors of phosphorus to the environment. However, in those parts of Europe with intensive agriculture, the contribution from agriculture approaches 50% of the total (http://www.eea.eu.int/).

Nutrients in ground and surface waters

The nitrogen surplus in the European Union between 1990 and 1995 remained stable at 60 kg ha^{-1}. Differences between countries were large. The nitrogen surplus in Portugal is below 25 kg ha^{-1} while the surplus in the Netherlands is over 200 kg ha^{-1}. In the Netherlands, vegetable production has high surpluses as well, although lower than average for agriculture. This large surplus is caused by very intensive production with high yields per hectare.

Large nutrient surpluses cause high concentrations of nitrogen in groundwater in many places. In the European Environment Agency's databases, it appeared that in half the groundwater sampling sites, the Drinking Water Directive guideline of 25 mg nitrate per litre was exceeded. Improvement is measured in coastal waters of the North Sea and Baltic Sea; nitrate concentrations fell by nearly half between 1985 and 1998. However, in some places, there were increases as well.

Since 1980, nitrate concentrations in major rivers in the European Union have remained constant (about three mg nitrogen per litre). There is no evidence that reduced application of nitrogen fertilisers to agricultural land has resulted in lower nitrate concentrations in rivers. Agriculture continues to be the main source of nitrate pollution in Europe (http://www.eea.eu.int/).

The reduction of phosphorus concentrations in major rivers in the European Union from above three mg l^{-1} to below two mg l^{-1} is mainly due to improved wastewater treatment and less phosphorus in household detergents, but not due to agricultural improvements. However, phosphate use in agriculture has declined between 1980 and 1995 by 38%. This reflects a growing trend within the European Union towards soil analysis, which assesses the soil's need for additional phosphates. Despite considerable reduction in phosphorus inputs, many lakes and coastal areas have not yet shown the expected environmental and ecological improvement. This is due to accumulation and release of phosphorus from lake and sea bottoms and continued contamination from agricultural sources (http://www.eea.eu.int/).

Acidification

Agriculture, particularly manure from livestock is the main source of acidification due to ammonia (NH_3). Volatilisation losses of ammonia from stables and during storage and spreading are estimated at 15-20%. Ammonia emissions have decreased slightly between 1990 and 1996, due to reduced agricultural activity and measures taken by a few member states of the European Union. In Denmark, Germany and the Netherlands, a reduction of over 10% has been attained. Emissions in some member states increased.

Nitrate content in vegetables

A special topic is the nitrate content in vegetables especially leafy vegetables. Nitrogen in crops can be converted to nitrite, which is harmful at high concentrations. This is supposed to be especially dangerous for young children. However, scientific evidence on this topic is not complete. High levels of fertilisation cause high nitrate contents in crops.

Unfortunately, figures on emission and damage of nutrients and fertilisation are not available for vegetable farming specifically. However, because of the intensive character of vegetable farming, nutrient inputs tend to be high. Some crops have lower nutrient usage efficiencies and leave high nutrient contents in the soil after harvest. Other crops leave large amounts of crop residues in the field. In some cases, nutrient advice used by the farmers is outdated. Therefore, environmental problems in vegetable farming are rather larger than other sectors of agriculture on the average.

2.1.2 Policy and legislation

Ground and surface water

EU level

At the EU level, policy and legislation has tried to reduce the adverse effects of eutrophication and drinking water contamination for more than 25 years. Most important were the directive on surface water quality for drinking water (EC 75/440) and the Nitrate directive (EC 91/676).

In 1975, the European Union passed the Council Directive EC 75/440 concerning the quality required of surface water intended for the abstraction of drinking water in the member states. In this document, maximum concentrations of several elements were set for three categories of surface water. Imperative values were set that may not be exceeded in member states' national laws. The imperative concentration for nitrate is 50 mg l^{-1}. The guideline concentrations are 25 mg l^{-1} for nitrate and 0.4 – 0.7 mg l^{-1} for phosphate (depending on category of surface water).

The Nitrates Directive (EC 91/676), which was adopted in December 1991, seeks to prevent the pollution of water by nitrate from agricultural sources. Therefore, member states are required to place mandatory restrictions on agricultural practices where these contribute to the nitrate pollution of water. The objective of the directive is to reduce water pollution caused or induced by nitrates from agricultural sources and prevent this type of pollution in the future.

In order to do so member states had to identify waters affected by nitrate pollution or which may be affected in the near future, if action is not taken. The criteria for identification are either a concentration of nitrate above 50 mg/l in freshwater, eutrophication, or water, which may become one of these in the near future. The agricultural areas, which drain into these waters and contribute to pollution, have to be designated as vulnerable zones. In addition, mandatory measures concerning applications on the land and storage of fertilisers had to taken such as:

- The requirement for each farm to have sufficient livestock manure storage capacity for the periods when they are not permitted to apply the manure to land.
- The requirement for fertiliser application to be based on a balance between the requirements of the crops and the supply to the crops from the soil and from fertilisation.
- The requirement for the application of livestock manure to be limited to 170 kg N ha^{-1} per year for each farm from the end of 2002.

In addition, each Member State had to draw up at least one code of Good Agricultural Practice (GAP).

Implementation of this directive is severely behind schedule. Many countries have not met the obligations set by the directive. No vulnerable zones were designated and no action programmes for these zones were set (http://europa.eu.int/water/water-nitrates/report.html). Regulation (EC 92/2078, 'agri-environmental measures') provides incentives for reduction of the use of fertilisers and plant protection products. This includes organic farming, for the extensification of crop and livestock production, and for voluntarily setting aside of areas of farmland for the long-term and benefiting the protection of fresh water. Compensatory payments are given for the provision of services and goods by rural societies. In the future, these payments will be extended. In addition, basic environmental regulations will be set up which all farmers have to comply with.

The Netherlands

To address the nutrient problems mentioned above, policy has reacted to the environmental damage caused by

Table 2.1 Targets for nitrate and phosphate levels in ground and surface water in The Netherlands

	Groundwater		Surface water
	Sandy soils	Clay and peat soils	
Emission reduction			50% P and N in 1995 70-75% P and N end target[1]
Limit value	11.3[2] mg N l^{-1}	11.3[2] mg N l^{-1}	0.15[3] mg total-P l^{-1} 2.2[4] mg total-N l^{-1}
Target value	0.4 mg total P l^{-1} 5.6[5] mg N l^{-1}, 3.0 mg total P l^{-1}	5.6[5] mg N l^{-1}, 0.05 mg total P l^{-1}	1 mg total N l^{-1}l

1. final target compared to 1985 from "third note water household" and "national plan for environmental policy 2"
2. all groundwater (national plan for environmental policy 2)
3. summer average for specific waters and year average for all surface water (BOWA 2)
4. summer average
5. for protection of special oligotrophe areas lower values can be demanded

Table 2.2 Targets for surplus (included fertiliser inputs and fixation, excluded deposition) of nitrogen and phosphate (kg ha^{-1}) in the MINAS legislation for arable land in The Netherlands

Year	N		P_2O_5[1]
	clay/peat	sand	
2001	150	125	35
2002	100	100	25
2003	100	60	20

[1] excluded mineral phosphate for the time being

agronomic activities by implementing legislation to reduce nutrient emissions. Targets of the Dutch policy to protect ground and surface water are summarised in Table 2.1. For ammonia volatilisation, a maximum deposition target is determined on 1600 acid equivalents in 2000 and 1000 in 2010.

In the MINAS legislation, farmers are required to register nutrient use on a farm level. From 1998 until 2000, only organic manure had to be registered. Starting in 2001, chemical nitrogen fertilisers have to be recorded as well. Maximum surpluses for nitrogen and phosphate at a farm level are set (Table 2.2). Starting in 2003, the maximum input of animal manure will be set at 170 kg N ha^{-1} for arable land. The control mechanism will be based on registration. There is a penalty when the allowed surplus is exceeded. The main purpose of the MINAS legislation is to reduce the pollution of surface and shallow groundwater with nutrients.

In addition to MINAS, there are restrictions for the application method and application time of organic manure to reduce leaching and acidification. On sandy soils, no application of animal manure is allowed between 1 September and 1 February. It is required to work animal manure under within 24 hours after its application. New legislation is being put forward to forbid nitrogen fertilisation and ploughing of grassland between September and February.

Switzerland

In reforming the agricultural policy in Switzerland (Agrarpolitik 2002), the reduction of the adverse impact of agricultural activities was an important goal. Therefore, in a first step, the payment of ecological services was introduced, in addition to the separation of price policy and income policy.

Until 2005, the following targets (compared to the average of the years 1990-1992) concerning the nutrient management should be attained (BLW, 1998):

- Reduction of the nitrogen surplus of agriculture by 33.3%.
- Decrease of the average nitrate content in groundwater about five mg nitrate l^{-1}.
- Reduction of the phosphorus surplus of agriculture by 50%.
- Reduction of phosphate content in surface water by 50%.

The maximum value for ground and surface water in Switzerland is 40 mg Nitrate per litre; the target value is 25 mg nitrate per litre. In the long term, the target is to reduce to 15 mg nitrate per litre. For P in water, no exact maximum value exists.
In the first six years after the introduction of direct payments for ecological services, the reduction of the P-surplus by 50% has already been achieved. Concerning the reduction of the nitrogen surplus, only 40% of the target has been achieved so far. It seems that the target for nitrogen in 2005 will not be attained.

The farmers are required to fulfil specific conditions in order to receive direct payments. Concerning nutrient management and soil, the law demands a nutrient balance for the entire farm and measurements for soil protection. To avoid soil erosion, an optimal soil cover in winter is required (Landwirtschaftsgesetz Art. 70).

In Switzerland, the nutrient balance has to be in equilibrium for nitrogen and P. This means that the total amount of nutrients brought onto the farm is compared to the nutrient requirements (demand) of all cultivated crops. This is different than the Annual Balance calculation used by the other VEGINECO partners, in which the nutrient input is compared to the nutrient off-take.

Nitrate in crop produce

The regulation of nitrate content in spinach and lettuce was established in 97/194/EEC. Maximum levels are 2 500 mg kg^{-1} for spinach and 2 500 – 4 500 mg kg^{-1} for lettuce, depending on time of the harvest. These values are based on 'acceptable daily intake' levels for nitrate and nitrite.
In the Netherlands, the maximum residue values for nitrate in vegetables are set for endive, spinach, beetroot and lettuce. An overview of these values is found in Table 2.3. Values are overall higher than EU values for lettuce and spinach.

Nitrate in crop produce is measured in beetroot, lettuce and endive. There are large differences between levels in summer and winter. Average levels are below the norms. However, 95 percentile values were higher for endive (summer) and lettuce (summer) (http://www.agralin.nl/kap/).

In Switzerland, maximum values for nitrate in vegetables are set for some leafy vegetables (Table 2.4). Nitrate in crop produce in Switzerland is only measured in the winter because in the summer the nitrate content is much lower. In contrast to the European Union, the maximum

Table 2.3 Maximum residues of nitrate in vegetables in the Netherlands (1993-1997) (http://www.agralin.nl/kap/)

Vegetable	Harvested in the period:	Maximum level (mg kg^{-1})	Average level (mg kg^{-1})	95 percentile level (mg kg^{-1})
Endive	Summer (May 1 - November 1)	2 500	2 000	3 300
	Winter (November 1 - May 1)	3 500	2 100	3 300
Beetroot	Summer (April 1 - July 1)	4 000	1 300	2 700
	Winter (July 1- April 1)	3 500	3 500	-
Spinach	Summer (April 1 - November 1)	3 500	-	-
	Winter (November 1 - April 1)	4 500	-	-
Lettuce	Summer (May 1 - November 1)	3 500	2 600	3 700
	Winter (November 1 - May 1)	4 500	3 500	4 400

level for nitrate residues in vegetables is the same during the entire year in Switzerland.
As a result of latest findings, the health risks of high nitrate content in vegetables are considered much lower than previously. Therefore, the maximum levels of nitrate in Switzerland will possibly be adapted to the European Union levels in the near future (BAG, 2000).

Effectiveness of the policies

In general, nutrient pollution in the European Union has been reduced when compared to 1980-1985. However, reduction is not enough to sufficiently improve the environmental quality. Different laws and regulations have been implemented to reduce nutrient pollution and to improve the environmental quality, but they have not yet been successful enough. Current nutrient management seems to be inadequate in reducing environmental pollution from agriculture to the desired levels. Especially in vegetable farming systems, nutrient surpluses are large and thus the possibilities of nutrient losses are also large. Therefore, nutrient management in vegetable farming needs to be improved to reduce these losses and to satisfy the environmental criteria.

2.1.3 Label guidelines

Integrated production

In the Netherlands in integrated production under the 'Milieukeur' label, guidelines are set for fertilisation at a crop and/or farm level. Farmers have to set up a fertilisation plan for the whole farm. The amount of nitrogen and phosphate is based on the need of the crop or rotation and on soil fertility levels.
In Emilia Romagna, the QC label ("Qualità Controllata", Quality Control) is applied to vegetable production obtained through the application of Regional Integrated Production Guidelines. These Guidelines are inspired to the IOBC directives. The current guidelines do not fix or suggest a desired balance level for nitrogen, phosphate and potash nutrient management, but simply set a maximum quantity of fertiliser permitted.
In Switzerland, the 'Schweizerische Gemüse Union' publishes the guidelines for the integrated production of vegetables. The requirements for nutrient management include a nutrient balance for an entire farm with a margin of error for nitrogen and phosphate of 10%. A fertiliser report is required with the date of application, field, crop varieties, amount and nutrient content of fertilisers. Furthermore, the soil has to be analysed every four years. The application of nitrogen fertilisers should be done according to developmental stage of the crop and N-min or plant sap analysis. The maximum single doses of nitrogen are up to 60 kg ha^{-1} and in exceptional cases up to 100 kg ha^{-1}. It is also required to provide minimum crop cover during the winter for soil conservation defined as the soil cover index.

Table 2.4 Maximum levels of nitrate in vegetables in Switserland (Fremd- und Inhaltsstoffverordnung)

Vegetable	Maximum level (mg kg^{-1})
lettuce	3 500
spinach	3 500
corn salad	3 500
fennel	2 000
Chinese leaves	1 500
cabbage varieties	875

Organic production

The EC 91/2092 is followed for organic production. This guideline does not fix any limit regarding the total amount of fertilisers, but only restricts the number of organic and natural fertilisers used.
In integrated and organic farming, farmers are required to record in special forms the amount and the type of fertilisers distributed. No extra conditions are set up for nutrient management for the DEMETER label when compared to the EU guideline.
In Switzerland, the most important label for *organic farming* is the 'Knospe' (bud) of the 'BIO SUISSE'. The certification of the farms is done by 'bio.inspecta'. The requirements for nutrient management include a nutrient balance for the whole farm with a tolerance for nitrogen and phosphate

of 10%. A positive list of fertilisers exists. The application of chemical nitrogen fertilisers is not allowed. Soil analysis has to be done once every five years. It is recommended to analyse the soil for the mineral nitrogen in springtime. A minimum of 25% of the total area has to be covered with leys or green manure.

2.2 Theoretical Background

2.2.1 Definition and objectives of I/ENM

Definition

Integrated/Ecological Nutrient Management (I/ENM): I/ENM provides directions on the supply of nutrients to crops in such amounts, forms and at such time to achieve 1) optimal quality production, 2) minimal nutrient losses to the environment and 3) adequate levels of nutrients and organic matter in soil reserves both agronomically as well as environmentally.

The nutrient management method is used in the prototype that can either be an integrated model or an ecological model. The general principles of the method are the same for both versions of the prototypes. The difference between the prototypes is based on the requirements of fertiliser type in organic systems (in general, only organic fertilisers may be used).
The I/ENM methodology in this manual is focussed on the macronutrients: nitrogen (N), phosphate (P_2O_5) and potassium (K_2O) and organic matter. These nutrients are essential for all crops in achieving quality production. In Chapter 2.3, I/ENM strategies will be described. Attention will be paid to both versions (agronomical and environmental) of the method. First, general nutrient management theory is reviewed.

Relationship of I/ENM with other methods

Nutrient management does not function independently of other farming methods. The farming methods Multifunctional Crop Rotation (MCR) and Minimum Soil Cultivation (MSC) are closely related to I/ENM. There are many interactions between these farming methods, especially MCR. The rotation is defined in the MCR, and each rotation has its own nutrient requirements. Especially in organic systems, the link between MCR and nutrient management is very important because balanced nutrient inputs from organic fertilisers, crop residues and biological fixation is one of the pillars of the MCR for an organic system. In integrated systems, this is of less importance because nutrient inputs can be balanced with simple, inorganic fertilisers. However, it is possible that an integrated rotation has to be adjusted as well to better meet the objectives.
Timing and intensity of soil cultivation influence mineralisation rates. There are links between I/ENM and other methods as well, but these are more indirect or of less importance. For example, pests and diseases or weed competition can influence nutrient uptake or levels of nitrogen that are too high can induce diseases.

I/ENM related themes

There is a strong connection between I/ENM and the themes 'Clean environment (nutrients)', Sustainable management of resources' and 'Quality production', which were explained in paragraph 1.3. Nutrient management influences the environment through leaching, acidification, erosion and depletion. It influences sustainable use of resources by keeping soil reserves at acceptable levels and by preventing erosion and leaching. Nutrient management influences quality production through nutrient content in the produce and the quantity and quality of produce. I/ENM has indirect connections with the objective 'Farm continuity' through quality production and costs of fertilisation.

2.2.2 Nutrient management theory

Soil-plant system

Nutrients in the soil can be present in the nutrient pool or in the soil solution, in which it is available for plant uptake (Figure 2.1). Plant uptake depends on crop characteristics, amount of nutrients in the soil solution and external factors such as soil characteristics and climate. Nutrients in the nutrient pool are in organic or in (solid) mineral form. Equilibrium exists between the nutrients in the nutrient pool and the soil solution. Different factors such as the amount of nutrients in the nutrient pool and the soil solution, temperature, rainfall, organic matter content and texture, influence this equilibrium. Processes that play a role in the equilibrium are, for example, mineralisation-immobilisation and adsorption-solution. The speed and direction of these processes are different for each nutrient.

I/ENM attempts to fulfil the nutrient requirements of the crop, while preventing or minimising losses. Therefore, the amount of nutrients in the soil solution has to be large enough to fulfil the crop requirements (agronomically acceptable) and small enough to prevent environmental losses. Fertilisation can be directly added to the soil solution with easily soluble mineral fertilisers or indirectly added to the nutrient pool with organic fertilisers and insoluble mineral fertilisers.

In formulating strategies, nitrogen is treated in more detail than phosphate and potash. This difference is necessary because of the difference in behaviour in the soil-plant system (Figure 2.1). The difference between nitrogen and phosphate or potash in the soil system is that nitrogen is easily soluble and phosphate and potash are not. In addition, in the nutrient pool, the most important nitrogen compounds are mainly present in the organic form while important phosphate and potash compounds

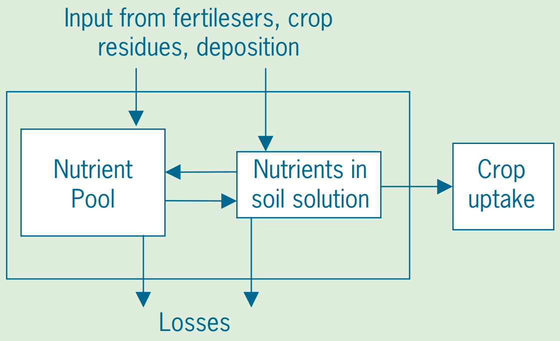


Figure 2.1 Nutrients in the soil-plant system

are mainly present in mineral form. Therefore, the amount of nitrogen in the soil solution is relatively large in comparison to the amount in the nutrient pool. The amount of phosphate and potash in the soil solution is relatively small in comparison to the amount in the nutrient pool. Frequently used terms are defined in Table 2.5.

Nitrogen

As stated above, the amount of nitrogen in the soil solution is relatively large. This is necessary for crop growth as well because the crops' demand for nitrogen is relative large. The disadvantage of this large amount in the soil solution is, in addition to the high solubility, that the risk of leaching losses is high. Availability of nitrogen from the nutrient pool is important, but variable and it is difficult to estimate. Nitrogen from the nutrient pool is stored in organic matter. It is released by mineralisation, a process that is difficult to estimate due to variation in weather, soil properties and the input of organic materials. Therefore, in contrast to phosphate and potash, there is no close relationship to the amount of nitrogen in the

Table 2.5 Definition of terms used in nutrient management

N available	mineral nitrogen available for plant growth.
$N/P_2O_5/K_2O$ content	the nutrient content in fertiliser, manure or crops expressed in kg per 100 kg or per ton and in the case of crops, usually as kg per ton of fresh material. In the case of organic manure, total nitrogen is mend; as well the organic as inorganic nitrogen in the manure.
N demand	nitrogen demand is nitrogen uptake divided by nitrogen recovery (theoretically). This often is the nitrogen demand input of some non-fertilisation sources such as soil organic matter and deposition are included as well, then nitrogen demand is lower then the theoretical demand.
P_2O_5/K_2O demand	phosphate/potash demand is equal to phosphate/potash off-take corrected for the soil reserve level. If soil reserves are high, then demand is lower than off-take. If soil reserves are low, then demand is higher than off-take.
$N/P_2O_5/K_2O$ deposition	Total nutrient input from dry and wet deposition within 12 months, only used on farm scale calculations that are obtained from regional measurements (kg ha^{-1}).
N fixation	The amount of nitrogen fixed in leguminous crops to be calculated as a standard amount per ha crop or to be based on a standard per ton of crop produce (kg ha^{-1}).
$N/P_2O_5/K_2O$ input	all nutrients from external sources that are put into a crop, field or farm.
N mineral soil	The mineral nitrogen available in soil reserves in a specific depth of the soil profile at a given moment (kg ha^{-1}) to be defined later.
$N/P_2O_5/K_2O$ off-take	nutrients exported from the fields either in crop produce or in crop residues or in both.
$N/P_2O_5/K_2O$ output	all nutrients that are exported from the fields or farms (could be livestock as well).
N recovery	fraction of a defined amount and type of nitrogen (1) found again in biomass (2). (1) and (2) have to be clearly defined.
$N/P_2O_5/K_2O$ uptake	nutrients included in the biomass, to be defined if it concerns above ground biomass, root biomass, or both or produce or crop residues.
Working coefficient	percentage of total amount of nutrients that have the same effect as mineral fertiliser.

nutrient pool and in the soil solution. In integrated systems, this can be overcome by measuring soil reserves regularly and fertilising based on the reserves in the soil solution.

Phosphate and Potash

Phosphate and potash are added to the crop indirectly via the nutrient pool. By keeping the amount of nutrients in the nutrient pool within certain limits, the amount of nutrients in the soil solution is influenced in such a way that a sufficient amount of nutrition can be supplied to the crop. Because of low solubility and bonding to organic agents, the amount of nutrients in the soil solution is limited and the risks of losses are minimised. The amounts of phosphate and potash in the soil solution and in the nutrient pool are closely related to each other. Therefore, the processes of exchange between the two nutrient pools are not as important as for nitrogen.
When measuring the size of the nutrient pool, the entire nutrient pool is not measured because extraction methods cannot extract all forms in which nutrients are available in the nutrient pool. In fact, the same is true for the soil composition. Some forms of the nutrients cannot be taken up by plants or can be insoluble. Therefore, the part that is measured is called the available reserves.
It appeared that the partners in the project measure phosphate and potash available soil reserves in different ways. To get an impression what the partners in the project call agronomically acceptable and to compare the different analysis methods of the partners, we have conducted a ring test for soil analysis of phosphate, potash, magnesium, calcium, texture, pH and organic matter. In addition, each partner had to set up fertiliser recommendations for four crops. In Annex 6, the results of the measurements are described.

Organic matter

Soil organic matter is an important factor in crop production, although its role is still poorly understood. Soil organic matter influences physical, chemical and biological properties of the soil. Organic matter dynamics are very important in nutrient management because of the large amounts of nutrients that can come available from the mineralisation of organic materials.
Effects of organic matter in the soil are:

- Soil physical effects.
  - Increase in resistance to wind erosion.
  - Increase of water holding capacity.
  - Increase in soil pore volume.
- Effects on chemical soil fertility.
  - Bonding of elements because of increased cat ion exchange capacity.
  - Availability of micronutrients.
- Effects on plant protection.
- Effects on soil-born diseases.
- Effects on chemical weed control.

Probably for every soil, there is an optimum organic matter content based on the different functions of organic matter, and the soil and climate type. This optimum content has to be reached or stabilised. The optimum level is difficult to establish because it is dependent on many factors. Influencing the organic mater content of the soil will take a long time because the organic matter that is added is very small compared to the amount of organic matter in the soil.

2.3 Design of nutrient management strategies

2.3.1 Procedure to construct I/ENM strategies

This chapter describes how strategic plans for nutrient management are set up that meet the objectives of the prototype. These objectives have to be defined before a strategy is set up (see Manual on Prototyping Methodology and Multifunctional Crop Rotation). In the previous paragraph, attention was paid to the relationship between the nutrient management method, the objectives (categories) and other methods.
The base for a fertilisation plan is crop rotation. This rotation is drawn up with aid of the method of the Multifunctional Crop Rotation (see Manual on Prototyping Methodology and Multifunctional Crop Rotation). In formulating an I/ENM strategy based on a defined rotation, the following procedure has to be followed (see Figure 2.2):

1. Calculate the nutrient demand for the crop rotation taking into account the specific needs of the crops and the soil reserves.
2. Calculate nutrient availability from non-fertilisation sources. External sources (deposition, irrigation water and fixation) and internal sources (crop residues, green manure and soil mineralisation) are discussed.
3. Establish the need for fertilisation taking into account timing, application method and choice of fertiliser.
4. Evaluate the strategy according to the objectives (parameters and target values). In first case, this is done on paper based on calculations and expert judgement. In second case, this is done in practice by testing and improving. When the plan does not meet sufficiently the set targets, the strategy has to be changed. When it is not possible to change the strategy sufficiently, the rotation should be altered (see Figure 2.2).

Each step is treated in the following paragraphs. In Annex 4, biomass amounts, yields and nutrient concentrations are given for the different systems. Examples from the Netherlands for the integrated (NL INT1) and the organic farming systems (NL ORG) are used to illustrate the procedure. In Chapters 3 to 6, region specific examples of these plans and their results during the project are presented.

2.3.2 Nutrient demand

The first step is to quantify the nutrient demand of the rotation. This means that for all crops in the rotation, the nutrient demands have to be established and a mean for

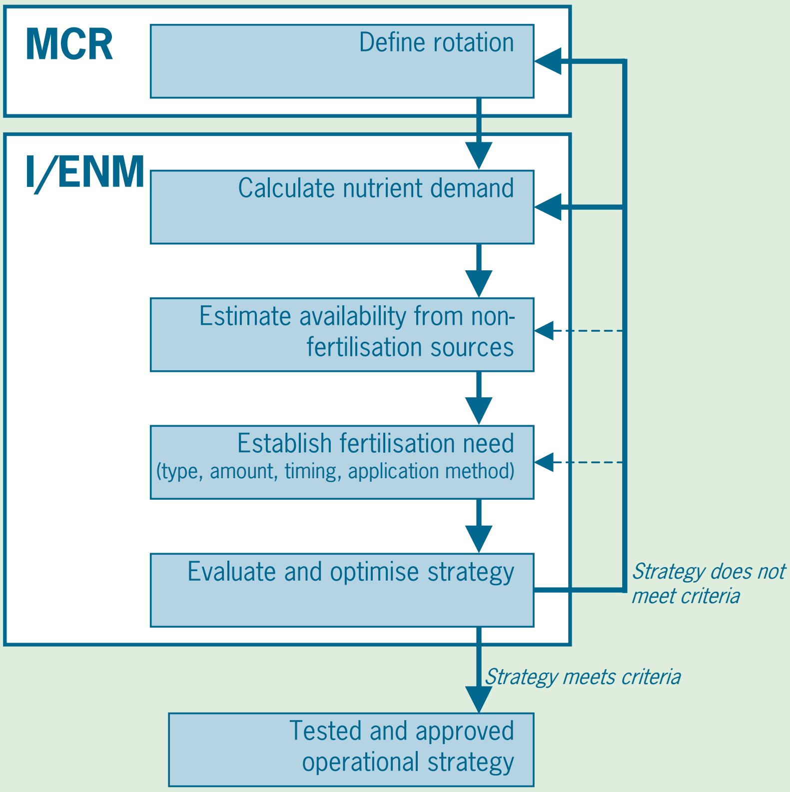


Figure 2.2 Procedure to construct a fertilisation strategy

the rotation has to be calculated. Nutrient demand is based on the objective to achieve an optimal quality production and to keep soil reserves within acceptable limits. Nitrogen demand and phosphate and potash demand is treated separately. Establishing nitrogen demand is more complicated and soil reserves do not play an important role.

Nitrogen demand

Theoretically, nitrogen demand is equal to the nitrogen uptake of the above ground crop parts divided by the recovery factor. However, in practice, sources such as fixation, soil organic matter mineralisation and deposition are not excluded in determining the nitrogen demand. Nitrogen demand data as defined above is not readily available. Therefore, nitrogen demand is redefined as the site-specific, empirically determined amount of nutrients that is necessary for crop growth. This practical demand is generally lower than the theoretical demand and defined by using conventional techniques. When fertilisation techniques are changed, a correction on the nitrogen demand has to be made. More efficient fertilisation techniques require lower nitrogen demand than inefficient techniques. When fertilisation is split in smaller doses, it is important to know the nitrogen uptake pattern of the crop, or the nitrogen demand in specific periods.

Phosphate and potash demand

Nutrient demands of phosphate and potash are dependent on the off-take for crop produce and soil reserve levels. When soil reserve levels are within the desired levels, phosphate and potash demand should be equal to the nutrient off-take from crop produce (Figure 2.3). At the crop level, the demand can be calculated by multiplying the off-take with the nutrient content in the crop produce:

$$P_2O_5/K_2O \text{ demand crop (kg ha}^{-1}\text{)}$$
$$= P_2O_5/K_2O \text{ off-take crop (kg ha}^{-1}\text{)}$$
$$= \text{off-take crop (ton ha}^{-1}\text{)} * P_2O_5/K_2O \text{ content off-take crop (kg ton}^{-1}\text{)}$$

The average demand of phosphate and potash per year per hectare can be calculated by adding up all of the crops' demand and dividing by the length of rotation. Levels of phosphate and potash in the soil that are too high are ecologically unacceptable (Figure 2.3). Phosphate and potash demand at the rotation level are, therefore, lowered or reduced to zero when soil reserves

Appraisal available soil reserves of phosphate and potash	Low levels Agronomically undesirable	Optimum range	High levels Ecologically unacceptable
Nutrient management to be followed	Input > output (+ repair gifts)	Input = output	Input < output (reduced gifts)

Figure 2.3 Integrated approach for phosphate and potash fertilisation

are higher than the desired range. Levels that are too low are agronomically undesirable, and endanger quality of production.

The demand is therefore increased when soil reserves are lower than the desired range. In addition, phosphate and potash demand can be increased, when unavoidable losses are taken into account. Total availability of phosphate and potash can be calculated as follows:

P_2O_5/K_2O demand rotation (kg ha^{-1})
= $\sum$ (P_2O_5/K_2O demand crop (kg ha^{-1})) + correction soil reserves (kg ha^{-1}) + unavoidable losses (kg ha^{-1})

Example
Examples of nutrient demand for NL ORG and NL INT1 are presented in Table 2.6. Nutrient demands in NL ORG are lower for all crops compared to NL INT1 because of lower estimated yields in this system and because more crops with low nitrogen demand are included in the rotation. In the Netherlands, soil mineralisation and deposition are included in determining the nutrient demand.
For phosphate, an annual unavoidable loss of 20 kg ha^{-1} is estimated. Therefore, in conclusion, the phosphate balance should have a remainder of 20 kg ha^{-1} phosphate.
Nutrient contents of crop produce, crop residues and target yields are summarised for all systems in Annex 4.

2.3.3 Nutrient availability from non-fertilisation sources

In optimal crop production, the nutrient demand is equal to the nutrient availability. Nutrients can become available from fertilisation, but other sources can be very important as well. Although the amount of nutrients available from these sources is not usually sufficient for crop growth, it is often a considerable amount, especially for nitrogen. Other sources can be divided into external and internal sources. External sources are deposition, irrigation water and fixation. Internal sources are crop residues, catch crops or green manures preceding the present crop and mineralisation of soil organic matter.

In internal sources, only nitrogen availability is important as phosphate and potash availability is assessed at the rotation level. In external sources, phosphate and potash are generally of little importance. Internal sources, green manures and catch crops can be an important input of organic matter. External sources can be important as well as large amounts of organic matter can be imported with paper or peat pots. The input of nutrients of these sources is often limited.

Some of the sources are implicitly taken into account in determining the nutrient demand. In these cases, these sources should not be assessed again. For example, if soil mineralisation was not taken into account in deter-

Table 2.6 Nutrient demand, NL ORG and NL INT1 in kg ha^{-1}, the demand includes deposition and mineralisation from soil organic matter

Year	Crop / green manure	N	P_2O_5	K_2O
NL ORG				
1	Iceberg lettuce summer	105	13	63
	Iceberg lettuce autumn	60	13	63
2	Spring barley	50	48	36
	White clover	0	0	0
3	Brussels sprouts	170	29	84
4	Fennel early	105	9	108
	Fennel autumn	60	9	108
5	Spring barley	50	48	36
	White clover	0	0	0
6	Potatoes	130	39	179
	Vetch/grass	0	0	0
Average		**122**	**35**	**113**
NL INT1				
1	Fennel early	120	10	120
	Fennel autumn	100	10	120
2	Potatoes	190	50	230
3	Brussels sprouts	220	38	108
4	Spring barley	70	56	42
Average		**175**	**41**	**155**

mining the nitrogen demand, it would not be taken into account in determining the amount of nutrients available from within the rotation.

External sources

The most important external sources are deposition and irrigation water. Deposition of nutrients from the air can be a considerable source of nutrients. The amounts are site-specific. Nitrogen deposition can be as high as 50 kg ha^{-1}. The deposition of other nutrients is negligible, measuring only a few kilograms. Often, deposits are already included in the empirical estimation of the nutrient demand.

Irrigation water can contain considerable amounts of nutrients. The amount of nutrients in irrigation water varies dramatically between locations. In addition, the need for irrigation is dependent on rainfall, evapo-transpiration and the crops grown. Therefore, the importance of this source is strongly dependent on the system and its location.

Fixation can be an important source of nitrogen within cropping systems, especially in biological cropping systems where often one or more legumes (peas, beans and clovers) are included to input nitrogen into the system. In fact, the crop does not actually fixate the nitrogen, but it is done by the symbiotic bacteria Rhizobia. This bacterium "invades" the plant and causes the formation of a nodule by inducing localised proliferation of the plant host's cells. The amount of nitrogen that can be fixated is dependent on presence of the Rhizobium bacteria, length of growing period, weather conditions and level of nitrogen in the soil. High nitrogen content in the soil or nitrogen fertilisation slows nitrogen fixation. In the Netherlands, the rule of thumb used to estimate the nitrogen fixation of green manure is:

N fixation (kg ha^{-1})
*= 4/3 * N-content above ground biomass (kg ton^{-1})*
** above ground biomass production (ton ha^{-1})*

Part of the nitrogen fixated is available for plant growth for following years. This availability is seen as an internal source as at the moment of availability, the nitrogen is already in the system.

Internal sources

From green manures, catch crops or crop residues from the preceding crop, a considerable amount of nutrients can become available for the next crop, as the organic material is very young and decomposition and mineralisation is fast. The different processes, which play a role in nitrogen availability, have lead to general rules of thumb for the nitrogen availability from green manure, catch crops and crop residues. These rules of thumb are expressed as working coefficients (percentage) for a certain crop, time of incorporation and soil type (see Annex 5, Table 1). The nitrogen that becomes available as mineral nitrogen for the present crop can be expressed as follows:

N gm av (kg ha^{-1})
= (working coefficient (%) /100) x N-content (kg ton^{-1})
x biomass (tons ha^{-1})

The working coefficient is dependent on different factors such as type of material (however not often considered), the time of incorporation (before or after a period of surplus precipitation), depth of incorporation and biological activity in the soil. Although soil organic matter is often relatively old (compared to organic matter in crop residues), the amount of nitrogen that becomes available for crop growth can be as large as the size of the nutrient pool, which is enormous. Often it is a net mineralisation term that expresses the result of many processes resulting in a net contribution to the nutrient pool of available mineral nitrogen.
There are many difficulties in estimating decomposition of soil organic matter and mineralisation of nitrogen. Therefore, nitrogen from organic matter in the soil is in many fertilisation strategies not taken into account directly, but included in the nitrogen demand or estimated through assessments of mineral nitrogen amounts. In this way, amounts of fertilisation are based on the crop's need minus the amount of mineral nitrogen in the soil.

Establishing the fertilisation need

The nutrients needed from fertilisation can be calculated by subtracting the nutrients available from non-fertilisation sources from the nitrogen demand. Only those sources have to be subtracted, which are not included in the estimation of nutrient demand. If the nitrogen contribution from some sources is not estimated, fertilisation can be corrected with the aid of N-min measurements during the growing season. This is only possible in integrated systems because in organic systems fertilisation during the growing season is almost impossible.

In Table 2.7, the nitrogen availability from non-fertilisation is shown for the two systems in the Netherlands. Other nutrients are not shown because deposition is taken up in the determination of nitrogen demand and the amount of nutrients in irrigation water is negligible. Nitrogen availability of soil organic matter was included in determining the nitrogen demand as well. Therefore, these sources were not taken into account in calculating nitrogen availability. Total availability from non-fertilisation sources is the sum of the values in the columns green manure and crop residues. Nitrogen fixation is added to the total input, but is not added directly to the nitrogen availability. The nitrogen fixation is recalculated to the amount of available nitrogen from green manure for the next crop in the following year. Therefore, the resultant is given in the column 'green manure'. For example, white clover fixates 100 kg ha^{-1} of nitrogen for the next crop, which indicates nitrogen

Table 2.7 Nitrogen demand, nitrogen availability from non-fertilisation sources and nitrogen availability needed from fertilisers for NL ORG and NL INT1 system in kg ha^{-1}. Only the internal sources green manure and crop residues are considered, other sources are not important or included in the determination of the nutrient demand.

Year	Crop / green manure	N-demand	N-availability Total	N-availability Green manure	N-availability Crop residues	N-available needed from fertilisers
NL ORG						
1	Iceberg lettuce summer	105	10	10	0	95
	Iceberg lettuce autumn	60	60	10	50	0
2	Spring barley	50	0	0	0	50
	White clover	0	0	0	0	0
3	Brussels sprouts	170	50	50	0	120
4	Fennel early	105	17	0	17	88
	Fennel autumn	60	58	0	58	2
5	Spring barley	50	0	0	0	50
	White clover	0	0	0	0	0
6	Potatoes	130	50	50	0	80
	Vetch/grass	0	48	0	48	-48
Average		**122**	**49**	**20**	**29**	**73**
NL INT1						
1	Fennel early	120	0	0	0	120
	Fennel autumn	100	58	0	58	42
2	Potatoes	190	0	0	0	190
3	Brussels sprouts	220	0	0	0	220
4	Spring barley	70	17	0	17	53
Average		**175**	**19**	**0**	**19**	**156**

available from green manure is 50 kg ha^{-1} (working coefficient 50%). In the last column, the available nitrogen needed from organic and chemical fertilisers is given per crop. This nitrogen need is calculated by subtracting the total nitrogen availability from the nitrogen demand. In NL ORG, 60% of the nitrogen is required from fertilisers, and in NL INT1, the figure is 90%.

2.3.4 Fertilisation

Nutrients from non-fertilisation sources are, in many cases, not able to counterbalance nutrient demand at the desired yield levels. Therefore, nutrients have to be applied with fertilisers to achieve the quality of production targets. As stated previously, the amount of nutrients available from fertilisers has to be equal to the demand minus the available nutrients from non-fertilisation sources (see Table 2.7).

Fertiliser choice

There are many types of fertilisers. Important characteristics of fertilisers are the rate of availability of the nutrients in the fertiliser and the number of nutrients in a fertiliser (single or compound fertilisers). In addition, there is also additional organic matter in the organic fertilisers.

The main groups of fertilisers are organic and mineral fertilisers. Each group can be subdivided into many different types. The type of fertiliser used is dependent on the objectives. For example, if nutrient losses are large, it is better to choose mineral fertilisers because fewer nutrients have to be supplied to fulfil crop needs. On the other hand, if organic matter needs to be applied as well, organic fertilisers can be a better choice. In addition, availability and price can play a role. In organic systems, the choice is generally limited because mineral fertilisers may not be used at all.

Organic fertilisers

Organic fertilisers, such as animal manure and composts, deliver several nutrients at once to soil and crop. In addition, organic fertilisers add organic matter to the soil as well. The choice of organic fertiliser to use can depend on the desired nutrient ratios, the need or desire for organic matter, and the price and availability of organic fertilisers.

The nutrient ratios (NP, NK) in the manure should roughly be equal to the nutrient ratios of the fertilisation demand that are already available within the system. This is especially important for organic systems because there are only few, single mineral fertilisers allowed to adjust the needed ratios. In integrated systems, this is a small problem because deficits can be corrected with mineral fertilisers. Except for liquid cow manure, most organic fertilisers have a nitrogen-phosphate ratio that is below two, while most ratios between nitrogen demand and phosphate demand from fertilisers for crop rotations are well above two. If the nutrient ratio differs greatly compared to the crop need, accumulation or losses of nutrients in the soil or nutrient deficits in the crop can occur.

Concerning nitrogen, only the mineral fraction of nitrogen in the organic material is directly available for plant uptake. The organic fraction has to mineralise first, before uptake is possible. Part of this organic fraction mineralises within the first year after application; the rest mineralises in the following years. The pattern of mineralisation is dependent on weather conditions and is difficult to influence. Therefore, nitrogen leaching can occur, as nitrogen can be available at times that it is not needed for crop growth.

To calculate the nitrogen available from organic manure, the working-coefficient has to be available. The working-coefficient represents the percentage of nitrogen, which will become available as mineral nitrogen in the first year after application. Working-coefficients (percentage) are dependent on the type of manure, application time, and soil type (see Annex 5, Table 2). The formula to calculate the availability of nitrogen (kg ha^{-1}) from organic manure is as follows:

N organic manure (kg ha^{-1})
*= working-coefficient (%) * N-content manure (kg ton^{-1})*
** weight applied manure (tons ha^{-1})*

The nutrient content of one type of organic fertiliser can vary greatly in time and between different supply sources. For example, nutrient concentrations in animal manure depend on the feed given to the animals, moisture content and additions (such as straw). Ammonium in manure can volatise, the amount depends on the type of storage. Therefore, by choosing the best fertiliser on paper will not always work out well in practice because concentrations differ from what is expected. In that case, corrections need to be made in the fertilisation levels during the following months (nitrogen) and years (phosphate and potash). The same corrections have to be made when off-take is not equal to what was planned.

If organic matter needs to be applied in addition to nutrients, organic fertilisers can be used. Dependent on the need for organic matter and nutrients, a different type of organic fertiliser should be chosen. Solid manures and composts have a relatively high content of organic matter and low nutrient content. Liquid manures have a relatively low content of organic matter and high nutrient content. In addition, liquid manure has normally higher nitrogen-phosphate ratios and liquid manure has higher working-coefficients as it contains more mineral nitrogen that is directly available. Solid manures and compost have low working-coefficients because nitrogen is mainly present in organic form and in mineral form with low solubility.

Mineral fertilisers
Mineral fertilisers make it possible to apply the precise amount needed by the crop because mineral fertilisers can be applied in the desired ratio, which is often not possible with organic fertilisers. Generally, mineral fertilisers are directly available for plant growth, although increasingly slow release fertilisers are being developed. The advantage of slow release fertilisers is that nitrogen becomes available over a long period in small amounts for plant growth. It is expected that leaching of nutrients is lower when slow release fertilisers are used.
In organic systems, some fertilisers are allowed that are considered to be mineral fertilisers. Although they have often an organic origin, they are considered mineral because mineralisation is fast. It is recommended to avoid these fertilisers because the sources are questionable or are finite. However, they are sometimes used to cover (partially) nitrogen shortages for the short term.
In the long term, soil mineralisation needs to be at such levels that these fertilisers are not necessary any longer. For example, in the organic system in the Netherlands, hydrolysed blood is used as is illustrated in Table 2.9.

Timing of fertilisation
Timing of fertilisation is important in lowering nutrient losses. This is especially important when fertilisation is done to stimulate crop growth (nitrogen fertilisation).
In this case, the best situation is, if possible, to apply fertilisers short before planting. When fertilisation is done to "refill" the nutrient pool, timing is less important.
Although when mineral nitrogen content in the fertiliser is high, growing a (catch) crop after application can prevent nitrogen leaching.

Timing in rotation
Phosphate and potash fertilisation is done before crops with high demands or before crops with low recoveries.
In addition, fertilisation is often carried out before crops that are growing in periods with low availability. This can be the case in early spring. In this case, often a relative easily soluble form of the nutrient is supplied and fertiliser is placed in the cropping row or plant hole. Phosphate and potash fertilisation is field-specific, depending on the fertility levels of the fields (see paragraph 2.3.2).

To be able to spread fertilisers throughout the rotation in organic systems, crops with high demand are alternated with crops that have lower demands. Fertilisers are applied before crops with high demands. By following these strategies, the amount of nutrients in the soil solution is relative large for these crops and smaller for crops with lower demands.

On heavy soils in wet climates, it is often not possible to apply organic fertilisers just before planting. If manure has to be applied long before the start of crop growth, it is better to choose organic manure with low mineral nitrogen content. Up until now, there are only limited possibilities to apply organic fertilisers during crop growth, although experiments are being done on the application of liquid manure in row fertilisation.

Timing during crop growth

To be able to anticipate variations in mineralisation of organic material (because of variations in temperature and humidity) and to keep the amount of nitrogen in the soil solution within certain limits, it is better not to apply all of the nitrogen at once, but to divide the application into smaller doses. The quantity per dose can be based on the crop's uptake-requirements patterns, or be made dependent on the nitrogen content of the plant tissue or the soil. One of these should be measured several times during the growing season to judge if nitrogen soil reserves are sufficient. An extreme variant of this is fert-irrigation. In this system, a small amount of nutrients is added every few days with the irrigation water through plastic tubes on or in the ground. Splitting doses can be eliminated by the use of slow release fertilisers as mentioned in the previous section. A disadvantage of slow release fertilisers is that it is impossible to correct for higher availability from other sources.

Application technique

Application techniques are specific for each fertiliser type. For instance, organic fertilisers are often very bulky and needs to be applied in a different way than mineral fertilisers. Within each group, there are different types as fertilisers that need to be applied differently as well (solid and liquid fertilisers).
Most fertilisers are applied on or in the soil and taken up by the plants' roots. One exception is leaf fertilisation, when fertilisers are sprayed directly on the leaves. However, part of the fertiliser is still absorbed through the soil by the roots. Fertilisers can be applied to the soil full field, in row applications or by irrigation tubes (fert-irrigation). Row application is preferred over full field application if the row distance is large (≥ 75 cm) or for first applications of planting or seeding. In these cases, roots are not capable (yet) of absorbing nutrients from the entire surface. Nutrients between the rows cannot be absorbed by the plants and will be lost.

It is often difficult to apply fertilisers equally over the field, especially for organic fertilisers. However, this problem is largely solved with improved mechanisation. When organic fertilisers are applied in the soil or worked under shortly after application, volatilisation losses will be limited.

Example

In Table 2.8, the organic fertilisation plan for the systems in the Netherlands is presented. In the organic system, liquid and solid cow manure was used. In the integrated systems, Champost was used. In Table 2.9, the planned amount of nutrients from mineral fertilisers, the total availability of nutrients from fertilisers, the total nitrogen availability and the balance between demand and availability are listed. Total planned availability of phosphate and

Table 2.8 Organic fertilisation for NL ORG and NL INT1

Year	Crop / green manure	Type[1)]	Amount ton ha^{-1}	N kg ha^{-1}	P_2O_5 kg ha^{-1}	K_2O kg ha^{-1}	N-available kg ha^{-1}
NL ORG							
1	Iceberg lettuce summer	LCM	30	144	51	195	58
	Iceberg lettuce autumn			0	0	0	29
3	Brussels sprouts	SCM/LCM	35/30	193/144	133/51	123/195	39/86
6	Potatoes	SCM	30	165	114	105	25
	Vetch/grass			0	0	0	8
Average		**SCM/LCM**	**11/10**	**108**	**58**	**103**	**41**
NL INT1							
1	Fennel early	CHP	20	116	72	174	41
	Fennel autumn				0	0	0
2	Potatoes	CHP	20	116	72	174	41
Average		**CHP**	**10**	**58**	**36**	**87**	**20**

1) LCM = Liquid Cow Manure, SCM = Solid Cow Manure, CHP = Champost

Table 2.9 Planned input of organic and mineral fertilisers for NL ORG and NL INT1 in kg ha[-1]

Year	Crop / green manure	Mineral fertiliser input			Total fertiliser available			Total N-availability	Demand–Total availability		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O		N	P_2O_5	K_2O
NL ORG											
1	Iceberg lettuce summer	35	0	0	93	51	195	103	-2	38	132
	Iceberg lettuce autumn	15	0	0	44	0	0	104	44	-13	-63
2	Spring barley	0	0	0	0	0	0	0	-50	-48	-36
	White clover	0	0	0	0	0	0	0	0	0	0
3	Brussels sprouts	0	0	0	125	184	317	175	5	155	234
4	Fennel early	95	0	0	95	0	0	113	7	-9	-108
	Fennel autumn	35	0	0	35	0	0	93	33	-9	-108
5	Spring barley	0	0	0	0	0	0	0	-50	-48	-36
	White clover	0	0	0	0	0	0	0	0	0	0
6	Potatoes	60	0	0	85	114	105	135	5	75	-74
	Vetch/grass	0	0	0	8	0	0	48	56	0	0
Average		**40**	**0**	**0**	**0**	**81**	**58**	**129**	**8**	**24**	**-10**
NL INT1											
1	Fennel early	80	50	54	121	122	228	122	1	112	108
	Fennel autumn	60	0	54	60	0	54	118	18	-10	-120
2	Potatoes	150	0	0	191	72	174	181	1	22	170
3	Brussels sprouts	220	50	226	220	50	226	220	0	12	-108
4	Spring barley	50	0	0	50	0	0	67	-3	-56	-42
Average		**140**	**25**	**70**	**161**	**61**	**171**	**178**	**4**	**20**	**2**

potash was equal to the planned availability of nutrients from fertilisers.

2.3.5 Evaluation and optimisation of the nutrient management strategy plan

Evaluation and optimisation

The strategy is evaluated and optimised on basis of the defined agronomical and environmental parameters at two points: before implementation in practice and during the testing and improving phase. Expert evaluation is necessary before the strategy can be implemented in practice.

In the evaluation, the expected or attained parameter values are compared with the targeted values or ranges. Often, shortages can occur between the targets and the results, and these shortages can be assessed for acceptably. In Annex 2, an overview is given of the parameters chosen to evaluate the prototypes. The parameters used to evaluate I/ENM can be divided in three groups (Table 2.10). The first group of parameters is influenced by I/ENM directly. The second group of parameters is influenced by I/ENM directly as well, but other methods are at least as important to determine the parameter values. The third group is only indirectly influenced by I/ENM.

The parameter values have to estimated in order to evaluate the prototype. If the total parameters cannot be estimated, supporting parameters can be used. For instance, it is difficult to estimate the complete net surplus. However, costs and revenues of new fertilisation strategies can be compared to conventional strategies. Optimal quality of production should be guaranteed when the available nutrients meet the demand. Potential losses can be estimated for expected surplus, expected nitrogen availability at the start of the leaching season and estimated development of nutrient pools (build up, reduction or stabilisation in nutrient pool). The latter can be used as well to evaluate sustainability of resource use.
To evaluate developments in the soil's organic matter content in general, the organic matter balance for the fertilisation plan can be calculated. Within a stable system, the decomposition (or respiration) of organic matter should be compensated for by the input of external (organic manure, compost, straw, paper pots) and internal (crop residues, green manures) organic matter sources. In this way, the beneficial effects of organic matter can be preserved.

If the conclusion is that the strategy does not meet sufficiently the objectives, the strategy should be adjusted. The strategy can be changed at different points (Figure 2.2):

Table 2.10 I/ENM related major objectives, parameters and other methods

Parameter	Theme	Other methods involved
Parameters directly influenced by I/ENM		
Phosphate Annual Balance (PAB)	Clean Environment	MCR
Potash Annual Balance (KAB)		
Nitrogen Available Reserves (NAR)	Clean Environment	MCR
Phosphate Annual Reserves (PAR)	Sustainable management of resources	MCR
Potash Annual Reserves (KAR)		
Organic Matter Annual Balance (OMAB)	Sustainable management of resources	MCR
Nitrate Content of crop produce (NCONT)	Quality production	MCR
Parameters partially influenced by I/ENM		
Energy Input (ENIN)	Sustainable management of resources	all methods
Quantity Production (QNP)	Quality production	all methods
Quality Production (QLP	Quality production	all methods
Net Surplus (NS)	Farm continuity	all methods

1. Within the I/ENM method:
   a. *Change nutrient demand.*
      The amount of phosphate and potash can only be adjusted by changing objectives because the off-take has to be changed. There are many options for changing the nitrogen demand by improving the recovery fraction. Recovery can be improved by implementing fertilisation techniques, which limit nutrient losses as dividing doses over different portions or using liquid instead of solid mineral fertilisers.
   b. *Change nutrient availability from non-fertiliser sources.*
      External inputs cannot be changed, but internal inputs can be changed. It is possible to improve nutrient availability from these sources by managing the green manures, crop residues and catch crops. For instance, time of ploughing has an influence on the mineralisation behaviour of these sources. However, changes are small if the rotation is not altered at the same time.
   c. *Change input of total nutrients.*
      Choosing another type of fertiliser can change input of total nutrients. For example, replacing an organic fertiliser with a mineral fertiliser reduces nutrient emission. Mineral fertilisers can be supplied with a higher efficiency to the crop and total nutrient input will be lower as well.
2. In the MCR method:
   The rotation can be changed in the MCR method. If it is not possible to change nutrient input and availability sufficiently to reach the objectives, a change in the rotation is necessary. Therefore, it is necessary to return to the MCR method. Sometimes it may be necessary to review other methods (MSC or I/ECP as well).

Example

Nutrient balances and expected nitrogen availability at the start of the leaching season for the two systems in the Netherlands are presented in Tables 2.9 and 2.11.
In Table 2.9, the availability and surplus (except nitrogen) of nutrients is presented. In Table 2.11, the simplified nitrogen balance and the expected mineral nitrogen, based on expert evaluation, are presented.

In NL ORG at a rotation level, nitrogen availability was almost equal to the demand because of the doses of hydrolysed blood. In general, quality production targets would be attained. However, at a crop level, this was not the case: spring barley was not fertilised and the second crops of iceberg lettuce and fennel had too large reserves of nitrogen. The surpluses for the second crops were caused by the goal to fertilise the first crops sufficiently. Spring barley had a low financial return, thus optimal fertilisation was not targeted for this crop. Probably, actual yield levels would be lower than target values in this crop. The difference at a rotation level between demand and availability for phosphate was 24 kg ha^{-1}, which is almost equal to the expected unavoidable loss of 20 kg ha^{-1}. There was a small shortage of potash. This was in the range of the soil fertility levels at the farm, which are within the target limits.

In the Integrated system, chemical fertilisers were used to supply nitrogen, phosphate and potash. All nutrients were in ample supply in the mineral fertilisers. This was valid for nitrogen at a crop level as well. Thus, all quality production targets should have be achieved. The difference between demand and availability for phosphate was exactly equal to the unavoidable loss of 20 kg ha^{-1}. This was in the range of the soil fertility levels at the farm, which are within the target limits.

The expected nitrogen surplus in NL ORG was about 20 kg higher than in NL INT1, mainly because of lower expected off-take of nitrogen. The mineral nitrogen values

Table 2.11 Simplified nitrogen balance and expected N-min after harvest and at the start of the leaching season (based on expert evaluation) for NL ORG and NL INT1 in kg ha^{-1}

Year	Crop / green manure	Input	Off-take	Surplus	N-min after harvest	N-min start leaching season
NL ORG						
1	Iceberg lettuce summer	179	38	141	70	
	Iceberg lettuce autumn	15	38	-23	70	90
2	Spring barley	0	90	-90	10	
	White clover	100	0	100		30
3	Brussels sprouts	337	77	260	10	20
4	Fennel early	95	36	59	10	
	Fennel autumn	35	36	-1	30	50
5	Spring barley	0	90	-90	10	
	White clover	100	0	100		30
6	Potatoes	225	116	109	70	
	Vetch/grass	80	0	80		70
Average		**194**	**87**	**108**	**47**	**48**
NL INT1						
1	Fennel early	196	40	156	30	
	Fennel autumn	60	40	20	30	60
2	Potatoes	266	149	117	70	90
3	Brussels sprouts	220	99	121	10	10
4	Spring barley	50	105	-55	20	30
Average		**198**	**108**	**90**	**40**	**48**

were on average for the rotation sufficiently within the target value of 70 kg ha^{-1}, although after some crops, the value was expected to be higher than the target.

Table 2.12 OMAB for NL ORG and NL INT1 in kg ha^{-1}

		NL ORG	NL INT1
Organic matter supply			
External	Organic fertiliser	1 033	1 000
	Paper pots	825	838
Internal	Crop residues	1 156	1 579
	Green manure	554	0
Total		3 568	3.416
Organic matter respiration			
Organic matter content		3.1%	2.3%
Respiration per ha/year		2 558	1 898
OMAB		*1.40*	*1.80*

For phosphate and potash, the surplus is presented in Table 2.11 because demand is equal to input for these nutrients. The phosphate surplus is about equal to the unavoidable loss of 20 kg ha^{-1}. The potash surplus is within the range of balance fertilisation. The organic matter balance is discussed separately in the next paragraph.

Both systems met the legal requirements. Under the Dutch legislation, input of nitrogen should be smaller than 265 kg ha^{-1} of which a maximum of 170 kg ha^{-1} from animal manure. Input of phosphate should be a maximum of 85 kg ha^{-1}. These requirements will be in force starting in 2003. In the years before, input maximums are being gradually reduced.
In Table 2.12, an example of organic matter calculations for the Netherlands is given. All organic matter sources were counted. It is remarkable that paper pots contributed a quarter of the total organic matter. In both systems, crop residues contributed most to the supply. Respiration is estimated at 2.5% of the total active organic matter content. The OMAB is for both systems above the target of one. It is expected that organic matter content in both systems will rise.

3 A practical case of nutrient management in the Southwest of the Netherlands

J.J. de Haan & J.A.M. Rovers
Applied Plant Research (PPO), Lelystad, The Netherlands

3.1 Design of the nutrient management strategies

In this chapter, the general VEGINECO strategies for I/ENM (chapter 2.3) are applied to the situation in the Netherlands. In the following section, the same procedure is followed as in Chapter 2.3 (Figure 2.2). Part of the NL INT1 system (Brussels sprouts system with barley, fennel and potato) and the organic system (NL ORG) were chosen as examples of the nutrient management strategies tested.

3.1.1 Integrated system

Nutrient demand
Fertilisation advice levels are well established for most vegetable crops (based on experimental research). Nutrient demanddemand isis based on these advice levels. Soil organic mineralisation and deposition are taken up in the nutrient demand. The amount of nutrients in irrigation water was ignored.
The nitrogen demand is summarised in (Table 3.1, column 1). Potatoes and Brussels sprouts are crops with high demands. The phosphate and potash demands are equal to the off-take as is presented in Table 3.3 column 5 and 6).

Nutrients from non-fertilisation sources
In the Dutch integrated system, non-fertilisation sources that contributed to nutrient availability came from crop residues only. No green manures could be used because of the late harvest of the crops. Relatively little is known about the nitrogen content and amount of crop residues. There are no standard guidelines for the working coefficient of crop residues or soil organic matter mineralisation. However, this is not a problem in fertilisation practices in integrated systems because the fertilisation is based on repeated measurements of N-min in the soil. In this way, mineralisation from crop residues is measured directly. The contribution of crop residues is presented in Table 3.1 column 5.

Fertilisation
The nutrient demand had to be supplied by fertilisation except for a small amount of nitrogen in crop residues. Most nutrients were supplied through mineral fertilisers. Manure is not necessary for the organic matter balance. Champost was used to help to close nutrient cycles at higher levels. Champost was applied in autumn. It is mainly used to stabilise the organic matter content of the soil. Because of the relative low working coefficient (35%) (See Annex 5 for working coefficients of different organic fertilisers), it only adds 20 kg ha^{-1} to the nitrogen availability (Table 3.1, column 7). 20 ton of Champost ha^{-1} was applied before fennel and potato. These crops required the most potash and Champost is rich in potash. Nitrogen fertilisation is crop-specific. The recommended levels are based on mineral nitrogen in the soil measured before sowing. For most crops, split dosage systems for nitrogen are available (guided fertilisation). For fennel, these are based on repeated N-min assessments. For potato and experimentally for Brussels sprouts, these are based on repeated measurements of nitrogen in leaf stalks.

As the soil fertility is, on average, within the desired range, phosphate and potash fertilisation is balanced with off-take. Exceptions are:

- 20 kg ha^{-1} was added as compensation for unavoidable losses for phosphate.
- If soil fertility of phosphate is within or lower than the desired range, all crops planted or sown before May 15th receive a phosphate fertiliser. This fertilisation of early crops was reduced from the standard of 50 kg ha^{-1} to 20 kg ha^{-1} by using a row application of polyphosphates.

Table 3.1 Nitrogen demand and planned nitrogen availability (kg ha^{-1}), split in different sources for NL INT1. Ideally, nitrogen demand should be equal to total nitrogen availability for each crop.

Year	Crop/green manure	N-required	Total N-availability	N-availability from internal sources			N-fixation	N-availability from fertilisers	
				Total	Green manure	Crop residues		Organic	Mineral
		1	2=3+7+8	3=4+5	4	5	6	7	8
1	Fennel early	120	121	0	0	0	0	41	80
	Fennel autumn	100	118	58	0	58	0	0	60
2	Potatoes	190	191	0	0	0	0	41	150
3	Brussels sprouts	220	220	0	0	0	0	0	220
4	Spring barley	70	67	17	0	17	0	0	50
Average		**175**	**179**	**19**	**0**	**19**	**0**	**20**	**140**

Table 3.2 Planned organic and mineral fertilisation (kg ha-1), NL INT1, organic manure was applied before fennel and potato (20 ton ha-1 champost)

Year	Crop / green manure	N		P_2O_5		K_2O	
		Org	Min	Org	Min	Org	Min
1	Fennel early	116	80	72	50	174	54
	Fennel autumn	0	60	0	0	0	0
2	Potatoes	116	150	72	0	174	226
3	Brussels sprouts	0	220	0	50	0	0
4	Spring barley	0	50	0	0	0	0
Average		**58**	**140**	**36**	**25**	**87**	**70**

- If the soil fertility levels of phosphate or potash are lower than the desired range, repair doses are applied. For phosphate, 50 kg ha-1 per Pw-point and for potash 100 kg ha-1 per K-count point was applied for every point lower than the desired level.

Most of the phosphate and potash for the entire cropping plan was applied before the crops that need these minerals were planted such as phosphate before early (leaf) crops and potash before potatoes. Mineral phosphate fertiliser was applied before fennel and Brussels sprouts. Mineral potash was applied before fennel and potato. Phosphate and potash were applied to balance the fertilisation over the entire cropping plan.

An overview of the nutrients applied with fertilisation is presented in Table 3.2.

Evaluation and optimisation

In the average rotation, nutrients are sufficiently available (Table 3.3 for phosphate and potash and Table 3.1 for nitrogen). Normally nitrogen availability is almost equivalent to the nitrogen demand. In practice, testing should indicate if the planned fertilisation is sufficient enough for the optimal quality and quantity of the produce.
It is expected that emissions of phosphate and potash would be limited because surpluses were limited. The nitrogen surplus was rather high with on average 90 kg ha-1. Large differences existed at a crop level (Table 3.3, column 7). The surplus was high for early fennel, Brussels sprouts and potatoes, and very low for spring barley. The N-min after harvest (based on expert evaluation) was expected not to exceed the maximum limit of 70 kg ha-1. However, the N-min at start of the leaching season was expected to be too high for potatoes. On average, the expected N-min after harvest and at the start of the leaching season was expected to be well below the desired level of 70 kg ha-1.

3.1.2 Organic system

There are not recommended standards for fertilisation currently available for organic systems. This was reflected in the large variation in fertilisation strategies between organic farms, which was observed in the BIOM project (Wijnands, 2000).

Nutrient demand

Nutrient demand was derived from conventional experiments and adjusted for the organic system. Organic mineralisation and deposits in soil were included in the nutrient demand. The amount of nutrients in irrigation is negligible. Nitrogen demand is summarised in Table 3.4 (column 1). Phosphate and potash demand is equal to the average off-take. Average off-take is summarised in Table 3.5 (column 6, 7 and 8).

Nutrient availability non-fertilisation sources

In NL ORG, non-fertilisation sources that contribute to nutrient availability are from green manures and crop residues. In the rotation, optimal use is made of the

Table 3.3 Nutrient balance (kg ha-1) NL INT1

Year	Crop / green manure	Input			Off-take			Surplus		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
		1	2	3	4	5	6	7=1-4	8=2-5	9=3-6
1	Fennel early	196	122	228	40	10	120	156	112	108
	Fennel autumn	60	0	0	40	10	120	20	-10	-120
2	Potatoes	266	72	400	149	50	230	117	22	170
3	Brussels sprouts	220	50	0	99	38	108	121	12	-108
4	Spring barley	50	0	0	105	56	42	-55	-56	-42
Average		**198**	**61**	**157**	**108**	**41**	**155**	**90**	**20**	**2**

Table 3.4 Nitrogen demand and nitrogen availability (kg ha^{-1}) are split into different sources for NL ORG. Ideally, nitrogen demand should be equal to total nitrogen availability for each crop.

Year	Crop/green manure	N-demand	Total N-availability	N-availability from internal sources			N-fixation	N-availability from fertilisers	
				Total	Green manure	Crop residues		Organic	Dried blood
		1	2=3+7+8	3=4+5	4	5	6	7	8
1	Iceberg lettuce summer	105	103	10	10	0	0	58	35
	Iceberg lettuce autumn	60	104	60	10	50	0	29	15
2	Spring barley	50	0	0	0	0	0	0	0
	White clover	0	0	0	0	0	100	0	0
3	Brussels sprouts	170	175	50	50	0	0	125	0
4	Fennel early	105	112	17	0	17	0	0	95
	Fennel autumn	60	93	58	0	58	0	0	35
5	Spring barley	50	0	0	0	0	0	0	0
	White clover	0	0	0	0	0	100	0	0
6	Potatoes	130	135	50	50	0	0	25	60
	Vetch/grass	0	56	48	0	48	80	8	0
Average		**122**	**130**	**49**	**20**	**29**	**47**	**41**	**40**

green manures white clover and vetch/grass. White clover was utilised as under sowing with summer barley. White clover fixates 100 kg nitrogen ha^{-1} of which 50% is available for uptake by the crop in the next growing season. Vetch/grass fixates 80 kg nitrogen ha^{-1} of which 25% is available for uptake by the crop in the next growing season. In Table 3.4 (column 3, 4 and 5), the availability from internal sources is presented. The nitrogen demand of 122 kg ha^{-1} so 73 kg ha^{-1} had to be supplied with fertilisers.

Fertilisation

All of the phosphate and potash required and 60% of the nitrogen required had to be supplied with fertilisation. Organic manure was given to the crops with the highest demands and with the highest financial return. Experience has shown that it is most difficult to supply sufficient amounts of phosphorus. Therefore, the first step is to fulfil phosphorus demand and adjust for the expected unavoidable losses of 20 kg ha^{-1}. At least two thirds of the phosphate supplied with manure needs to be from solid manures. This rule is set to supply a sufficient amount of fresh organic matter to the soil in addition to nutrients, and to create a soil with a higher mineralisation potential, which can lower nutrient required from fertilisers in the long term.

Solid and liquid cow manure were chosen as fertilisers because the nitrogen and phosphate availability corresponds the best to the fertilisation demand for the crop compared to other animal manures. In addition, these manures were readily available.

Manure was applied before the crops with high nutrient demands. Solid cow manure was applied in the autumn after clover but before ploughing. Solid cow manure can not be applied in spring because of the difficulty of use.

Liquid cow manure is applied in spring shortly before crop growth. 30 ton ha^{-1} liquid cow manure was used before iceberg lettuce because nitrogen is directly available. Brussels sprouts require a lot of nitrogen so before it is planted, 30 ton ha^{-1} liquid manure is applied. If an insufficient amount of nitrogen is available for crops that have high yields from internal sources and manure, then dried blood is applied. The input of the dried blood can possibly in future be replaced by the organic matter mineralisation. In Table 3.4 (column 8) indicates for which crops dried blood is applied and which amounts are used.

Evaluation and optimisation

In the average rotation, nutrients are sufficiently available. The results show in Table 3.5 (column 8 and 9) that the average phosphate and potash surpluses were close to or larger than zero (phosphate included the unavoidable loss of 20 kg ha^{-1}). Table 3.4 (column 1 and 2) shows that the average nitrogen availability was larger than the average amount of nitrogen required. At a crop level, however, the nitrogen availability for barley was 50 kg ha^{-1} too low. Barley is a crop with low financial return, so the low nitrogen availability was acceptable. Iceberg lettuce and fennel in the autumn have too much nitrogen available because nitrogen is mineralised from the fertilisers during early growth. In practice, testing should indicate if the planned fertilisation is sufficient enough for the optimal quality and quantity of the produce, and if the remaining nitrogen in the soil is within acceptable levels.

Surpluses are presented in the last part of Table 3.5 (column 7 to 9). It was expected that emissions of phosphate and potash would be limited because surpluses were limited. Large differences existed in nitrogen surplus

Table 3.5 Nutrient balance (kg ha-1), NL ORG. Nutrient off-take of phosphate and potash is equal to nutrient demand. Input consists of animal manure and dried blood. The amount of nitrogen applied with animal manure only can be calculated by subtracting the amount of dried blood applied (Table 3.4 column 8) from the total input of nitrogen (this Table, column 1).

Year	Crop / green manure	Input			Off-take			Surplus		
		N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
		1	2	3	4	5	6	7=1-4	8=2-5	9=3-6
1	Iceberg lettuce summer	179	51	195	38	13	63	141	38	132
	Iceberg lettuce autumn	15	0	0	38	13	63	-23	-13	-63
2	Spring barley	0	0	0	90	48	36	-90	-48	-36
	White clover	100	0	0	0	0	0	100	0	0
3	Brussels sprouts	337	184	318	77	29	84	260	155	234
4	Fennel early	95	0	0	36	9	108	59	-9	-108
	Fennel autumn	35	0	0	36	9	108	-1	-9	-108
5	Spring barley	0	0	0	90	48	36	-90	-48	-36
	White clover	100	0	0	0	0	0	100	0	0
6	Potatoes	225	114	105	114	39	179	109	75	-74
	Vetch/grass	80	0	0	0	0	0	80	0	0
Average		**195**	**58**	**103**	**87**	**35**	**113**	**108**	**24**	**-10**

at a crop level (Table 3.5). It was expected that N-min after harvest (based on expert evaluation) did not exceed the maximum limit of 70 kg ha-1. However, the expected N-min at start of the leaching season was expected to be too high for iceberg lettuce in the autumn. On average, the N-min after harvest and at the start of the leaching season was expected to be well below the desired level of 70 kg ha-1.
The mineralisation of soil organic matter was still not accounted for in the nitrogen availability. If organic manure is continuously applied, then the extra mineral nitrogen from soil organic matter needs to be taken into account.

3.2 Testing and improving

3.2.1 Results for each parameter

Overview of desired and achieved levels of parameters related to IENM
In Tables 3.6 and 3.7, an overview is presented of the desired and achieved levels of the parameters related to IENM.

Annual balance of phosphate and potash (PAB, KAB)
The desired levels for phosphate and potassium Annual Reserves were within the desired range (Table 3.6). According to the fertilisation strategy, phosphate and

Table 3.6 Desired level and achieved level of parameters related to IENM of NL INT1 (see Annex 2 for explanation of parameter acronyms)

Theme	Parameter	Desired level	Realisation 1997	1998	1999	2000
Environment						
Nutrients	PAB	1.0	1.15	0.91	0.81	1.06
	KAB	1.0	0.84	1.25	1.04	1.03
	NAR	<70 kg ha-1 (0-100 cm)	58	25	33	32
Sustainable use of resources	PAR	20 < Pw < 30	30	28	29	24
	KAR	20 < K-count < 29	26	24	23	23
	OMAB	>1	1.5	1.7	1.5	1.4
Quality Production	QNP	1.0 (GAP)	0.95	0.71	0.90	0.96
	QLP	1.0 (GAP)	0.99	0.92	0.80	0.88
	NCONT	1 (<2 500 ppm)	1	1	1	1

Table 3.7 Desired level and achieved level of parameters related to IENM of NL ORG (see Annex 2 for explanation of parameter acronyms)

Theme	Parameter	Desired results	Realisation 1997	1998	1999	2000
Environment	PAB	1.0	0.70	0.93	1.19	1.42
Nutrients	KAB	1.0	2.62	0.93	1.77	1.85
	NAR	<70 kg ha^{-1} (0-100 cm)	80	14	52	41
Sustainable use of resources	PAR	20 < Pw < 30	29	29	29	23
	KAR	20 < K-count < 29	25	24	25	25
	OMAB	>1	1.4	1.3	1.4	1.4
Quality Production	QNP	1.0 (GAP)	0.72	0.73	0.85	0.61
	QLP	1.0 (GAP)	0.49	0.64	0.65	0.71
	NCONT	1.0 (<2 500 ppm)	1	1	1	1

potash input in fertilisers should then be equal to the phosphate and potash off-take in the produce (averaged over the experimental years). For phosphate, the off-take is raised with 20 kg ha^{-1} of unavoidable losses (input = off-take + 20 kg ha^{-1}). A circumstantial surplus or shortage in previous years was compensated in the following years.

In NL INT1, the average PAB and KAB for the period 1997-2000 was 1.0, which is equal to balanced fertilisation. In NL ORG, the average PAB was close to 1.0 as well. However, the KAB was on average 1.8, which was too high. The high KAB was caused by the variation in the nutrient content of the organic manure and the ratio between phosphate and potash in the manure. It was not possible to lower KAB without adding sufficient phosphate and nitrogen to the rotation. Phosphate-potash ratios of manure normally do not correspond with the desired phosphate/potash ratio of the rotation.

Nitrogen available reserves at the start of leaching season (NAR)

In most years, the NAR was lower than the target level of 70 kg ha^{-1} in NL ORG as well as in NL INT1 (Figure 3.1). Only in NL ORG in 1997, the NAR at a system level was higher than the target. The data for NAR of 1998 was taken too late because of the wet weather conditions. At this date, a lot of the mineral nitrogen had probably already leached out of the soil. Therefore, they were not comparable with the data from the other years and the target levels. In addition, nutrient off-take was low and surplus was high because the potatoes were not harvested.

The NAR at a farm level is very dependent of the type of crops in the rotation. In the integrated system, (NL INT1) none of the crops had a high NAR, thus the farm level was relatively low. In the other integrated system (NL INT2) with iceberg lettuce, the actual level was close to the desired level (69 kg ha^{-1}) because of the high NAR

Table 3.8 Average Nitrogen Available Reserves per crop and per system for NL INT1 and NL ORG) (layer 0-100; kg ha^{-1}) in November 1997, December 1998, November 1999 and November 2000

Crop	Integrated 1997	1998	1999	2000	Organic 1997	1998	1999	2000
Brussels sprouts	34	20	20	36	15	11	22	14
Cauliflower	65[1]	50[1]	20[1]	12	-	-	-	-
Celeriac	34	20	41	55	-	-	-	-
Cereals	47	25	36	46	38	16	19	44
Fennel	124	32	70	66	124	15	56	12
Grass/clover	-	-	-	-	-	16	22	18
Iceberg lettuce	111	44	123	134	140	17	81	42
Potato	48	29	30	28	124	10	110	104
System	**58**	**35**	**33**	**32**	**80**	**14**	**52**	**41**

[1] Except Winter Cauliflower

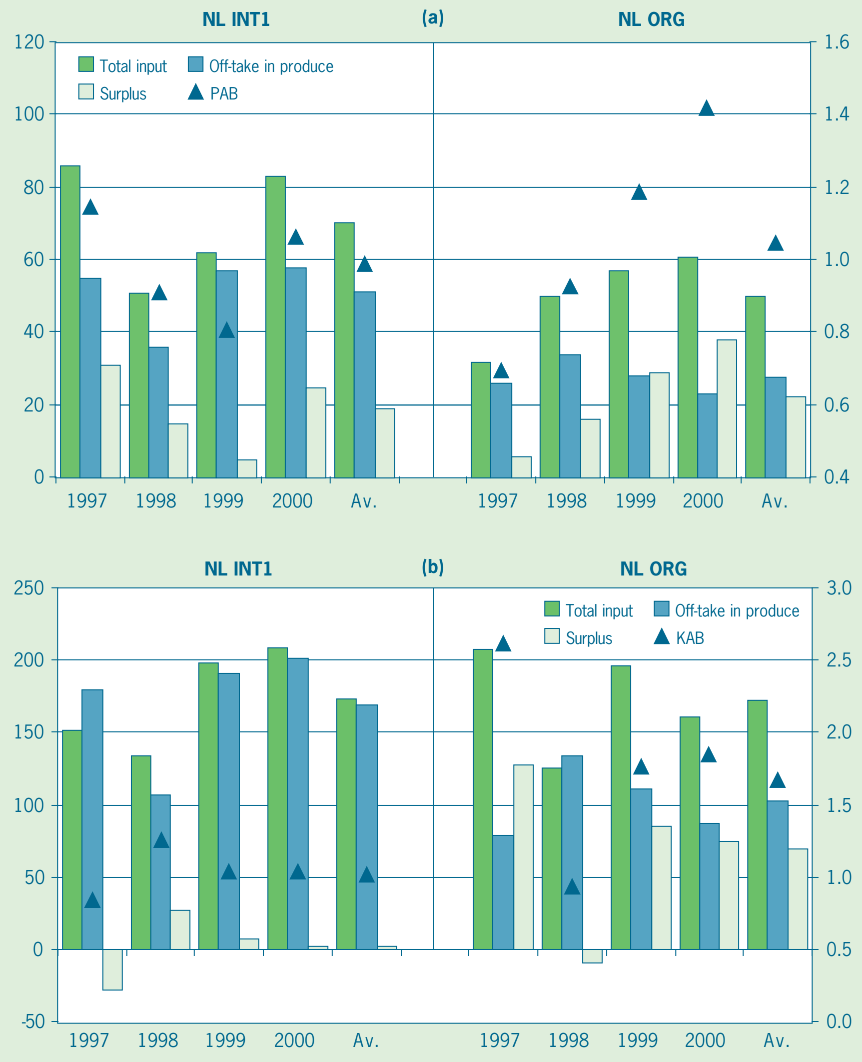


Figure 3.1 Phosphate (a) and potassium (b) input, off-take and surplus (left y-axis, (kg ha-1)) and phosphate and potassium Annual Balances (PAB and KAB, right y-axis (-)) for NL INT1 and NL ORG

after the cultivation of iceberg lettuce. In NL ORG, iceberg lettuce and potato caused a high NAR. Iceberg lettuce had a high NAR because of the low efficiency and large amounts of crop residues. Potato had a high NAR caused by an early harvest because of late blight.

Available reserves of phosphate and potash (PAR, KAR)

Available reserves of phosphate and potash were on average throughout the fields within the desired range for both systems (Pw between 20 and 30, K-count between 20 and 29). Variations between years and between systems were small. In order to maintain these levels for the long term, balanced fertilisation for potash and a surplus of 20 kg ha^{-1} for compensation of unavoidable losses for phosphate were used.

Organic matter annual balance (OMAB)

In sustainable farming, effective organic matter input should be higher than decomposition. For this reason, it was necessary in integrated as well as in organic systems to apply organic manure and input crop residues.
Input sources of effective organic matter are:

- Organic manure: Champost in the integrated systems, and solid and liquid cow manure in the organic system.
- Green manures: clover, yellow mustard, phacelia and grass clover in the organic system, no green manures were used in NL INT1.
- Crop residues: especially Brussels sprouts and spring wheat/barley add a large amount.
- Peat pots.

Decomposition is calculated by multiplying the amount of organic matter in the tillage zone by the decomposition coefficient. The decomposition coefficient was estimated at 2.5% per year. The amount of organic matter in the tillage zone (0 – 30 cm) was higher in NL ORG (3.1%) than in NL INT1 because of a higher organic matter content (2.3%).
Subsequently, total decomposition in the organic system was estimated higher than in NL INT1.
Table 3.9 gives an estimation of the OMAB. It appears that for both systems, OMAB was well above one. For OMAB in both systems, organic manure was not necessary. However, organic manure was necessary for nutrient supply in the organic system. In the integrated system, organic manure was used to close nutrient cycles.

Quality and quantity of produce parameters (QLP, QNP)

In order to calculate QLP and QNP at a system level for every crop, a target for yield and quality was set. The level at which the targets were set should reflect the Good Agricultural Practice (GAP). The targets were equal to average practice.
In NL INT1, the realised levels for quantity and quality almost reached the desired levels. It is assumed that nutrient availability was sufficient to reach yield quantity

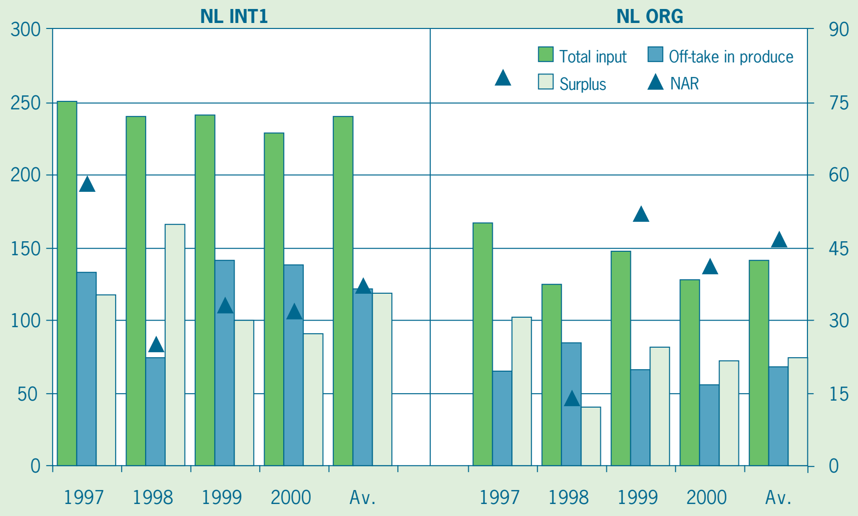


Figure 3.2 Simplified Nitrogen balance (left y-axis, (kg ha-1)) and Nitrogen Available Reserves at the start of the leaching season (NAR, right y-axis (kg ha-1, 0-100 cm)) for NL INT1 and NL ORG

and quality targets. Yield quantity and quality was most influenced by external factors (weather), diseases, and plagues, which were not treated sufficiently.

For organic farming, there was hardly any data available to support the quantification of the Good Agricultural Practice (GAP) in terms of yield and quality. The calculated QNP and QLP was an average for all the crops in one system. Comparing the results (Table 3.7), QNP varied from 61 to 85% of the target values and QLP improved over the years with 20%. In addition to problems in crop protection, nitrogen supply needs to be improved for all crops to reach target values.

Nitrate content in crop produce (NCONT)
Nitrate content in crop produce was only measured for iceberg lettuce and fennel. No crop or cultivation exceeded the target level of 2 500 ppm. Values for iceberg lettuce were always below 750 ppm; values for fennel varied between 500 and 2 000 ppm. Nitrate levels in the integrated systems were always higher than in the organic system, probably because of higher nitrogen availability in the integrated systems.

Table 3.9 Example of the organic matter annual balance (OMAB) for NL INT1 and NL ORG in 1997, inputs and decomposition in kg effective organic matter ha-1

	NL INT1	NL ORG
Total Input	*3 416*	*3 533*
Crop residues	1 579	1 156
Green manure	0	519
Peat pots	838	825
Organic manure	1 000	1 033
Decomposition	*1 898*	*2 558*
OMAB	1.8	1.4

Energy input (ENIN)
Nutrient management influences energy efficiency by fertiliser choice. To produce mineral fertilisers (especially nitrogen), a lot of energy is required, while production of organic manure cost no energy. This is reflected in the energy use between the organic and integrated system. To produce iceberg lettuce organically, 1 340 MJ ha-1 is required for fertilisation, while for integrated production 9 040 MJ ha-1 is needed. Of the total energy needed to produce one hectare of iceberg lettuce, in the integrated system, 22% of the energy is needed for fertilisation while in the organic system, only 4% is needed. No target value was set because ENIN is a new parameter.

3.2.2 Optimisation of nutrient management

Changes have been made over the four years of testing and improving to optimise the integrated and organic systems.

Integrated systems
In the rotation, the period between two iceberg lettuce crops had been increased. In this way, the succeeding crop could make better use of the nitrogen released in the crop residues of the previous crops. It is expected that NAR of iceberg lettuce, which is very high, will be lowered with this measure.
In fertilisation, different changes had taken place:

- Early crops received a row application of polyphosphates of 20 kg ha-1. Before, a gift of 50 kg ha-1 was given. If every early crop received a gift of 50 kg ha-1, the phosphate Annual Balance (PAB) would be larger than 1. In the row application, PAB can be lower than one when necessary.
- Leaf stem method to determine the nitrogen required by Brussels sprouts was developed and tested. The leaf stem method allows the input to be adjusted better to the crops' nitrogen requirements. This could enhance quality and quantity production.
- Adjustments of fertilisation levels for different crops improved quality and quantity of production:
  - Brussels sprouts: nitrogen fertilisation of Brussels sprouts was raised to obtain sufficient plant height.

- The initial nitrogen gift for cauliflower had been increased from 200 – N-min to 225 – N-min.
- The initial gift of nitrogen for iceberg lettuce had been changed from 80 – N-min to 100 – N-min.
- The nitrogen gift for potatoes had been based on the cultivated variety.

- Sulphur shortage was found in Brussels sprouts, which influenced quality and quantity of production. Sulphur reserves in the soil have been assessed and shortages have been solved with top dressings. In addition, sulphur fertilisation was carried out for Brussels sprouts before cultivation based on assessment of sulphur reserves.

Organic system

Rotation:

- Grass-clover was introduced to replace one of the barley crops. The clover under sown in the barley appeared to be variably successful. The replacement was done to ensure that sufficient nitrogen was brought in to the system by fixation.
- The green manure type after the potato was changed to a non-leguminous crop. Originally vetch was included in the plans, but because of the high amount of mineral nitrogen in the soil after potatoes, it was decided to choose for yellow mustard, phacelia or fodder radish. The use of a non-leguminous green manure should lower NAR-values.
- The period between two iceberg lettuce crops has been lengthened. In this way, the succeeding crop can make better use of the nitrogen released from the crop residues of the previous crops. It is expected that NAR of iceberg lettuce, which is very high, will be lowered with this measure.

Fertilisation:

- Animal manure application:
  - Use of more composted and less straw-rich, solid cow manure allowed better application in the field.
  - Use of a 'sleepslangen' machine for liquid cow manure could be spread better.
  - Other amounts of manure, liquid manure was used more to better meet the nitrogen demand.
- Hydrolysed blood:
  - Earlier application of hydrolysed blood shortly before planting so that nitrogen would be available in time. This means that hydrolysed blood cannot be used when crops have shortages because it is slow mineralisation. By applying hydrolysed blood before planting, efficiency of application was improved and quality and quantity of production was possibly higher.
  - More hydrolysed blood was applied before iceberg lettuce because of nitrogen shortages and subsequently low quality and quantity of production.
- Straw from barley was applied to the iceberg lettuce field after harvest to lower NAR. Storage of straw and application of straw appeared to be difficult. The effect of application is (still) unknown.
- The nitrogen gift for potatoes had been based on the cultivated variety.

In addition, the ecoplough was used in combination with a device for breaking the old plough-layer instead of the normal ploughing method. This improved nitrogen availability by enhancing mineralisation in the upper layers. The ecoplough ploughs only 10-15 cm. The problem in using it was the creation of a plough layer and the soil structure declined. If use of the ecoplough has stimulated nitrogen mineralisation and has improved yield quality and quantity is questioned.

4 A practical case of nutrient management in Emilia-Romagna, Italy

V. Tisselli, L. Rizzi, G.P. Sarno & D. Scudellari
Centro Ricerche Produzioni Vegetali (CRPV), Cesena, Italy

4.1 Design of the nutrient management strategy

An example the fertilisation strategy of the organic (I ORG) and the integrated industry system (I INT1) are given.

4.1.1 Nutrient management in the first year

In the first year, fertilisation management in the integrated systems was based on the Emilia-Romagna integrated guidelines. These guidelines required a low input strategy compared to conventional fertilisation management. In I ORG, the fertilisation management followed EC 91/2092, only fertilisers from organic origin were used. Off-take data were taken from the literature. To compare these with real off-take data, the nutrient off-take was analysed.

Strategy in integrated systems

Phosphate and potash fertilisation
General strategy in integrated guidelines for phosphate and potash fertilisation is based on the off-take of the crop corrected for the soil reserves. Normally the advice includes a starting phosphate gift for early crops. For some crops as for example sugar beet and tomato, application is done in rows.

Nitrogen fertilisation for arable crops: simplified balance
For arable crops including tomato, a simplified balance is drawn up to calculate the fertilisation demand. This nitrogen fertilisation demand is based on the general nitrogen demand minus:

- 1% of nitrogen total soil (corrected for access rainfall).
- Nitrogen from mineralisation soil organic matter (based on a table taking into account C/N quotient, texture and organic matter content of the soil).
- Nitrogen in crop residues of the preceding crop.
- Nitrogen from repeated organic manure applications.

The nitrogen fertilisation demand is well established for most crops based on experimental data and experience. The nitrogen fertilisation demand is *not* dependent on *soil mineral nitrogen* assessments, these types of recommendations are not available in Italy. Italy is the only country that takes explicitly soil organic matter *mineralisation* into account, even in a double terminology, by the total nitrogen and by a mineralisation factor. The nitrogen from repeated applications of organic manure suggest that a fraction of residual nitrogen from organic manure is taken into account. Working coefficients of *organic manure* are well established, the mineralisation from organic manure is taken into account during 24 months after application.

Nitrogen fertilisation for vegetable crops
Nitrogen fertilisation for vegetable crops is based on nitrogen demand minus nitrogen available from crop residues (previous crops) and nitrogen fixation (only for crop following green beans or other leguminous species). There is no advice based on available mineral nitrogen in the soil.

Strategy in the organic system
The nitrogen fertilisation was based on the use of different kinds of organic manure. The amount of nitrogen available from fertilisers together with the nitrogen from crop residues had to cover the nitrogen requirements. Phosphate and potash requirements were not assessed. Input of phosphate and potash was dependent on the contents in the organic manures.

Evaluation of the first year results
The results of applying the first year strategies are shown in tables 4.1 to 4.4 for I INT1 and I ORG.
The nitrogen demand in INT1 is met with the available nitrogen. The calculated nitrogen surplus is low (23 kg ha^{-1} year). Organic manure is not applied because is difficult to find near the farm. Looking at OMAB, a little improvement is necessary because the values are lower than one.
The phosphate and potash surpluses are low. Considering that the phosphate and potash soil fertility levels are lower than the desired range it would be reasonable to expect higher phosphate and potash surpluses in order to bring the soil fertility levels within the desired range.
The nitrogen demand in I ORG of 248 kg ha^{-1} $year^{-1}$ is high and is covered by the available nitrogen. A second year effect of the applied manure is added to the available nitrogen. The calculated nitrogen surplus of 172 kg ha^{-1} is high. In order to cover the nitrogen need, the phosphate surplus of 159 kg ha^{-1} $year^{-1}$ is much too high, especially considering that the level of available soil reserves is higher than the desired range.
However, the strategies were not satisfactory. In addition, the analysis of the nutrient content in produce and crop residues showed lower values in respect of reference data. Therefore, the fertilisation strategy has been changed as reported in Table 4.5. In I ORG, the rotation has been changed as well.

4.1.2 Actual nutrient management strategy

The application of the new strategy brought a great improvement of the reduction of the planned surplus especially for nitrogen and phosphate as shown in Tables 4.6 to 4.9. The improvements are particularly evident in I ORG. This is due to the change in the rotation in which the nitrogen demand is reduced, a better estimation of the potential productivity of the crops and the use of organic manure with high nitrogen content and low phosphate and potash content. In I INT1, changes were small because the starting situation was more balanced

Table 4.1 Nitrogen demand and nitrogen availability (kg ha⁻¹), split into different sources for I INT1

Crop	N-demand	Total N availability	N-availability from internal sources			N-fixation	N-availability from fertilisers	
			Total	Green manure	Crop residues		Organic	Mineral
	1	2=3+7+8	3=4+5	4	5	6	7	8
Melon	130	130	35	35	0	0	0	95
Spinach	150	150	4	0	4	0	0	146
Tomato	130	130	10	0	10	0	0	120
Winter wheat	150	146	22	0	22	0	0	124
Green beans	30	0	-40	0	-40	70	0	40
Sugar beet	130	130	35	0	35	0	0	95
Catch crop	0	22	22	0	22	0	0	0
Average	**180**	**195**	**22**	**9**	**13**	**18**	**0**	**155**

Table 4.2 Nutrient balance (kg ha⁻¹), I INT1

Crop	Input			Off-take			Surplus		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	1	2	3	4	5	6	7=1-4	8=2-5	9=3-6
Melon	95	44	130	45	24	120	50	20	10
Spinach	146	29	70	105	29	70	41	0	0
Tomato	120	70	170	106	50	160	14	20	10
Winter wheat	124	84	40	158	64	40	-34	20	0
Green beans	110	7	60	35	7	75	5	0	10
Sugar beet	95	70	120	80	50	110	15	20	10
Catch crop	0	0	0	0	0	0	0	0	0
Average	**173**	**76**	**147.5**	**132**	**56**	**137**	**41**	**20**	**10**

Table 4.3 Nitrogen demand and nitrogen availability (kg ha⁻¹), split in different sources for I ORG

Crop	N-demand	Total N availability	N-availability from internal sources			N-fixation	N-availability from fertilisers	
			Total	Green manure	Crop residues		Manure	Organic fertilisers
	1	2=3+7+8	3=4+5	4	5	6	7	8
Lettuce SP	100	76	13	0	13	0	63	0
Lettuce SU	100	73	10	0	10	0	63	0
Lettuce A	100	83	10	0	10	0	73	0
Italian ryegrass	0	41	10	0	10	0	31	0
Green beans	30	52	16	16	0	70	36	0
Strawberry	150	149	35	0	35	0	84	30
Fennel	200	166	14	0	14	0	95	57
Vetch	0	55	24	0	24	40	31	0
Melon	130	119	37	37	0	0	42	40
Cauliflower	180	141	13	0	13	0	96	32
Average	**248**	**239**	**46**	**13**	**32**	**28**	**154**	**40**

Table 4.4 Nutrient balance (kg ha-1) I ORG

Crop	Input			Off-take			Surplus		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	1	2	3	4	5	6	7=1-4	8=2-5	9=3-6
Lettuce SP	223	218	150	30	30	90	193	188	60
Lettuce SU	0	0	0	30	30	75	-30	-30	-75
Lettuce A	134	131	90	30	30	90	104	101	0
Italian ryegrass	0	0	0	0	0	0	0	0	0
Green beans	70	0	0	35	7	50	35	-7	-50
Strawberry	190	120	320	25	50	80	165	70	240
Fennel	213	153	105	92	37	182	121	116	-77
Vetch	40	0	0	0	0	0	40	0	0
Melon	129	87	60	45	24	120	84	63	-60
Cauliflower	210	174	120	125	39	80	85	135	40
Average	**302**	**221**	**211**	**103**	**62**	**192**	**199**	**159**	**20**

Table 4.5 Actual VEGINECO fertilisation strategy

Nutrients	Availability	Desired fertilisation level
P	*Low*	Off-take + repair.
	Normal	Off-take; initial gift of 20 kg ha-1 phosphate for early crops during a cold period.
	High	No fertilisation; initial gift of 20 kg ha-1 phosphate for early crops during a cold period.
K	*Low*	Off-take + repair.
	Normal	Off-take + extra gift of 10 kg ha-1 potash for unavoidable loss.
	High 144 - 250 ppm K_2O on sandy soil 180 - 300 ppm K_2O on loam soil 216 - 350 ppm K_2O on clay soil	50% Off-take + extra gift of 10 kg ha-1 potash for unavoidable loss.
	Very high >250 ppm K_2O on sandy soil >300 ppm K_2O on loam soil >350 ppm K_2O on clay soil	No input of potash.
N		Nitrogen input determined in two different ways: 1. Amount calculated on nitrogen simplified balance (from guidelines of Integrated Production of Region Emilia-Romagna, see above). 2. Amount calculated on nitrogen demand - nitrogen available from crop residues.
Organic matter	*Low*	Plough down of crop residues, use of manure and cultivation of cover crop species to obtain an humus production higher than the loss during the mineralisation period.
	Normal	Plough down of crop residues, use of manure and cultivation of cover crop species to obtain an humus production higher than the loss during the mineralisation period.
	High	Plough down of crop residues, and the temporary opportunity to not use cover crop, manure and organic fertilisers.

Table 4.6 Nitrogen demand and nitrogen availability (kg ha-1), split into different sources for I INT1

Crop	N-demand	Total N availability	N-availability from internal sources			N-fixation	N-availability from fertilisers	
			Total	Green manure	Crop residues		Organic	Mineral
	1	2=3+7+8	3=4+5	4	5	6	7	8
Melon	130	156	61	61	0	0	0	95
Spinach	150	149	10	0	10	0	0	139
Tomato	130	81	25	0	25	0	0	56
Winter wheat	150	132	14	0	14	0	0	118
Green beans	30	0	-40	0	-40	70	0	40
Sugar beet	130	76	0	0	0	0	0	76
Catch crop	0	23	23	0	23	0	0	0
Average	**180**	**172**	**23**	**15**	**8**	**18**	**0**	**131**

Table 4.7 Nutrient balance (kg ha-1), I INT1

Crop	Input			Off-take			Surplus		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	1	2	3	4	5	6	7=1-4	8=2-5	9=3-6
Melon	95	38	190	29	18	190	66	20	0
Spinach	139	13	73	75	13	96	64	0	-23
Tomato	56	35	148	90	15	148	-34	20	0
Winter wheat	118	76	40	152	26	37	-34	50	3
Green beans	110	0	28	7	3	28	33	-3	0
Sugar beet	76	85	48	69	29	80	7	56	-32
Catch crop	0	0	0	0	0	0	0	0	0
Average	**148**	**62**	**132**	**106**	**26**	**145**	**42**	**36**	**-13**

Table 4.8 Nitrogen demand and nitrogen availability (kg ha-1), split into different sources for I ORG

Crop	N-demand	Total N availability	N-availability from internal sources			N-fixation	N-availability from fertilisers	
			Total	Green manure	Crop residues		Manure	Organic fertilisers
	1	2=3+7+8	3=4+5	4	5	6	7	8
Green beans	0	0	0	0	0	70	0	0
Fennel	140	101	14	0	14	0	53	34
Melon	90	82	0	0	0	0	9	73
Barley-Vetch	0	25	12	0	12	40	0	13
Strawberry	100	93	91	91	0	0	0	2
Lettuce SU	100	63	13	0	13	0	20	30
Lettuce A	100	66	6	0	6	0	32	28
Average	**133**	**135**	**34**	**23**	**11**	**28**	**29**	**45**

Table 4.9 Nutrient balance (kg ha^{-1}) I ORG

Crop	Input			Off-take			Surplus		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	1	2	3	4	5	6	7=1-4	8=2-5	9=3-6
Green beans	70	0	0	13	3	15	57	-3	-15
Fennel	87	89	66	29	13	84	58	76	-18
Melon	82	21	11	129	61	333	-47	-40	-322
Barley-Vetch	53	0	0	0	0	0	53	0	0
Strawberry	2	0	0	18	7	30	-16	-7	-30
Lettuce SU	50	41	30	67	23	112	-17	18	-82
Lettuce A	60	61	46	24	7	45	36	54	1
Average	**101**	**53**	**29**	**70**	**29**	**155**	**31**	**25**	**-117**

Table 4.10 Desired level and achieved level of parameters related to I/ENM of I INT1

Theme	Parameter	Desired level	Realisation			
			1997	1998	1999	2000
Environment Nutrients	PAB	1	1.86	3.20	1.28	1.00
	KAB	1	1.43	1.16	0.93	0.48
	NAR	<70 kg ha^{-1} (0-100cm)	144	163	78	73
Sustainable use of Resources	PAR	35 < ppm P_2O_5 < 40	15.4	33	50	21
	KAR	144 < ppm K_2O < 216	99	148	171	108
	OMAB	1	0.69	0.96	1.00	0.94
Quality Production	QNP	1 (GAP)	0.90	0.87	0.83	0.81
	QLP	1 (GAP)	0.93	0.97	0.89	0.95
	NCONT	1 (<2 500 ppm)	-	1	1	1

Table 4.11 Desired level and achieved level of parameters related to I/ENM of I ORG

Theme	Parameter	Desired level	Realisation			
			1997	1998	1999	2000
Environment Nutrients	PAB	1	3.03	4.50	1.48	1.95
	KAB	1	1.05	0.85	0.21	0.27
	NAR	<70 kg ha^{-1} (0-100cm)	302	220	160	146
Sustainable use of Resources	PAR	35 < ppm P_2O_5 < 40	98	251	220	156
	KAR	144 < ppm K_2O < 216	499	650	553	480
	OMAB	1	1.24	0.77	0.72	0.77
Quality Production	QNP	1 (GAP)	0.83	0.79	0.86	0.79
	QLP	1 (GAP)	0.98	0.99	0.90	0.99
	NCONT	1 (<2 500 ppm)	1	1	1	1

Figure 4.1 Phosphate (a) and potassium (b) input, off-take and surplus (left y-axis, (kg ha-1)) and phosphate and potassium Annual Balances (PAB and KAB, right y-axis (-)) for I INT1 and I ORG

Annual balance of phosphate and potash (PAB, KAB)
Results in the first year differ greatly from the following years because of the change in strategy (Chapter 4.1). In 1998, PAB was still too high in all systems as off-take data was still based on reference values. An analysis of the results indicates that implementing the new strategy was justified (Figure 4.1). The increase of PAB in 2000 was caused by low off-take values compared to the fertilisation plan and at I INT1, this made it necessary to input phosphate to improve the soil reserves (PAR).

Reaching the desired balance values was very difficult in Italy:

- For early crops, it was necessary to supply an initial gift to reach the sufficient levels of quality and quantity of production.
- In I INT2 and I ORG, the balance between the nutrients in the organic manure did not meet the crop and soil requirements. In I INT2, organic manure was needed to build up organic matter reserves in order to improve soil structure.
- Off-take values were highly variable over the years, as was observed in the soil and crop analyses.

Balance values lower than one for KAB were optimal for our situation, which is characterised by very high potash soil reserves (KAR), particularly in I ORG and I INT2 (Tables 4.10 and 4.11).

and the nitrogen fertilisation was better fit to the need of the crop. In I INT2 system (not show in tables), a comparable change as in I ORG was made.

4.2 Testing and improving

4.2.1 Results for each parameter

Overview of desired and achieved levels of parameters related to I/ENM
In the tables 4.10 and 4.11, an overview of the desired and achieved levels of the parameters related to I/ENM is shown. Only data of I ORG and I INT1 are shown, in the text reference is made to I INT2 as well. In the final report, a full overview of all data is given.

Nitrogen available reserves at the start of leaching season (NAR)
In I ORG and I INT1, NAR decreased strongly. In I INT2, the result fluctuated through all of the years (Tables 4.12 and 4.13 and Figure 4.2). In I ORG, the trend was that the NAR decreased at system level was confirmed for various crops except strawberry. For this crop, the high values of NAR were probably caused by the catch crop, which was cut down before the strawberry was planted. In I INT2, the targets were reached in 1999, while the NAR in 2000 was too high, which was caused by celery (NAR = 267 kg ha-1). This value could not be explained by changes in fertilisation or soil type. In I INT1, the target

Table 4.12 *Average Nitrogen Available Reserves per crop and per system (I ORG and I INT1) (layer 0-100; kg ha-1)*

Crop	I INT1 1997	I INT1 1998	I INT1 1999	I INT1 2000	Crop	I ORG 1997	I ORG 1998	I ORG 1999	I ORG 2000
Green beans	112	86	184	23	Fennel	423	155	66	82
Spinach	159	74	47	13	Lettuce	428	103	166	87
Wheat	135	216	34	221	Strawberry	73	318	181	225
Catch crop	178	275	48	35	Cauliflower	281	-	-	-
					Catch crop	-	304	227	192
Average	**146**	**163**	**78**	**73**	**Average**	**302**	**220**	**160**	**146**

Table 4.13 *Average Nitrogen Available Reserves per field and per system (I ORG and I INT1) (layer 0-100; kg ha-1)*

I INT1	1997	1998	1999	2000	Average
Field 1	135	275	184	13	152
Field 2	178	86	47	221	133
Field 3	112	74	34	35	64
Field 4	159	216	48	23	112
I ORG	**1997**	**1998**	**1999**	**2000**	**Average**
Field 1	428	155	227	225	259
Field 2	73	103	66	192	109
Field 3	428	304	181	87	250
Field 4	281	318	166	82	212

was reached in 1999 and 2000; particularly in 2000, only wheat had a NAR that was too high. This high NAR was probably caused by the high quantity of tomato crop residues cut down in the previous year.
It is clear that the NAR registered in the project was directly influenced by the nutrient management strategy (fertilisation amounts and techniques, catch crops and soil management).

Available reserves of phosphate and potash (PAR, KAR)
It is difficult to explain the dynamic of PAR and KAR over time. The phosphate and potash analyses were always carried out in the same laboratory, during the same period of the year, with the same methodology. However, the measured values were sometimes varied dramatically. These fluctuations cannot be ascribed to the applied strategy or to the off-take in produce from the different crops. Still, in I ORG and I INT2, these fluctuations were not a problem as soil reserves were very high and no fertilisation with phosphate and potash was necessary. However, in order to meet nitrogen demand (I ORG) or organic matter demand (I INT2), the balance values were still above one for phosphate. In I INT1, PAR and KAR were lower than the target in some cases. For this reason, soil reserves were corrected with an extra phosphate and potash application.

Organic matter annual balance (OMAB)
The role of organic matter in the soil planted with vegetables crop is most important, particularly for the positive effects on soil fertility and improvement of structure for clay and compact soils. During the four years, the content of organic matter in the soil (OMAR) had been higher than the target range in I ORG, within the target range in I INT2, and lower than the target range in I INT1.

In I ORG, the need to add nutrients with organic matter and the high content of phosphate and potash in the soil represented a limit for the input of organic matter. In this

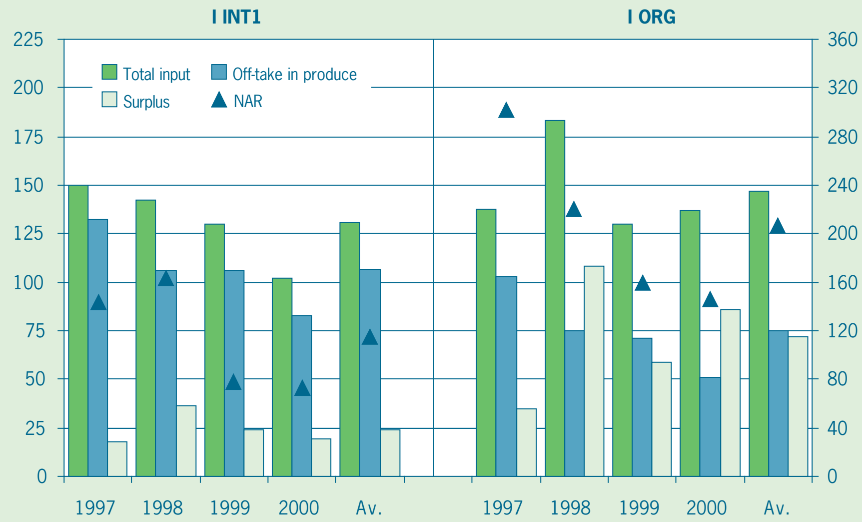


Figure 4.2 Simplified Nitrogen balance (left y-axis, (kg ha-1)) and Nitrogen Available Reserves at the start of the leaching season (NAR, right y-axis (kg ha-1, 0-100 cm)) for I INT1 and I ORG

Table 4.14 Example of the Organic Matter Annual Balance (OMAB) for the integrated and I ORG 1997, inputs and decomposition in kg effective organic matter ha-1

	1999		2000	
	I INT1	I ORG	I INT1	I ORG
Total input	*1 396*	*2 070*	*1 305*	*1 793*
Crop residues	1 028	567	1 020	489
Green manure	296	724	219	553
Peat pots	72	571	66	592
Organic manure	0	207	0	160
Decomposition	*1 397*	*2 877*	*1 388*	*2 336*
OMAB	1.00	0.72	0.94	0.77

way, the input of organic matter from organic manure and crop residues had not compensated for the loss of quantity through the mineralisation and the balance had reached values low than one.
In I INT2, the values of OMAB had always been close to the target range as a result of inputs of Champost (mushroom residues). At the same time, values of PAB had been higher than target range(high content of phosphate in Champost).

In I INT1, the value of organic matter lost through mineralisation was minor in comparison to the other two systems. Organic manure was not added to this system and the input of organic matter came from crop residues and catch crops only. These sources of organic matter had been sufficient to reintegrate mineralisation losses and for this reason, OMAB reached values very near one for all four years.

OMAB values obtained from 1997 to 2000 had no direct influence on OMAR and this probably is due to the short period of the project.

Table 4.14 provides an estimation of OMAB. The final results of the three systems show that the organic system needed to improve OMAB. OMAB can be improved with larger inputs of organic manure, by changing the rotation through a crop substituted by a cover crop to increase the quantity of crop residues.

In I INT1, OMAB could be improved by a relatively small amount of organic manure or with a cover crop's long growth cycle to obtain a large quantity of crop residues. In I INT2, the good values of OMAB suggest the maintenance of the current fertilisation strategy. It should be possible to reduce the input of organic matter. However, it is more desirable to change the rotation by eliminating one crop to preserve soil structure (reduced need for organic matter and good management).

Quality and quantity of produce (QLP,QNP)
In none of the systems did the nutrient management influence the quality and quantity of production.

Nitrate content in crop produce (NCONT)
The content of nitrate had been estimated for leafy vegetables and the target was fixed at 2 500 ppm. During the project, only in first year was the level higher than the target for two crops (lettuce summer in I ORG and celery in I INT2). In all other situations, the values of nitrate content were lower than the target.

Energy input (ENIN)
Fertilisation influences ENIN depending on the quantity and the type of fertilisers used. The ENIN comparison was for three crops: green beans, cauliflower and fennel. Regarding cauliflower, the energy consumption was much higher in I INT2 compared to I ORG: in I INT2, the energy cost for fertilisers was double compared to I ORG. Total energy input ton-1 was 1 920 MJ in I INT2 while in I ORG, it was 997 MJ. In I INT2, energy for fertilisation represented 16% of the total energy while in I ORG, it was 13% of the total.

4.2.2 Optimisation of nutrient management
The main changes were carried out in order to reduce the elements considered surplus in the MCR in I ORG and the fertilisation strategy was changed for all three systems. To reduce the organic matter mineralisation, ploughing was eliminated in both fresh market systems (I ORG and I INT2). In organic system, using a rotary hoe was substituted with using a hoe.

Organic system (I ORG)
The rotation was simplified by eliminating two crops (cauliflower and lettuce in spring); in this way, the nitrogen demand was reduced and a better synergy among the crops in rotation was obtained. Fert-irrigation was used for melon and strawberry; this cultivation permitted the efficiency of the fertilisers to be improved and there was positive influence also on the internal equilibrium of the

plants. With the fert-irrigation, some organic fertilisers such as hydrolysed blood were tested. However, these fertilisers are expensive. To optimise nitrogen fertilisation in crops with a medium to long growth cycle, fertilisers (Italpollina) that quickly available were combined with fertilisers that release slowly over time were utilised. The cover crops of vetch and barley were combined with horse bean to increase the amount of nitrogen available and the vegetable mass. To improve fertilisation management, it was necessary to increase the number of cover crops in the rotation and to use more organic manure. However, organic manure was not readily available in Emilia Romagna, as livestock is not raised in the region.

Integrated fresh market system (I INT2)

To optimise the fertilisation in I INT2, the distribution technique was improved. No change was made in the type of fertilisers used. Fert-irrigation, normally used in strawberry, was utilised for melon as well to improve the efficiency of the fertilisers for this crop. In lettuce, celery and cauliflower, small quantities of nitrogen were applied periodically through the irrigation system. The fert-irrigation was tested as well in celery in 1998 by using two water tube hoses each four rows. Results of this association have been negative because of imperfections in the water tube hose (close tip and Mole cricket), which have caused differences in plant growth.

Integrated industry system (I INT1)

The initial situation of I INT1 was good and the fertilisation management needed fewer improvements compared to the other systems. By using mineral fertilisers, good results were achieved in the nutrient balances. Nitrogen input was lowered by fert-irrigation in tomato and melon. To improve OMAB, the wheat crop residues were incorporated into the soil. For this reason, a negative input of 40 kg ha^{-1} of nitrogen was estimated before the green beans to balance the negative residual fertility of these crop residues.

5 A practical case of nutrient management in the Valencian Community, Spain

F. Pomares, H. Gómez, B. Cabot & M. Ribó
Instituto Valenciano de Investigaciones Agrarias (IVIA), Valencia, Spain

5.1 Design of the nutrient management strategies

5.1.1 Integrated Systems

The integrated systems located at Pilar de la Horadada (ES INT1), Benicarló (ES INT2) and Paiporta (ES INT3) were chosen as examples for the fertilisation plan, see Tables 5.1 to 5.6.

Fertilisation with N

Recommended fertilisation programs for vegetable crops were based on experimental research and local experience. Nitrogen demand was based on these recommended dosages. Soil organic mineralisation was included in the nutrient demand. Nitrogen from deposits was ignored. Available mineral nitrogen in the soil (0-30 cm layer) before planting was used to adjust the required amount of nitrogen. This amount was supposed to supply the nitrogen from internal sources (green manures and crop residues), and nitrogen from fixation, irrigation water and fertilisers (organic and mineral).

To obtain available nitrogen from green manures, crop residues and organic fertilisers, a working coefficient was used (see Annex 5) for all crops grown within 12 months after incorporation.

The required amount of nitrogen fertiliser was split into

Table 5.1 Nitrogen demand and nitrogen availability (kg ha^{-1}), split into different sources for ES INT1. Ideally, nitrogen demand should be equal to total nitrogen availability for each crop.

Crop/green manure	N-demand	Total N-availability	N-availability from internal sources: Total	Green manure	Crop residues	N fixation	Irrigation water	N-availability from fertilisers: Organic	Mineral
Watermelon	180	120	0	0	0	0	15	0	105
Vetch-oats	0	62	19	0	19	40	3	0	0
Pepper	240	343	49	49	0	0	7	0	287
Lettuce Little Gem 1	50	78	60	0	60	0	1	0	17
Lettuce Little Gem 2	50	12	0	0	0	0	1	0	11
Lettuce Iceberg	120	143	60	0	60	0	3	0	80
Sweet corn	150	30	0	0	0	0	3	0	27
Broccoli	250	72	14	0	14	0	4	0	54
Onion	150	51	0	0	0	0	4	0	47
Celery	200	124	46	0	46	0	6	0	72
Average	**347**	**259**	**62**	**12**	**50**	**10**	**12**	**0**	**175**

Table 5.2 Nitrogen demand and nitrogen availability (kg ha^{-1}), split into different sources for the ES INT2. Ideally, nitrogen demand should be equal to total nitrogen availability for each crop.

Crop/green manure	N-demand	Total N-availability	N-availability from internal sources: Total	Green manure	Crop residues	N-fixation	Irrigation water	N-availability from fertilisers: Organic	Mineral
Watermelon	180	152	23	0	23	0	67	0	62
Green manure	0	80	50	0	50	30	0	0	0
Cauliflower	240	271	13	0	13	0	91	0	167
Lettuce-1	150	177	52	0	52	0	45	0	80
Lettuce-2	150	146	23	0	23	0	43	0	80
Artichoke	200	228	50	50	0	0	178	0	0
Tomato	180	156	15	0	15	0	101	0	40
Green bean	100	111	0	0	0	50	61	0	0
Average	**300**	**330**	**56**	**12**	**44**	**20**	**146**	**0**	**107**

Table 5.3 Nitrogen demand and nitrogen availability (kg ha-1), split into different sources for the ES INT2. Ideally, nitrogen demand should be equal to total nitrogen availability for each crop.

Crop/green manure	N-demand	Total N-availability	N-availability internal sources: Total	N-availability internal sources: Green manure	N-availability internal sources: Crop residues	N fixation	Irrigation water	N-availability from fertilisers: Organic	N-availability from fertilisers: Mineral
Watermelon	240	212	3	0	3	0	209	0	0
Cauliflower	240	253	36	0	36	0	217	0	0
Potato	250	366	45	0	45	0	321	0	0
Fennel	150	281	25	0	25	0	256	0	0
Green bean	100	274	22	0	22	0	252	0	0
Artichoke	250	317	46	46	0	0	271	0	0
Onion	150	307	18	0	18	0	289	0	0
Green manure (barley)	0	18	18	0	18	0	0	0	0
Average	**345**	**507**	**53**	**11**	**42**	**0**	**454**	**0**	**0**

Table 5.4 Nutrient balance (kg ha-1), ES INT1

Crop/green manure	Input N	Input P_2O_5	Input K_2O	Off-take N	Off-take P_2O_5	Off-take K_2O	Surplus N	Surplus P_2O_5	Surplus K_2O
	1	2	3	4	5	6	7=1–4	8=2-5	9=3-6
Watermelon	105	0	0	122	89	227	-17	-89	-227
Vetch-oats	0	0	0	0	0	0	0	0	0
Pepper	287	0	0	201	111	157	86	-111	-157
Lettuce Little Gem 1	17	0	0	17	7	40	0	-7	-40
Lettuce Little Gem 2	11	0	0	36	17	69	-25	-17	-69
Lettuce Iceberg	80	0	0	76	22	242	4	-22	-242
Sweet corn	27	0	0	84	28	157	-57	-28	-157
Broccoli	54	0	0	294	84	420	-240	-84	-420
Onion	47	0	0	227	96	246	-180	-96	-246
Celery	72	0	0	132	98	134	-60	-98	-134
Average	**175**	**0**	**0**	**297**	**138**	**423**	**-122**	**-138**	**-423**

Table 5.5 Nutrient balance (kg ha-1), ES INT2

Crop/green manure	Input N	Input P_2O_5	Input K_2O	Off-take N	Off-take P_2O_5	Off-take K_2O	Surplus N	Surplus P_2O_5	Surplus K_2O
	1	2	3	4	5	6	7=1–4	8=2-5	9=3-6
Watermelon	153	0	2	129	58	126	24	-58	-124
Green manure	0	0	0	0	0	0	0	0	0
Cauliflower	290	0	2	160	69	90	130	-69	-88
Lettuce 1	141	0	1	116	48	72	25	-48	-71
Lettuce 2	137	0	1	67	29	92	70	-29	-91
Artichoke	524	0	29	13	6	18	511	-6	11
Tomato	175	0	1	44	21	33	131	-21	-32
Green bean	82	0	2	23	12	54	59	-12	-52
Average	**376**	**0**	**9**	**138**	**61**	**121**	**238**	**-61**	**-112**

several doses according to the crop growth pattern. When surface irrigation was applied, a basic application was given before planting and the remainder of the doses were split up in several times after planting. If drip irrigation is used, the normal advice is to apply all the nitrogen fertilisers (normally, ammonium nitrate or ammonium sulphate) as fert-irrigation, split up into several times according to the crop growth pattern.

Fertilisation with phosphate and potash

The phosphate and potash fertilisation is crop-specific, based on the nutrient demand and corrected for the available reserves of phosphate and potash in the soil. The nutrient demand is met with different sources: crop residues from previous crops, irrigation water and fertilisers (organic and mineral). The working coefficients of phosphate and potash in organic manure and crop residues are 100%.

The application time of the calculated amount of mineral fertiliser mainly depends on the irrigation system. For vegetable crops with surface irrigation, all phosphate and potash is applied before planting. However when drip irrigation is used, the recommendation is to apply most or all fertilisers (normally using phosphoric acid or mono-ammonium phosphate for phosphate and potassium nitrate or potassium sulphate for potash) as fert-irrigation, split up into several doses according to the crop growth pattern.

5.1.2 Organic systems

For vegetables in organic systems, no standard recommendations for fertilisation are yet available. However, the required amount of nutrients can be estimated from conventional systems. The organic system in Paiporta (ES ORG) had the same crop rotation and showed a similar nutrient input as the integrated system (ES INT3). Therefore, data on nitrogen availability and nutrient balances of the organic system were not included.

Fertilisation with N

In organic systems, as in any farming system, vegetables can obtain a part of the nitrogen demand from non-fertilisation sources (crop residues, green manures, nitrogen fixation by legumes and irrigation water). The difference between the nitrogen demand and availability from these sources had to be met by organic fertilisers, chosen from the EC 91/2092.

Table 5.6 Nutrient balance (kg ha^{-1}), ES INT3

Crop/green manure	Input			Off-take			Surplus		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O	N	P_2O_5	K_2O
	1	2	3	4	5	6	7=1-4	8=2-5	9=3-6
Watermelon	279	0	6	221	56	197	58	-56	-191
Cauliflower	290	0	6	75	25	118	215	-25	-112
Potato	428	0	7	148	34	203	280	-34	-196
Fennel	342	0	6	55	33	94	287	-33	-88
Green bean	336	0	6	21	7	22	315	-7	-16
Artichoke	362	0	7	37	10	33	325	-10	-26
Onion	385	0	7	109	20	129	276	-20	-122
Green manure	0	0	0	0	0	0	0	0	0
Average	**605**	**0**	**11**	**166**	**46**	**199**	**439**	**-46**	**-188**

Table 5.7 Desired level and achieved level of parameters related to IENM of ES INT1

Theme	Parameter	Desired level	Realisation 1998	1999	2000
Environment Nutrients	PAB	<1	2.12	0.80	0.00
	KAB	<1	0.65	0.40	0.00
	NAR	<70 kg N ha^{-1} (0-100 cm)	-	108	186
Sustainable use of Resources	PAR	30-45 mg P kg^{-1}	94	233	153
	KAR	150-300 mg K mg^{-1} soil	663	1 154	1 010
	OMAB	>1	1.59	1.08	0.70
Quality Production	QNP	1 (GAP)	0.76	0.80	0.73
	QLP	1 (GAP)	0.73	0.68	0.87
	NCONT	1 (2 500 ppm)	1	1	1

Fertilisation with phosphate and potash
In organic systems, the phosphate and potash input is derived from different sources (soil available reserves, crop residues and organic fertilisers). The input is usually higher than the amount of nutrientsdemand by the crops. In general, no natural mineral phosphate and potash fertilisers are needed.

5.2 Testing and improving

5.2.1 Results per parameter

Overview of desired and achieved levels of parameters related to I/ENM
Tables 5.7, 5.8 and 5.9 show an overview of the desired and achieved levels of the parameters related to I/ENM. Only data of the integrated systems ES INT1, ES INT2 and ES INT3 are given. In the final report, an overview of all data is included.

Annual balance of phosphate and potash (PAB, KAB)
Taking into account that levels of phosphate and potash available reserves are much higher than the desired range (Tables 5.7, 5.8 and 5.9), phosphate and potash input from the different sources should be lower than the phosphate and potash off take in the produce.

During 1998, the first year of the project, the PAB and KAB levels were higher than 1. Mainly, because of the large amounts of nutrients supplied with the organic fertilisers, however, these levels were reduced dramatically in the following years. In 2000, the achieved values were zero as was desired (Figure 5.1).

Nitrogen available reserves at start of leaching season
The Nitrogen Available Reserves in the fall, before the start of leaching season, showed in both years (1999 and 2000) values much higher than the target level of 70 kg N ha^{1} (Figure 5.2). In general, the level of NAR tended to decrease in the period of the project, except in the ES INT1 system, in which the NAR results were not consistent

Table 5.8 Desired level and achieved level of parameters related to IENM of ES INT2

Theme	Parameter	Desired level	Realisation 1998	1999	2000
Environment	PAB	<1	4.28	0.93	0.00
Nutrients	KAB	<1	2.16	0.79	0.07
	NAR	<70 kg N ha^{1} (0-100 cm)	-	374	238
Sustainable use	PAR	30-45 mg P kg^{1}	196	282	216
of Resources	KAR	150-300 mg K mg^{1} soil	715	918	659
	OMAB	>1	2.50	1.54	0.90
Quality Production	QNP	1 (GAP)	0.88	0.75	0.61
	QLP	1 (GAP)	0.89	0.98	0.84
	NCONT	1 (2 500 ppm)	1	1	1
	NCONT	1 (2 500 ppm)	1	1	1

Table 5.9 Desired level and achieved level of parameters related to IENM of ES INT3

Theme	Parameter	Desired level	Realisation 1998	1999	2000
Environment	PAB	<1	2.70	0.49	0.00
Nutrients	KAB	<1	1.14	0.37	0.06
	NAR	<70 kg N ha^{1} (0-100 cm)	-	410	252
Sustainable use	PAR	30-45 mg P kg^{1}	122	97	87
of Resources	KAR	150-300 mg K mg^{1} soil	599	471	353
	OMAB	>1	2.49	2.13	1.20
Quality Production	QNP	1 (GAP)	0.78	0.80	0.95
	QLP	1 (GAP)	0.73	0.92	0.93
	NCONT	1 (2500 ppm)	1	1	1

with the total nitrogen input. The reason of this discrepancy could be some variation in the soil organic matter mineralisation or in nitrogen content of the drainage water.

At a farm level, the crops included in the rotation mainly influenced NAR values. This means that if shallow root crops such as potato, onion and lettuce are grown, a high NAR level is expected with a great variation in the different fields in one year (Table 5.10). However, during a complete crop rotation, the average NAR levels of the different fields should be similar.

Available reserves of phosphate and potash (PAR, KAR)

Available reserves of phosphate and potash were much higher than the desired range for both systems (Tables 5.7, 5.8 and 5.9). The levels of PAR and KAR were particularly high in the ES INT1 and ES INT2. In the three systems, the levels of PAR and KAR showed a decreasing trend during the project (Figure 5.1), due to the reduction in phosphate and potash input. However, taking into account the slowness of the nutrient changes in the soil, a period of 2.5 years was not enough to adjust the PAR and KAR levels to the target values.

Organic matter annual balance

It is crucial to maintain or increase the level of soil organic matter as the main parameter influencing most of the physical, chemical and biological properties of soils. To achieve this target, the effective organic matter input should be higher than the decomposed amount. The input of effective organic matter is calculated from the amount of biomass supplied from different sources (manure, organic fertilisers, green manure, crop residues and peat pots), and the humification coefficients of each source. Decomposition of the soil organic matter is calculated from the amount of organic matter in the tillage zone (0-30 cm) and the estimated mineralisation rate (in our case, 2% per year).
Table 5.11 shows the levels of OMAB in 1999 in the four systems. In all cases, OMAB was higher than the target value.
Organic fertilisers are the main sources of humus in the systems ES INT1 and ES INT2. In the other two systems, (ES INT3 and ES ORG), crop residues were the most important source. The levels of soil organic matter were in the range of 2-3% in all systems.

Figure 5.1 Phosphate (a) and Potassium (b) input, off-take and surplus (left y-axis, kg ha^{-1}) and Phosphate and Potassium Annual Balances (PAB and KAB, right y-axis (-)) for the integrated systems

Quality and quantity of produce parameters (QLP, QNP)

The average values of QLP and QNP are given in Tables 5.7, 5.8 and 5.9. These results indicate that in the integrated systems yields and quality were somewhat lower than the targets (average Good Agriculture Practice).
The gap between the levels of yield attained and the targets cannot be based on the nutrient management strategy. Other factors such as diseases, pests and weather conditions also cause the difference.
The 12% decrease in yield (average of the different crops), obtained in the organic system

versus the integrated system (ES INT3), was also attributed to the higher incidence of pests and diseases in the organic system.

Nitrate content in crop produce
Nitrate content in crop produce was determined in all vegetables grown during the project. All measured values were lower than the target level of 2 500 ppm. The highest nitrate contents were measured in fennel, lettuce and celery. Nitrate levels in the crops grown in the organic system were similar to those obtained in the integrated because the total nitrogen input was similar in both systems.

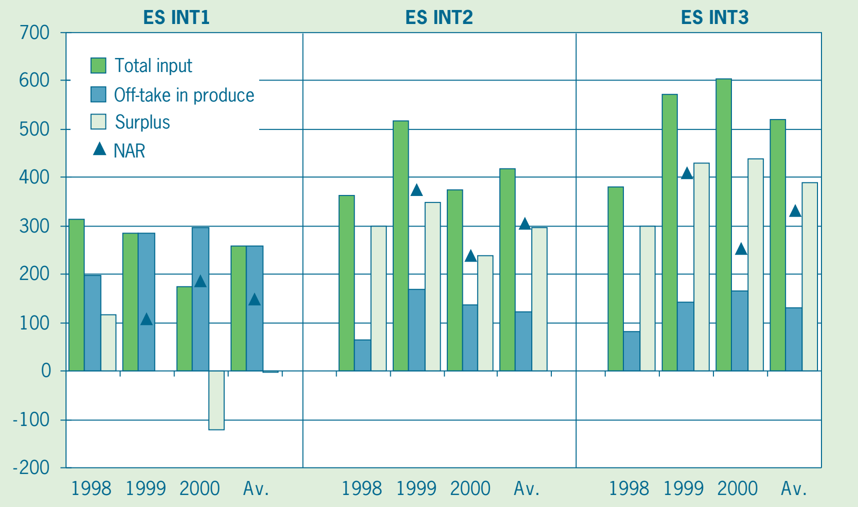


Figure 5.2 Simplified Nitrogen balance (left y-axis, kg ha-1) and Nitrogen Available Reserves at the start of the leaching season (in Fall) for the integrated systems

Energy input (ENIN)
The fertilisation strategy, both the type and quantity of fertiliser, can influence the energy efficiency. The energy required to produce synthetic fertilisers (especially nitrogen products) is much higher than that needed to produce organic manure or compost. However, the transportation and application of organic fertilisers require more energy than mineral fertilisers do. The ENIN comparison was carried out for three crops (cauliflower, fennel and lettuce), comparing integrated and organic management. Results show that the energy costs for fertilisers in the integrated system was up to six times higher than in the organic system. However, in our conditions with high nutrient contents in the irrigation water, the best way to reduce energy is by using the irrigation water efficiently.

Table 5.10 Average Nitrogen Available Reserves (kg ha-1) per field and per system (ES INT1, ES INT2 and ES INT3) in the 0-100 cm layer

ES INT1	1999	2000	Average
Field 1	74	223	148
Field 2	124	125	124
Field 3	127	162	144
Field 4	106	234	170
Average	**108**	**186**	**147**
ES INT2	1999	2000	Average
Field 1	410	225	317
Field 2	481	230	355
Field 3	238	196	217
Field 4	367	302	355
Average	**374**	**238**	**306**
ES INT3	1999	2000	Average
Field 1	446	236	341
Field 2	565	327	446
Field 3	327	260	293
Field 4	302	185	243
Average	**410**	**252**	**331**

5.2.2 Optimisation of nutrient management

Integrated systems
During the first or second year of the project, organic manure was applied in each field of the three integrated systems. This caused a relatively high nutrient surplus. In the third year (2000), the balanced fertiliser strategy followed in the systems caused a dramatic decrease in mineral fertiliser input (from 50-100% in nitrogen and from 80 to 100% in phosphorus and potassium) as compared as to the average dosages used in the conventional system. Meanwhile yield and quality levels were not visibly influenced by the strategy. The recycling of different organic materials (crop residues, green manure and peat pots) was very useful to reduce the need of organic manure in the systems while maintaining a positive effective organic matter balance.

Organic system
In the organic system, the fertiliser input consisted only of one application of 30 ton ha-1 of solid cow and sheet manure to each field at the start of the project, with the objective of increase the soil organic matter level. In the

Table 5.11 Example of the Organic Matter Annual Balance (OMAB) for the integrated and organic systems in 1999, Inputs and decomposition in kg effective organic matter ha^{-1}

	ES INT1	ES INT2	ES INT3	ES ORG
Total input	*2 211*	*3 205*	*2 790*	*2 954*
Crop residues	603	832	1 485	1 648
Green manure	209	762	106	107
Peat pots	219	85	277	277
Organic manure	1 180	1 526	922	922
Decomposition	*2 052*	*2 081*	*1 310*	*1 396*
OMAB	1.08	1.54	2.13	2.11

rest of the season and in other years, no additional fertiliser was needed because of the high nitrate level in the irrigation water used in the system.
The nutrient availability in the organic system was adequate for the crops included in the rotation.
Yields were 12% lower compared to the integrated system. This is caused a higher incidence of pests and diseases.

6 A practical case of nutrient management strategies in Switzerland

C. Gysi, B. Schwaninger, B. Reller & C. Hippe
Swiss Federal Research Station for Fruit-Growing, Viticulture and Horticulture (FAW), Wädenswil, Switzerland

6.1 Design of nutrient management strategies

In Switzerland, the VEGINECO research was carried out on pilot farms. The farms had to meet the legislation and the label guidelines. Therefore, no specific VEGINECO fertilisation strategies existed in Switzerland. Therefore, the official Swiss fertilisation strategy is described in this chapter. In the framework of the official strategy, the Swiss partner tested crop strategies in field trials to improve the nutrient management at integrated and organic farms. The demands for integrated and organic label production are shown in Table 6.1.

The fertilisation strategy for integrated and organic farms in Switzerland is the same. However, there are more restrictions for organic farms and, therefore, the available practices are more limited.

Soil analysis

Two methods are used in Switzerland for the analysis of phosphate, potash, and magnesium soil reserves. The reserves available for plants are extracted with water and the partially available reserves with NH_4-ac-EDTA. To the measured nutrient values, a correction factor is allocated and the values are divided in nutrient availability classes (Table 6.3). For each soil type (texture and organic matter content), different class levels and correction factors exist. The correction factor is multiplied afterwards with the demand of the cultivated crops to get the amount of the fertiliser application. If both extractions are made for the same field, the

Table 6.1 Fertilisation related demands for integrated and organic label production in Switzerland

	Integrated (Label SGU)	Organic (Label BIO SUISSE)
Soil analysis	At least every four years: organic matter, pH, P, K and texture	At least every four years
Nutrient balance	nutrient balance in equilibrium for nitrogen and phosphate with a tolerated surplus of 10% verification of additional nitrogen with N-min analysis	Nutrient balance in equilibrium for nitrogen and phosphate with a tolerated surplus of 10%
Fertiliser report	For every plot: Date of application, amount and kind of fertiliser	For every plot: Date of application, amount and kind of fertiliser
Restriction of single fertiliser application	At most 60 kg ha^{-1} nitrogen per single application	Forbidden: mineral nitrogen fertilisers, water soluble phosphate fertilisers, high percent K fertiliser (positive fertiliser list)

Table 6.2 Yield, nutrient demand, crop residues and net nutrient demand for five vegetable crops in kg ha^{-1}

crop	yield[1]	nutrient demand[2]				crop residues					net nutrient demand[5]			
		N	P_2O_5	K_2O	Mg	N_{avail}[3]	N_{cal}[4]	P_2O_5	K_2O	Mg	N	P_2O_5	K_2O	Mg
cauliflower	200	220	60	180	30	120	20	30	100	20	200	30	80	10
lettuce	350	100	40	120	20	40	10	20	50	10	90	20	70	10
leek	400	170	60	180	30	60	10	30	70	10	160	30	110	20
carrot	600	120	60	220	30	40	10	20	80	10	110	40	140	20
onion	500	100	60	200	30	0	0	0	0	0	100	60	200	30

1. Average yield in integrated production.
2. Nutrient demand for the fertilisation plan for single crops.
3. Available nitrogen for plants in crop residues (80% of the total nitrogen in crop residues, figures rounded off)
4. Nitrogen calculated in the nutrient balance in crop residues (20% of available nitrogen for plants)
5. Net nutrient demand = nutrient demand - nutrients in crop residues

Table 6.3 Nitrogen fertilisation with N-min analysis in mineral soils

crop	yield	total N demand	buffer for mineral soil[1]	depth of N-min analysis	N-min recommendation for harvest week[2]						
					0	2	4	6	8	10	12
	kg N ha^{-1}	kg N ha^{-1}	kg N ha^{-1}	cm	kg N ha^{-1}						
cauliflower	200	220	60	60	120	*260*	*210*	140	110	80	60
lettuce	350	100	40	30	100	*130*	70	40	40	-	-
leek	400	170	50	60	100	220	190	*160*	*140*	120	100
carrot	600	120	30	60	-	150	*150*	100	50	30	30
onion	500	100	50	60	-	-	*150*	*130*	*110*	100	100

1. Buffer in spring enhanced by 20-30 kg N ha^{-1}; In soils with high organic matter content, reduction of the buffer by 40 kg N ha^{-1} after June
2. The recommended dates for N-min analysis for each vegetable crop are written in italics

correction factor is calculated with the following formula:

(2 x correction factor of water extraction + correction factor of NH_4-ac-EDTA extraction) / 3

In the integrated vegetable production, the NH_4-ac-EDTA extraction has been controlled since 2001. The additional analysis of the water-soluble reserves is recommended in cases of malnutrition or in fields with very high or low nutrient contents. In the organic farming, calculating nutrient reserves is normally limited to the partially available reserves.

Nutrient demand

The amount of fertiliser depends on the nutrient off-take in the exported vegetable produce. The nutrient off-take is almost the equivalent to the net-demand. The net nutrient demand is defined as nutrient demand minus the nutrients in the crop residues (Table 6.2). Approximately 80% of

Table 6.4 Calculation of a import-demand nutrient balance (LBL 1995), example for a vegetable farm of 2 hectares cauliflower and 0.5 hectare head lettuce (Gysi et al. 2000)

	Unit	N	P_2O_5	K_2O	Mg
1. Net-nutrient demand of the entire farm					
Cauliflower					
Total nutrient demand	kg ha^{-1}	220	60	180	30
Crop residues (80% of total residues)	kg ha^{-1}	120	30	100	20
Net-nutrient demand (20% of N; 100% of P, K, Mg deduced)	kg ha^{-1}	200	30	80	10
Head lettuce					
Total nutrient demand	kg ha^{-1}	100	40	120	20
Crop residues (80% of total residues)	kg ha^{-1}	40	20	50	10
Net-nutrient demand (20% of N; 100% of P, K, Mg deduced)	kg ha^{-1}	90	20	70	10
Net-nutrient demand for entire farm for 2 ha cauliflower and 0.5 ha head lettuce	kg farm^{-1}	445	70	195	25
Correction factor from soil analysis			1.2	0.8	1.5
Total required nutrients	*kg farm^{-1}*	*445*	*84*	*156*	*38*
2. Imported nutrients					
Farmyard manure (50% of total N accounted for as available N)	35 ton	87	87	420	31
Ammonium-nitrate (27.5% N)	1 250 kg	344			
Total nutrients imported	*kg farm^{-1}*	*431*	*87*	*420*	*31*
3. Import / demand		0.97	1.04	2.69	0.82

nitrogen in the crop residues is available to the plants. Only 20% of the nitrogen theoretically available in the crop residues is accounted for, considering unavoidable nutrient losses and unfavourable growing conditions. For phosphate and potash, 100% of the nutrients in crop residues are considered available for the plants. During the winter most of the nitrogen is leached out of the crop residues from the vegetable crop harvested in the autumn. The first crop in spring is calculated with the total nutrient demand.

Phosphate, potash, and magnesium fertilisation
The fertilisers containing these nutrients are plot-specific. For a plot, the total nutrient net-demand for all cultivated crops for the entire year is calculated. For the nutrients phosphate and potash, a correction for the soil nutrient reserves is made according to the last soil analysis. This calculated amount of fertiliser is applied one time in spring or before a crop that requires a large amount of nutrients. The total amount of phosphate and potash applied should not exceed the total nutrient demand for all of the crops.

Nitrogen fertilisation
In contrast to the nutrients phosphate and potash, the nitrogen fertilisation is crop-specific and based on repeated measurements of the available mineral nitrogen in the soil (N-min). The measured N-min is compared with a recommended N-min value. This recommended value is the sum of the crop's nitrogen requirement and a buffer (for precaution). The buffer is dependent on the season and on the soil's organic matter reserves. The difference between the recommended and the measured values is the amount of fertiliser needed. Recommended values of N-min exist for fertiliser applied several times during the crop cultivation period (Table 6.3). The depth of N-min analysis is dependent on the crop roots.
Before each nitrogen fertilisation, the N-min content in the soil should be measured. Therefore, the use of the N-min method is labour intensive. As alternative to the N-Min

Table 6.5 Target levels and realised levels of parameters related to IENM of the integrated farms in Switzerland

			Realisation								
			CH INT1			CH INT2			CH INT3		
Theme	Parameter	Target level	1998	1999	2000	1998	1999	2000	1998	1999	2000
Environment Nutrients	PAB	≤1	0.96	0.79	0.78	-	0.77	1.02	1.00	1.00	1.10
	KAB	≤1	0.87	0.70	0.70	-	1.00	0.94	0.99	1.02	0.44
	MgAB	≤1	0.97	0.51	0.53	-	1.00	0.82	1.61	1.08	1.32
	NAR	<75 kg ha^{-1} (0-60 cm)	46	-	-	33	-	-	84	-	-
Sustainable use of resources	PAR	40 < P res < 80	143	-	-	116	-	-	143	-	-
	KAR	120 < K res < 200	244	-	-	243	-	-	244	-	-
	MgAR	150 < Mg res < 300	362	-	-	98	-	-	362	-	-
Quality Production	QNP	1.0 (GAP)	1.00	0.59	0.99	0.86	0.69	0.87	0.82	0.92	0.73
	QLP	1.0 (GAP)	1.00	0.67	1.00	0.98	0.84	0.92	0.87	0.99	0.95

Table 6.6 Desired levels and realised levels of parameters related to I/ENM of the organic farms in Switzerland

			Realisation								
			CH ORG1			CH ORG2			CH ORG3		
Theme	Parameter	Desired level	1998	1999	2000	1998	1999	2000	1998	1999	2000
Environment Nutrients	PAB	≤1	0.83	0.21	0.24	-	0.44	-	1.06	1.34	-
	KAB	≤1	0.65	0.14	0.14	-	0.47	-	0.29	0.46	-
	MgAB	≤1	0.94	1.17	0.59	-	0.12	-	0.36	0.72	-
	NAR	<75 kg ha^{-1} (0-60 cm)	55	-	-	76	-	-	26	-	-
Sustainable use of resources	PAR	40 < P res < 80	197	-	-	88	-	-	142	-	-
	KAR	120 < K res < 200	231	-	-	167	-	-	125	-	-
	MgAR	150 < Mg res < 300	271	-	-	154	-	-	100	-	-
Quality Production	QNP	1.0 (GAP)	0.88	0.71	0.85	0.76	0.63	0.82	0.92	0.76	0.92
	QLP	1.0 (GAP)	1.00	0.89	0.98	0.85	0.87	0.87	0.98	0.91	0.97

method, the plant sap analysis is used to determine the nitrogen top dressing.

Additional nitrogen demand can be included in the calculation for the nutrient balance if it is indicated by N-min or plant sap analysis.
In organic farming, N-min measurements are not common because organic fertilisers that work efficiently do not exist. This method does not give any information on the how the nitrogen is released from organic matter or organic fertilisers. The use of the N-min method in organic farming is only recommended before the first crop in spring, in order to develop an idea of how much nitrogen is available to the plants in the soil.

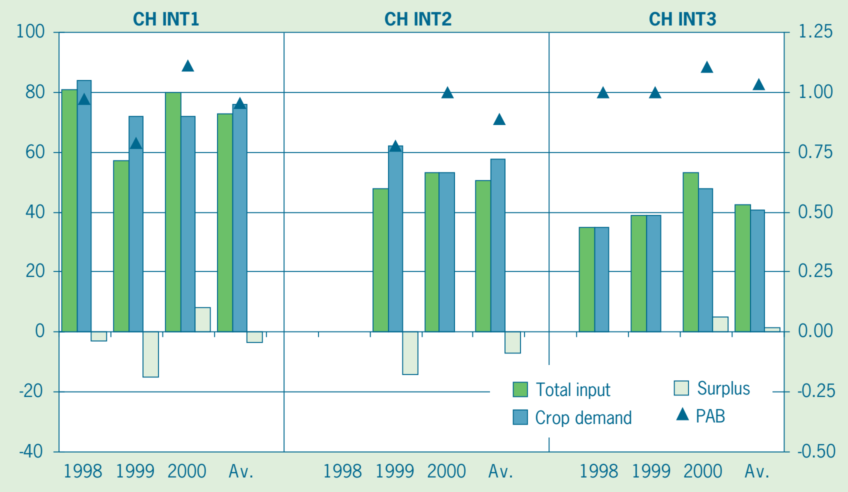


Figure 6.1 Phosphate input, demand and surplus and Phosphate Annual Balance (PAB) for the integrated farms

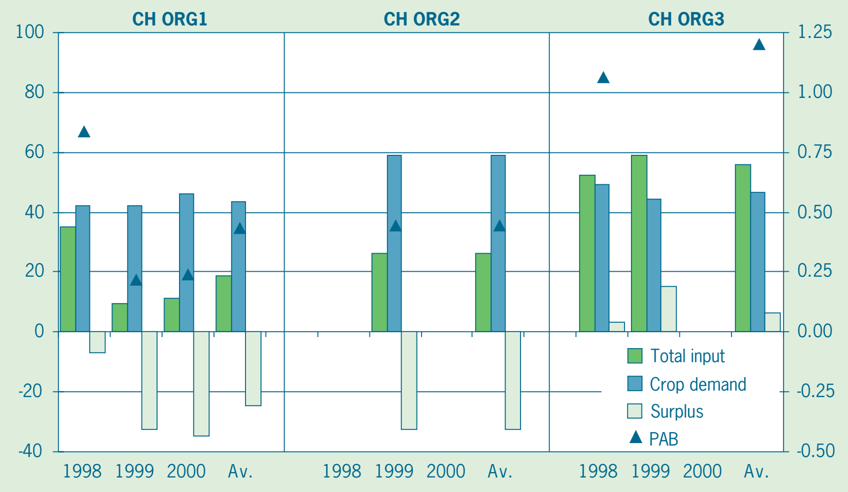


Figure 6.2 Phosphate input, demand and surplus and Phosphate Annual Balance (PAB) for the organic farms

Nutrient balance on the entire farm per year
The Swiss nutrient balance is defined differently than for the other VEGINECO partners. The VEGINECO Annual Balance definition is input/off-take. Instead, an input – export nutrient balance is calculated in Switzerland.

Experience showed that an import-export nutrient balance is not appropriate for the administrative control of the guidelines for integrated and organic farms. Therefore, in Switzerland, the input-export nutrient balance is used for the purpose of control. The import of nutrients into the entire farm is compared to the recommended amount of nutrients (demand) for all crops cultivated on the farm. An example of the calculation of a nutrient balance is given in Table 6.4. The calculation begins with the nutrient demand for the different crops. Crop residues are included in the calculation of the net -demand. The values of net-demand are then corrected with the result from a soil analysis for phosphate and potash. Finally, the total amount of imported nutrients into the farm is compared to the total nutrient demand.

For the administrative control, the import of nitrogen and phosphate should not exceed the total net-demand with a tolerance margin of 10%. The elements potash and magnesium are considered less harmful to the environment; therefore no official limit value exists.
The nitrogen fixation and release by leguminosae or by mineralisation are not considered in the nutrient balance. Therefore, a farm can have a low nitrogen supply without nutrient deficiency. This often occurs in organic farms.
The import-requirement nutrient balance provides no information on the distribution of nutrients to individual crops and plots. The farmer can make the fertiliser plan and distribute the fertiliser to fields and crops.

6.2 Testing and improving

6.2.1 Results per parameter

Overview of desired and achieved levels of parameters related to IENM
In Tables 6.5 and 6.6, an overview is presented of the desired and achieved levels of the parameters

related to IENM. The Swiss partner studied 14 pilot farms, but not all parameters were measured every year.

Annual Balance of Phosphate and Potash (PAB, KAB)

The integrated and organic vegetable farms reached, on average, the targets (input ≤ output) for the phosphate and potash annual balances (Reller and Gysi, 2001). Nevertheless, there were still some farms with a higher phosphate input than phosphate demand (Figures 5.1 and 5.2). In Switzerland, the phosphate input for the entire farm can be 10% higher than the crop's requirement (input = required + 10%).

The integrated farms used nutrient imports to meet the nutrient demand; the PAB and KAB are therefore closer to one than for the organic farms. The Swiss farmer has no potash limit, therefore, this nutrient is not considered as important as nitrogen and phosphate. This fact results sometimes in high positive or negative potash surpluses (Figures 6.3 and 6.4).

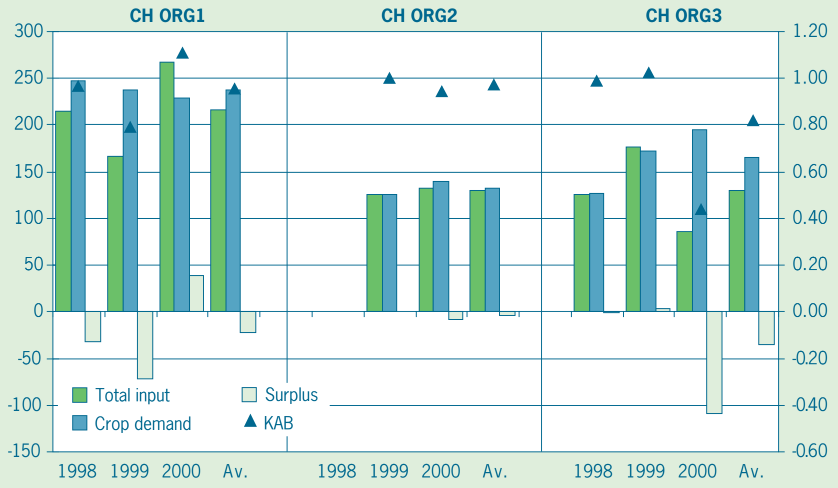


Figure 6.3 Potassium input, demand and surplus and Potassium Annual Balance (KAB) for the integrated farms

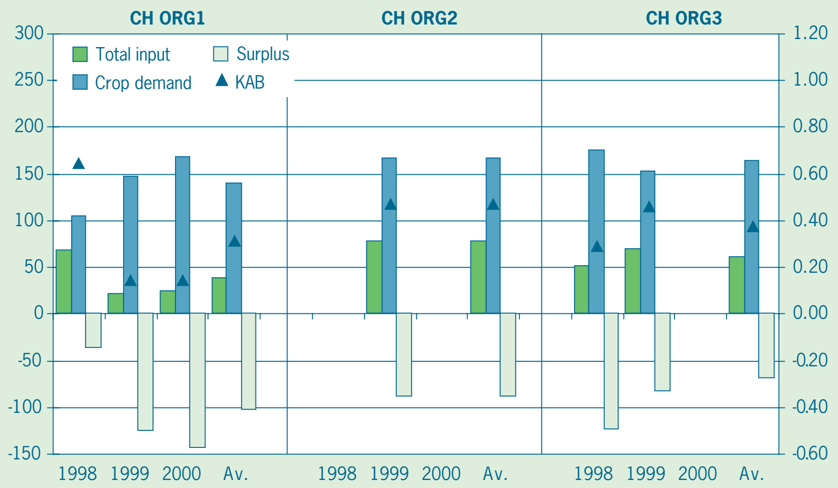


Figure 6.4 Potassium input, demand and surplus and Potassium Annual Balance (KAB) for the organic farms

Nitrogen available reserves at start of leaching season (NAR)

In Switzerland, the winter season has the highest risk for leaching. This means that measurements were taken of the available reserves of nitrogen after the last crop was harvested in autumn.

The NAR (Figure 6.5) for integrated and organic farms was almost equal and, on average, lower than the target of 75 kg N-min ha^{-1} (0-60 cm). There was a high variation in the NAR between the farms and within the plots of single farms. Collecting soil samples on 144 plots at 14 farms was time-consuming. Leaching within this time could have lowered the N-min in soil by the sampling date. In addition to fertilisation and leaching, the soil characteristics influenced the mineral nitrogen reserves in soil. In plots with more than 10% organic matter reserves, the mineral nitrogen was normally higher than the target in autumn. Integrated Farm III averaged organic matter reserves of 18% and a NAR over the target. Between the integrated production and organic production, no significant differences were found for the NAR.

Between NAR and nitrogen input, no significant connection was found in 1998. The influence of the sampling date and weather (leaching) was higher than the cropping system.

The nitrogen input of integrated farms was between 150 and 250 kg ha^{-1} (Figure 6.6). In the three organic farms, the nitrogen input was always lower than 200 kg ha^{-1}. Over the years, in integrated farms the nitrogen demand and input increased slightly. On CH ORG1 and CH ORG3, the nitrogen input increased remarkably.

Available reserves of phosphate and potash (PAR, KAR)

The Swiss soils were rich in phosphorus and potassium due to an excessive supply of compound fertilisers in the past. Figure 6.7 shows more than 60% of the analysed

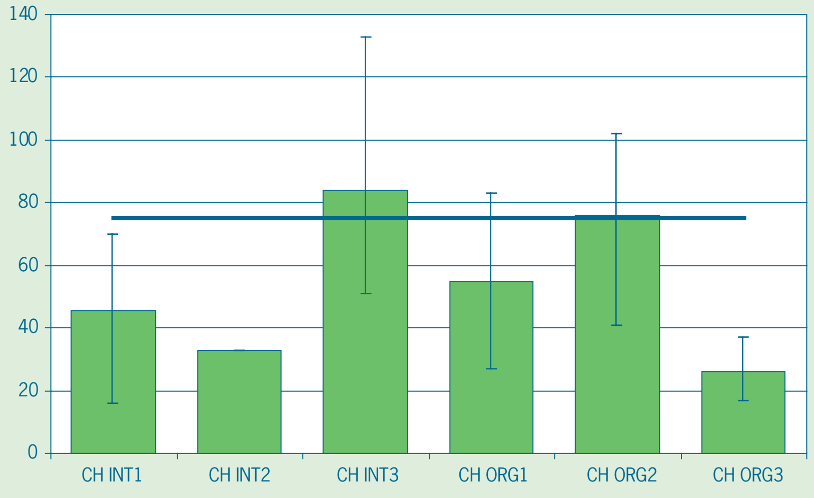


Figure 6.5 Nitrogen Available Reserves (0-60 cm) at the start of the leaching season (average and variation over fields, 1998). Target is 75 kg N ha-1.

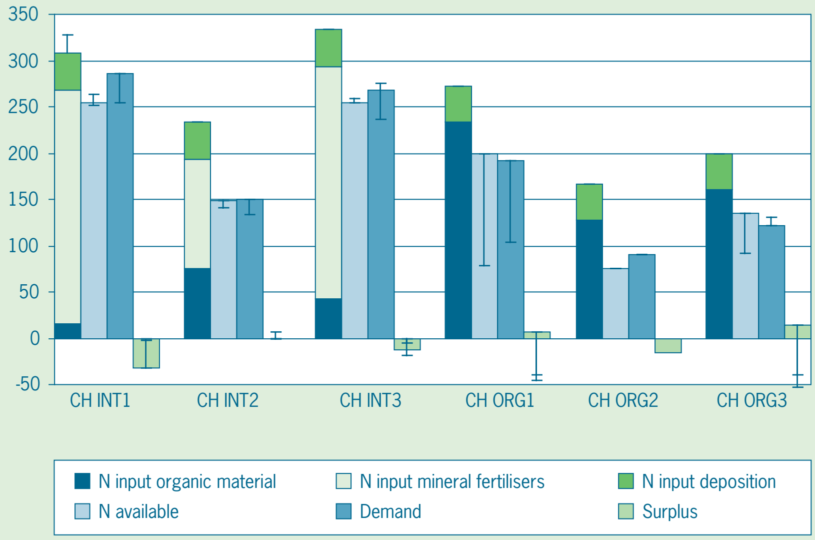


Figure 6.6 Nitrogen input, demand and surplus (data for 2000 with variation in 1998-2000)

Table 6.7 Organic matter content and organic matter input with fertilisers

Farm	Average organic matter content (%) in 1998	Total input with fertiliser (kg ha-1) 1998	1999	2000
CH INT1	4.6	0	0	799
CH INT2	2.5	-	2 123	2 083
CH INT3	18.5	0	0	1 153
CH ORG1	3.6	2 318	602	3 146
CH ORG2	3.5	-	968	-
CH ORG3	2.5	1 360	1 185	-

fields had PAR values over the desired range of 40-80 mg kg-1 (Reller et al., 2000). Phosphate does not normally leach out of the soil. However, high phosphate reserves are not desirable because phosphate can reach the surface water by erosion. This can cause an increase in algae growth.

One organic and all three integrated farms have KAR levels higher than the desired range, the remaining organic farms had KAR within the desired range of 120-200 mg kg-1.
The variation within the fields on a farm is sometimes very large.
In Switzerland, texture, pH, organic matter reserves and therefore the soil types vary greatly over small distances. A farm can have many different soil types and the nutrient reserves can differ dramatically within the same crop.

Organic Matter Annual Balance (OMAB)

For the pilot farms, only the organic matter input with fertilisers is estimated because other organic matter sources are difficult to assess at a pilot farm. The organic matter input with fertilisers includes manure, compost and other organic fertilisers. The organic matter content in Swiss vegetable farms is sometimes very high (Table 6.7). An increase of the organic matter content is normally not necessary. The organic matter input with fertilisers showed a large variation at integrated farms. For organic vegetable production, organic matter is imported every year and therefore, the total amount over years is larger than at integrated farms.

Quality and quantity of produce parameters (QLP, QNP)

It is very difficult to distinguish the cause of deficits in agriculture systems as many parameters can influence the growth of the crops.

In organic production as well as in integrated farming, yield and quality of field-grown vegetables depends on local weather conditions. Weather and other factors, such as pests, diseases and weeds, damage or inhibit the growth of the vegetable or the plants very slowly. In wet, cold or dry conditions, the nitrogen uptake often is delayed. The supply of nitrogen was a problem caused bad weather conditions, especially in organic cauliflower. In the wet year of 1999, the QNP and QLP were lower than in the two other project years. This was also true for the integrated production compared to the organic production.

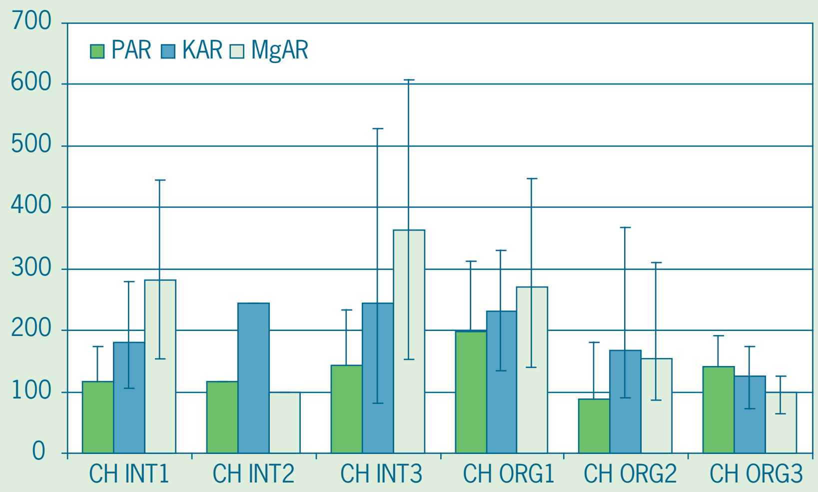


Figure 6.7 Available reserves of phosphate, potash and magnesium in integrated and organic farms (average and variation over fields, 1998) in mg kg-1

Nitrate content in crop produce (NCONT)

Lettuce the only sensitive crop for producing high nitrate contents out of the five important vegetables chosen in Switzerland. In field-grown lettuce, the nitrate content was not a problem. All samples measured were far below the maximum level of 3 500 ppm.

6.2.2 Optimisation of nutrient management (supporting research)

Field trials were carried out at the pilot farms to optimise the nutrient management of cauliflower, lettuce and carrot.

Nitrogen fertilisation is of major importance for cauliflower. Due to its high nutrient requirement and its long cultivation period, this crop is very sensitive to extreme weather conditions. Additionally, mineral fertilisers are not allowed in organic farming, and this makes nitrogen management difficult. To optimise the supply of nitrogen to cauliflower, the following cropping and fertilising strategies can be recommended:

- With a concentration of 0.5% liquid organic fertiliser (Vinasse, 9.5% nitrogen) in the irrigation water for cauliflower seedlings, higher nitrogen content in the young plants and in the substrate is achieved. This leads to better crop growth in the field in an early growing period (Schwaninger et al., 2000).
- Band application of an organic nitrogen fertiliser (Biorga N, 10% nitrogen) improves the supply of nitrogen than when the entire area is fertilised (Imhof et al., 1999).
- Nitrogen mineralisation is accelerated with ridges and black mulch plastic tissue in spring (Imhof and Schwaninger, 1999).
- Ridging two times leads to an increase in mineral nitrogen within the plant rows about 20-35 kg nitrogen ha^{-1}, resulting in a topsoil with 9% organic matter content (Imhof and Baumann, 1999).
- The nitrogen fertiliser recommendation for cauliflower in Swiss integrated production (220 kg nitrogen ha^{-1}) is confirmed (Schwaninger et al., 1999).
- Controlled uptake ammonium nutrition (CULTAN) over time simplifies the nitrogen fertilisation without reducing the yield. However, high precipitation can lead to nitrogen leaching (Schwaninger et al., 2001).

A Vinasse concentration of 0.3% in the irrigation water for lettuce seedlings resulted in a higher weight of the young plants. However, this effect was limited to the planting time and had no impact on the crop's yield. Ridging of carrots twice can lead to an increase in mineral nitrogen within the plant rows up to 35 kg nitrogen ha^{-1} in the upper layer of mineral soils.

7 Discussion and conclusions

J.J. de Haan & W. Sukkel
Applied Plant Research (PPO), Lelystad, The Netherlands

7.1 Introduction

In the European Union, agriculture is entwined in a complex set of problems. Many farmers have financial problems, quality standards are rising and environmental emissions have to be reduced. There are several agronomic problems concerning nutrients, however, preventing nutrient emission from agriculture is even more important. The main emission problems are:

- Nitrate levels in drinking water are too high.
- Eutrophication of surface waters.
- Acidification through ammonia emissions from animal manure.

Therefore, farmers need to improve their nutrient management to prevent emissions while maintaining their quality of production. Several legislation and label initiatives are stimulating farmers to actively pursue this goal.

The nutrient management method, as described in this manual, aims to greatly reduce nutrient emissions while safeguarding or improving quality and quantity of the produce.
In this chapter, the results of the systems are evaluated first to answer whether the method has contributed to more sustainable vegetable farming systems or not. Secondly, promising techniques and strategies are examined. Thirdly, the parameters are evaluated on their ability to indicate all problems and how can they be improved. Fourthly, the main obstacles and missing knowledge are identified for continuing the improvement of the method. Finally, the conversion is made to actual practice. Are they able to implement the strategies and techniques and what are major impediments?

7.2 Results of the method

The results were evaluated to assess if the method changed from a one-sided method that is focussed on quantity and return of investment to a better, multi-objective method that is focussed on other aspects such as the environment and sustainable resource management.

Large differences existed in the initial situations between the countries. In the Netherlands, nutrient management was already largely carried out following the described method. Changes during the project period fine-tuned the system. Therefore, the systems' performances were already reasonably good and only little progress was made in reaching the target values. In Italy and Spain, local nutrient management strategies were applied which were more directed to ensure quality of production instead of minimising emissions. In these countries, large changes in the nutrient management were made during the project and consequently, a large step was made in reaching more target values. For example in the Italian systems, NAR values in I ORG and I INT1 at the end of the project were half of those at the beginning.

Effects on the environment

Available reserves of nitrogen at the start of the leaching season were still too high in Spain and Italy. However, large reductions were achieved. These high NAR-levels were probably due to high mineralisation rates in Mediterranean soils, and in Spain, due to the high nitrate content in the irrigation water. In the Netherlands and Switzerland, levels are below the targets at a farm level. However, exceeding the limits still occur at a crop level (iceberg lettuce in the Netherlands). More efficient fertilisation and the use of more catch crops could help to solve the problem. Part of the nitrogen reserves in the soil will leach to ground and surface water. However, concentrations in ground and surface water were not measured.

Effects on the sustainability of resources

The project period was too short to evaluate the available reserves of phosphate and potassium (PAR/KAR). In Italy, Spain and Switzerland, PAR and/or KAR values were too high in most systems. During the project period, a tendency for PAR and/or KAR values to decline was recorded in these systems. However, target values were not reached and measurements were varied greatly in most cases. To reduce actual levels to target levels, a time span of ten years at least is necessary.

Organic matter input was no problem in the Netherlands because of the use of peat pots, organic manure and catch crops. In Italy, however, organic matter input in I ORG and I INT2 was too low. In I INT1, this was largely resolved by not removing the wheat straw from the field. In the organic system, replacing another crop by a cover crop should improve OMAB.

Effects on quality production and farm continuity

Effects of nutrient management on quality of production were limited. Only in the organic system in the Netherlands was a relationship found between nitrogen availability and quality of production. In addition, the nitrate content of the produce was below the target level in all cases.

Nutrient management only minimally influenced farm continuity. Fertiliser costs were about 5% of the total costs. Labour needs for fertilisation are generally low in compared to other tasks. Only changes in rotation due to nutrient management could have financial influence on the results. This was the case in the organic system in Italy where two crops were taken out of the rotation to reduce total nitrogen requirement. In the Netherlands, barley/clover was replaced by grass/clover with a reduced financial return. However, it is expected that the initial situation of other crops will be better because of more available nitrogen and that the total financial effect is at least neutral or even positive.

Conclusions

In Italy and Spain, large improvements were made during the project on some parameters influenced by the nutrient management strategy. For other parameters, the project was too short to evaluate progress (PAR/KAR). However, indications of improvement are clear. The main deficit was on the risk of leaching (NAR). In the Netherlands and Switzerland, only small improvements were made, which were almost not noticeable because of the influence of weather conditions on the parameters. Compared to reference data for the regions, improvements in the Netherlands, Italy and Spain were large. In general, quality of production was not influenced (either positively or negatively) by the strategies. Quality of production was comparable to average practice. In general, the nutrient management method decreases emissions to the environment while quality of production remained stable. Still, risk of leaching was too high.

7.3 Improvements in strategies and techniques

Improvements in the quantification of nutrient demand

In Italy, produce was analysed for nutrient concentrations to better estimate the phosphate and potash needs of the crops. Measured data varied greatly and they deviated significantly from reference data. However, new off-take figures for nitrogen, phosphate and potash were established.

Improvements in quantifying non-fertilisation sources

External sources

Nutrients in irrigation water were not important for most systems except for the integrated and organic system in Paiporta, Spain. In this system, nitrogen concentrations in irrigation water were very high, which made other fertilisation unnecessary. Although fertiliser input was zero, NAR values indicated that emission of nitrogen in this system is still very high. Growth of crop requiring a lot of nitrogen could possibly sanitise the system.

In all organic systems, leguminous crops or green manures were included in the rotation to lower nitrogen needed from fertilisers. In the Spanish organic system, this was not necessary because of the high nitrogen concentration in the irrigation water. In the organic system in the Netherlands, one year of barley/clover was replaced with grass/clover to secure nitrogen fixation because the success of clover after barley was variable. On the other hand, vetch after potato was replaced by a non-leguminous catch crop because potato leaves a lot of nitrogen in the soil. In that case, retaining the nitrogen in the soil to reduce losses is more relevant than bringing more nitrogen into the system by fixation.

Internal sources

Optimal levels of internal sources are very important in minimising nutrient input. In the systems, optimal use should be made of the nutrients already present in the system. Growing catch crops in periods without commercial crop growth is essential to retain nutrients in the system. However, it appeared that it was not always possible to grow a cover crop because of bad weather conditions. In the Netherlands, some catch crops could not be sown because of excessive rainfall.

Optimal use of mineralised crop residues is another option to reduce nutrient input. In the Netherlands, the time between two iceberg lettuce crops was extended to improve nitrogen uptake of crop residues from the first crop by the second crop. In the organic system in the Netherlands, vetch after potato was replaced by a non-leguminous catch crop because potato leaves a lot of nitrogen in the soil.

Nitrogen from soil organic matter is not always explicitly considered in calculations. Often, the soil organic matter mineralisation is included in establishing the nitrogen requirement. However, soil mineralisation can be variable (temperature and rainfall dependent) and can be influenced by soil cultivation. In Italy, nitrogen mineralisation is explicitly considered in all fertilisation recommendations. In the Netherlands and Switzerland, nitrogen mineralisation is included in split dosage systems, where the dose is based on nitrogen content in the soil or the plants.

In the organic system in the Netherlands, attempts were made to stimulate nitrogen mineralisation in the upper layers with the eco-plough, which ploughs shallowly. Unfortunately, this led to poor results because the soil structure was damaged and no extra mineralisation was measured. In Italy, soil cultivation was extensified to reduce mineralisation, ploughing in the systems for fresh markets was replaced with the use of a rotary hoe in the integrated systems and a hoe in the organic systems.

Improvements in fertilisation: timing, amount, choice and application method

To minimise emissions and optimise production, fertilisers have to be applied to the crop in such a way that they are available at the right time in the right amount at the right place. In addition to timing and amount, choice of fertiliser type and application method is important.
In organic systems, it is more difficult to fertilise in the correct manner because only organic fertilisers can be used. Often these are compounded fertilisers with

nutrients in proportions that are not the same as the plants need. In addition, only part of the nitrogen is available for plant uptake in the first year. This is clearly visible in the nutrient balances of the organic systems in all countries where often the balance values and reserves are too high. This is undesirable, eespecially in the situations with high soil reserves such as observed in Italy and Spain. In Italy, organic liquid fertilisers (hydrolysed blood) were used for fert-irrigation in melon and strawberry. Results were positive, however, the system was expensive.

In the organic system in the Netherlands, the application of liquid manure was done in spring instead of in the autumn as it is normally done in the region to prevent problems with the soil structure. This spring application caused the working coefficient of nitrogen to be higher because the manure was given shortly before seeding or planting of the crop.
In the project, various experiments were done on application methods such as fert-irrigation in Spain and Italy, the use of slow release fertilisers in Italy, row applications of phosphates and the use of organic manure in the Netherlands, Italy and Switzerland. All the methods were aimed at better availability and smaller losses.

Split doses based on measurements of soil or plant reserves can increase nitrogen efficiency as was done in the Netherlands and Switzerland. Implementing these methods in Spain and Italy for their situations could possibly increase nitrogen efficiency. Another possible solution, tested in the Netherlands, is the incorporation of straw after a crop with a high residual nitrogen reserve in the soil. The effect of this application was small, and application and storage appeared to be difficult.

Fertilisation of phosphate and potash is done on a rotation level based on measurements of the soil reserves. However, variability of these measurements can be large as observed in Italy. If this is the case, it is difficult to fertilise according to the soil's need. If phosphate fertilisation was necessary early in the season when the availability was low, row applications with easily soluble fertilisers were given.

In the organic system in the Netherlands, organic manure was used as well to build up the soil's mineralisation potential. If the mineralisation potential was high enough, less nitrogen was needed and nitrogen input from fertilisation could be diminished. Then, the use of hydrolysed blood, a fertiliser from a questionable source, could be omitted. However, until now, the effect of this mineralisation potential has been limited. This build up of mineralisation potential can have negative effects on nitrogen leaching, as mineralisation patterns often are not the same as plant uptake patterns.

Improvements in crop rotation
There is a close connection between the multi-functional crop rotation (MCR) and I/ENM. During the project, this was clearly visible in a few cases. In the organic system in Italy, two crops (cauliflower and lettuce spring) were eliminated to reduce the total nitrogen requirement. In addition, it was necessary to include another fixating, green manure crop to reduce the need for organic manure and improve the parameter values. Without the change in rotation, improvements in the nutrient parameters were not possible. However, these changes reduced the financial result of the rotation.

7.4 Evaluation of the parameters

Nutrient management in VEGINECO was mainly evaluated by the parameters NAR, PAB/KAB, PAR/KAR and OMAB. NAR was chosen as parameter to indicate nitrogen concentration to the upper groundwater as direct measurements were expensive and NAR has a good relationship with this concentration. However, leaching to surface water was not taken into account, while EU target values for surface water are even stricter than for groundwater. In systems with surface water, this should be taken into account in future projects.

PAB/KAB and PAR/KAR were very much connected. Dependent on the value of PAR/KAR, the PAB/KAB target value was set. Both sets of parameters were needed as PAR/KAR measurements were often variable and it was necessary to calculate the extra input with PAB/KAB. However, it was better to calculate the surplus than the balance because the surplus indicated an absolute amount. In a balance, it was not possible to see whether absolute figures were small or large. If there is separate policy on balances as there is in the Netherlands, it is good to present the balance levels as well.

The organic matter balance is often difficult to establish because decomposition rates of organic matter in soil are not known. These rates are often based on roughly estimated reference values. More information on organic matter decomposition in soil (and mineralisation) is desired.

In this method, only the macronutrients, nitrogen, phosphate and potash, were discussed. However, micronutrients can play an important role as was the case for sulphur in Brussels sprouts in the Netherlands. A sulphur shortage was observed. Most of the micronutrient requirements were fulfilled by organic manure, but when no manure was applied, chemical micronutrient fertilisers needed to be added. In most cases, micronutrients could be treated in the same way as phosphate and potash, regularly assessing soil reserves and keeping input and output in balance when levels were in the desired range. A problem could be that the desired ranges for these nutrients are not well-known. However, as these nutrients are only important in a few crops, they should not be taken up as parameters.

7.5 Theoretical shortfall

Nutrient demand

Nitrogen demand are site-specific, empirically determined and dependent on fertilisation techniques. For optimal quality of production, nitrogen demand should be accurately estimated, including the pattern of uptake during the growing season.
Deposition and estimations for the soil mineralisation are often included in the nitrogen demand. This leads to a rather rough estimate of the actual nitrogen demand. Theoretically, it is better to set nitrogen demand equal to nitrogen uptake divided by the recovery factor, excluding all inputs. The contribution to nitrogen availability of these inputs should then be estimated separately. Then the remaining problem is to define recovery factors for different crops. However, this is not a practical way because, for example, soil mineralisation is difficult to estimate.
On the other hand, phosphate and potash demand is not a problem because fertilisation is carried out at a rotation level and shortages or surpluses in phosphate and potash demand can be corrected over the years.

Non-fertilisation sources

Estimating the contribution of external, non-fertilisation sources (deposition, irrigation water and fixation) to nutrient availability is, in general, rather simple. On the other hand, estimating internal sources of nitrogen from crop residues, green manures and soil organic matter mineralisation (and although not a non-fertilisation source, organic manure as well) is very complex. Rules of thumb have been developed in most countries for estimating nitrogen availability from crop residues and green manures. Soil organic matter mineralisation is often implicitly estimated in the nitrogen demand. These estimations are not very accurate. However, despite all efforts, methods with more detailed estimations did not appear to be more valid and useful in practice.

Ideally, it is desirable to have detailed information about the total amount of nitrogen from non-fertilisation sources and the pattern of release. Supporting systems should then estimate and predict the nitrogen supply from these internal, non-fertilisation sources based on temperature, rainfall, soil characteristics and management (soil cultivation) for a few weeks. Then, fertilisation can be used to meet the total nitrogen demand, in total as well as in periods with low supply from non-fertilisation sources (early in the season). Probably, it will still take years to reach this ideal situation.

Another solution for integrated systems is to measure actual levels of nitrogen in crops or soil before fertilisation as was done in the Netherlands and Switzerland. Fertilisation can be adjusted to these levels. This approach is crop and often variety-specific. Again, estimation of the expected nitrogen mineralisation in the coming period can improve the fertilisation.

Fertilisation

There are still several options to improve and optimise fertilisation methods. Optimal timing, application technique and choice of fertiliser are possible in all countries. Fertilisation can be better adapted to the needs of the crop in a specific period. Fert-irrigation is developing quickly. However, it is still an expensive technique, only applicable in vegetable crops with a high financial return. These options are mainly directed to integrated farming because in the choice of types of fertiliser is limited in organic farming. However, processing manure into products with the desired proportions of nutrients can solve a part of the problems with organic manure in organic systems. Nutrient concentrations can be varied and possibly be known before applying the manure. In addition, techniques to apply organic manure during the crop's growing season are being developed. This is especially important in vegetable crops with a long growing season.

7.6 Disseminating nutrient management in practice

The general implementation of the nutrient management strategy as described in this manual in practice has not caused great problems. Technicians and advisors can set up these strategies rather easily. However, reliable reference data on nutrient contents in crop produce, or the nitrogen supply of a green manure crop have to be available. In addition, a conversion must be made to the specific situation of the farmer and location of the farm (local climatic and soil conditions).

The difficulty of the method is applying different techniques to minimise nutrient emissions. To minimise emissions, often doses are split and fertilisation is carried out during crop growth. Fertilisers are applied on the minimum border. To ensure crop quality, the farmer has to know when and how to react to changing conditions in crops and soil. Therefore, the farmer needs sufficient knowledge, which should be provided by support systems (from simple reference tables to sophisticated computer programs) and advisory services.

Probably, the theoretical borderlines will not be reached because farmers will not take too many risks. This is based on variability in weather (mineralisation of organic matter) and organic manure is large. Low fertility levels mean a larger risk for crop failure (quantity and quality) because the buffer is smaller. Organic matter quality can possibly be improved through better co-operation between livestock farmers and crop farmers. If the nutrient contents of organic manure are known and are constant, fertilisation can be carried out in a more precise manner. In addition, application techniques for organic manure should be improved as well and availability of manure has to be granted.

References

BAG. 2000. Neubewertung der gesundheitlichen Bedeutung von Nitrat in Gemüse. Bulletin des Bundesamtes für Gesundheit, Nr.2 Januar 2000. p. 24-31.

BLW. 1998. Evaluation der Ökomassnahmen und Tierhaltungsprogramme. Bereich Stickstoff und Phosphor. Erster Zwischenbericht.

Gysi Ch., J.P. Ryser, W. Heller. 1997. Bodenuntersuchung im Gemüsebau. Flugschrift FAW Nr. 112.

Gysi Ch., J.P. Ryser, D. Matthäus, W. Koch, A. Wigger, A. Berner. 2000. Düngung. in: Handbuch Gemüse 2000. Schweizerische Gemüse-Union. Ins. p. 55-80.

Imhof, T., B. Schwaninger. 1999. N-Mineralisierung im Damm und unter Folie. Der Gemüsebau. 61 (2). p. 17-19.

Imhof, T., D.T. Baumann (1999). Anhäufeln beschleunigt die N-Mineralisierung. Der Gemüsebau, 61 (9). p. 11-13.

Imhof, T., B. Schwaninger, G. Caloz. 1999. Banddüngung bei frühem Bio-Blumenkohl. Der Gemüsebau. 61 (12). p. 37-38.

LBL. 1995. Berechnungsformular und Wegleitung 'Gesamtbetrieblicher Nährstoffhaushalt'. Landwirtschaftliche Beratungszentrale. Lindau.

Reller, B., Ch. Gysi. 2001. Nährstoffbilanzen im Gemüsebau. Der Gemüsebau, 63 (2). p. 12-13.

Reller, B., T. Imhof, B. Schwaninger, C. Hippe. 2000. Nährstoffversorgung gemüsebaulich genutzter Böden. Der Gemüsebau, 62 (6A). p. 33-34.

Schwaninger, B., G. Caloz, B. Reller, Ch. Gysi. 2001. N-Düngung mit dem Cultan-Verfahren. Der Gemüsebau, 63 (2). p. 26-27.

Schwaninger, B., T. Imhof, Ch. Gysi. 1999. Überprüfung der Stickstoffdüngung für Blumenkohl. Der Gemüsebau, 61 (7). p. 16-17.

Schwaninger, B., T. Imhof, G. Caloz. 2000. Vinassedüngung in der Bio-Jungpflanzenanzucht. Der Gemüsebau, 62 (3). p. 32-34.

Vereijken P. 1994. 1. Designing prototypes. Progress reports of research network on integrated and ecological arable farming systems for EU- and associated countries (concerted action AIR3-CT927705). AB-DLO. Wageningen. 87 pp.

Vereijken P. 1995. 2. Designing and testing prototypes. Progress reports of research network on integrated and ecological arable farming systems for EU- and associated countries (concerted action AIR3-CT927705). AB-DLO. Wageningen. 76 pp.

Vereijken P. 1996. 3. Testing and improving prototypes. Progress reports of research network on integrated and ecological arable farming systems for EU- and associated countries (concerted action AIR3-CT927705). AB-DLO. Wageningen. 69 pp.

Vereijken P. 1998. 4. Improving and disseminating prototypes. Progress reports of research network on integrated and ecological arable farming systems for EU and associated countries (concerted action AIR3-CT927705). AB-DLO. Wageningen. 55 pp.

Vereijken P. 1999. Manual for prototyping integrated and ecological arable farming systems (I/AFS) in interaction with pilot farms. AB-DLO. Wageningen. 53 pp.

VEGINECO publication list

VEGINECO project reports

1. VEGINECO Final Report
W. Sukkel and A. Garcia (Eds.)
VEGINECO Report 1. 2002. Applied Plant Research. Lelystad.

2. Manual on Prototyping Methodology and Multifunctional Crop Rotation
J.J. de Haan and A. Garcia (Eds.)
VEGINECO Report 2. 2002. Applied Plant Research. Lelystad.

3. Integrated and Ecological Nutrient Management
J.J. de Haan (Ed.)
VEGINECO Report 3. 2002. Applied Plant Research. Lelystad.

4. Integrated and Ecological Crop Protection
W. Sukkel and A. Garcia (Eds.)
VEGINECO Report 4. 2002. Applied Plant Research. Lelystad.

5. Ecological Infrastructure Management
G.K. Hopster and A.J. Visser (Eds.)
VEGINECO Report 5. 2002. Applied Plant Research. Lelystad.

6. Proceedings of the VEGINECO workshop, 20-21 June 2001, Amsterdam
W. Sukkel and J.J. de Haan (Eds.)
VEGINECO Report 6. 2002. Applied Plant Research. Lelystad.

Other project-wide VEGINECO publications

Wijnands, F.G. and W. Sukkel. 2000. Prototyping organic vegetable farming systems under different European conditions. In Proceedings 13th IFOAM Scientific Conference, 28-31 August Basel. vdf Hochschulverlag. Zürich. pag. 202-205.

In addition, every partner has published many publications in national and regional agricultural journals. For a complete overview, contact the concerning partner.

Annex 1. Short description of the systems

Southwest region of the Netherlands

Regional Context

In the Netherlands, approximately 70 000 hectares of more than 50 different types of vegetables are grown (including onion and peas). The farms are be divided in two groups: 1) the very specialised, small farms that grow mainly fresh market vegetables (19 000 ha, 4 200 farms, average size 4.5 ha) and 2) the larger farms with arable activities (more industrial processing crops, 25 000 hectares of vegetables, 4 900 farms, 25-75 hectares per farm). Arable farms are increasingly including vegetables in their crop rotations. In addition, farm size and specialisation is growing and land lease and exchange is becoming more important. The most important crops in terms of area and financial turnover are onions, carrots, chicory, leek, asparagus, Brussels sprouts, cauliflower, cabbage, lettuce, beans and peas.

Site information

Soil characteristics	Integrated	Organic
main soil type	marine clay	marine clay
clay (%)	33	33
organic matter (%)	2.4	2.2
pH (KCl)	7.5	7.2

Climatic information	
annual average precipitation	760 mm
annual average sunshine	1 450 hours
annual average radiation	380 kJ cm^{-2}
annual average temperature	9.9 °C
average latitude	51 °N.
average altitude	0.8 m above sea level

Tested systems

In the Netherlands, two integrated and one organic systems were tested on an experimental location in the Southwest region of the Netherlands. A combination of vegetables and arable crops were chosen in all systems, this represented the developments in the region. The labour demand differed between the two integrated systems. The system with Brussels sprouts (NL INT1) as the main crop was designed as a labour extensive system. The other system, with iceberg lettuce (NL INT2) as main crop, was designed as labour intensive.

Location

Rotations

Integrated fresh market Brussels Sprouts (labour extensive) (NL INT1)	Integrated fresh market Iceberg Lettuce (labour intensive) (NL INT2)	Organic fresh market system (NL ORG)
1. potatoes	1. potatoes	1. iceberg lettuce
2. Brussels sprouts	2. fennel / celeriac / cauliflower	2. cereal / clover
3. winter wheat / spring barley	3. winter wheat / spring barley	3. Brussels sprouts
4. fennel / celeriac / iceberg lettuce	4. iceberg lettuce	4. fennel
		5. cereal / clover
		6. potato

Emilia-Romagna, Italy

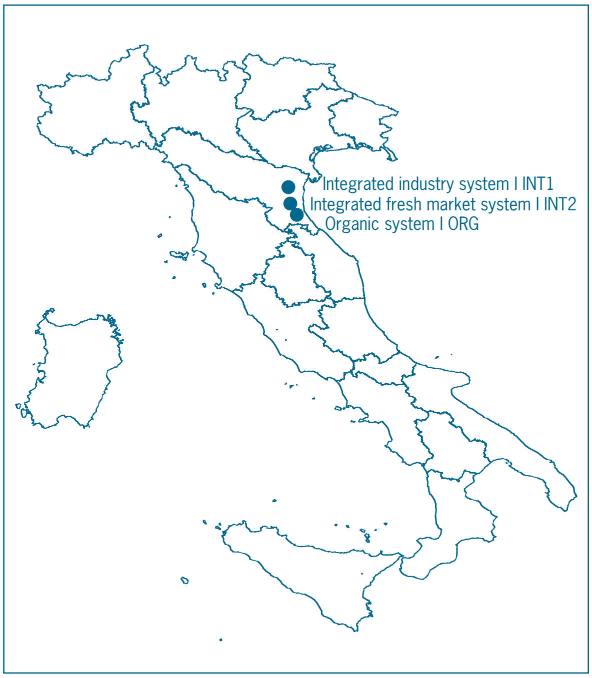
Regional context

In Emilia-Romagna, Italy, there are almost 4 000 specialised farms and 35 000 non-specialised farms in vegetable farming. Some 54 000 hectares are cultivated with vegetables at medium and large sized farms (5-20 ha). The main crops grown on large farms for industrial processing are tomatoes, green beans, (water)melons and onions. These farms have a high level of mechanisation. At small farms (2-5 ha), the main crops are grown for the fresh market (lettuce, fennel, spinach, celery, potatoes, melons and cauliflower). These small farms have a low level of mechanisation. Since 1993, integrated vegetable farming have produced crops under Quality Control (QC) labels.

Tested systems

In Emilia-Romagna, two integrated and one organic systems were tested in the eastern part of the region in Ravenna (I INT1) and Cesena (I INT2 and I ORG). I INT1 is focussed on industrial vegetable crops in combination with arable crops while I INT2 and I ORG are focussed on fresh market vegetables.

Location



Site information

Soil characteristics	I INT1	I INT2	I ORG
soil type	silt loam	silt clay	silt clay loam
% clay	20	42	35
% silt	63	47	53
% sand	17	12	12
% organic matter	1.2	1.8	2.7
pH (H_2O)	7.8	7.7	8.0

Climatic information	RAVENNA (I INT1)	CESENA (I INT2 and I ORG)
annual average precipitation	581 mm ('88-'94)	591 mm ('92-'94)
annual average sunshine	4.139 hour	4.139 hour
annual average radiation	439 kJ cm^{-2}	541 kJ cm^{-2}
annual average temperature	13.1 °C	13.9 °C
average latitude	44-45 °N.	44 °N.
average altitude	5 m above sea level	16 m above sea level

Rotation

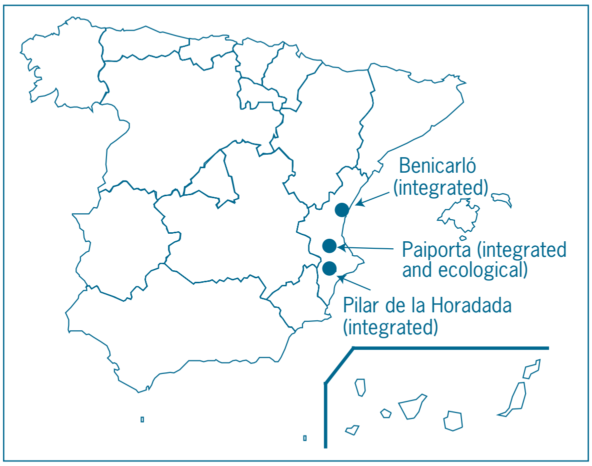
Integrated industry system (I INT1)	Integrated fresh market system (I INT2)	Organic fresh market system (I ORG)
1. spinach	1. lettuce spr./sum./aut.	1. green beans
tomato	catch crop	fennel
2. wheat	2. green beans	2. melon
green beans		
3. sugar beet	3. strawberry	3. catch crop
catch crop	celery + catch crop	
4. melon	4. melon	4. strawberry
		lettuce summer + autumn

Valencian Community, Spain

Regional context
In Valencia Region, Spain, an area of about 44 000 hectares are grown each year with more than 30 vegetable crops (including potato). The most important crops are tomato, onions, potato, artichoke, watermelon and cauliflower. Most of the vegetables are grown for fresh market production. The farms are small (more than 50% of the farms have a surface area less than three ha, and about 20% of the farms have a surface area less than one ha). Levels of mechanisation are generally low. Irrigation is necessary because of the dry conditions and low natural rainfall. Crops can be grown all year round.

In Spain, the area cultivated for organic farming was about 150 000 hectares (less than 1% of the agricultural area). In Valencia, the area with organic farming is about 3 000 ha, with about 3% area for vegetable crops.
Tested systems
In the Valencian region, three integrated and one organic systems were tested at different locations. The three integrated systems are representative for their area: Pilar de Horada (ES INT1 in the south of the Valencian Region, Benicarlo (ES INT2) in the north and Paiporta (ES INT3) in the centre. The organic system (ES ORG) is located at the same experimental farm as ES INT3. ES INT1 and ES INT2 are located at private farms, ES INT3 and ES ORG are located at an experimental station.

Location



Site information

Geodesic	co-ordinates	ES INT1	ES INT2	ES INT3 and ES ORG
Situation	Latitude	37° 51' N.	40° 23' N.	39° 28' N.
	Longitude	0° 43' W.	4° 4' E.	0° 25' W.
	Altitude	<50 m above sea level	17 m above sea level	52 m above sea level
Province		Alicante	Castellón	Valencia
Town		Pilar de la Horadada	Benicarló	Paiporta

Soil characteristics		ES INT1	ES INT2	ES INT3 and ES ORG
Soil texture	Sand (%)	23	27	34
	Loam (%)	44	47	49
	Clay (%)	33	26	27
Organic Matter (%)		2.3	2.5	1.8
pH (soil/H_2O 1/5)		8.4	8.1	8.5

Climatic characteristics	Mean temperatures	ES INT1	ES INT2	ES INT3 and ES ORG
Temperature	Max (°C)	26.2	20.7	21.9
	Min (°C)	11.1	10.7	13.2
	Mean (°C)	18.2	16.5	16.7
Average rainfall (mm)		292	482	481

Rotation

Pilar de la Horada integrated (ES INT1) private farm	Benicarlo integrated (ES INT2) private farm	Paiporta integrated (ES INT3) & organic (ES ORG) experimental station
1. vetch-oats	1. seed artichoke	1. artichoke
pepper + little gem	tomato	green bean
2. little gem	2. green bean	2. onion + watermelon,
sweet corn + broccoli	lettuce	cauliflower
3. lettuce	3. lettuce	3. potato
onion	watermelon	fennel
4. celery	4. cauliflower	4. oats
watermelon	vetch-barley + artichoke	seed artichoke

Switzerland

Regional aspects

In Switzerland, an area of 7 700 hectares is grown with open field-grown vegetables and 3 800 hectares with vegetables for industry. In total, it concerns 1 400 farms. Most of the farms grow many different crops. The most important crops are lettuces, cauliflower, carrot, onion, leek, fennel and celeriac. 40% of the national demand for vegetables is imported. Integrated crop production and organic farming is of increasing importance in Switzerland (production under label guidelines). The government intends to convert 90% of the farms to integrated or organic farming within the next ten years. At present, more than 75% of vegetable farms already met the requirements for integrated crop production. An increasing number of farms (5% to 20%) will convert to organic production in the near future. Practical difficulties on organic and integrated vegetable farms mainly concern the following topics: (1) availability of nitrogen, (2) weed control and (3) pests and diseases (Gysi et al., 1996).

Tested systems

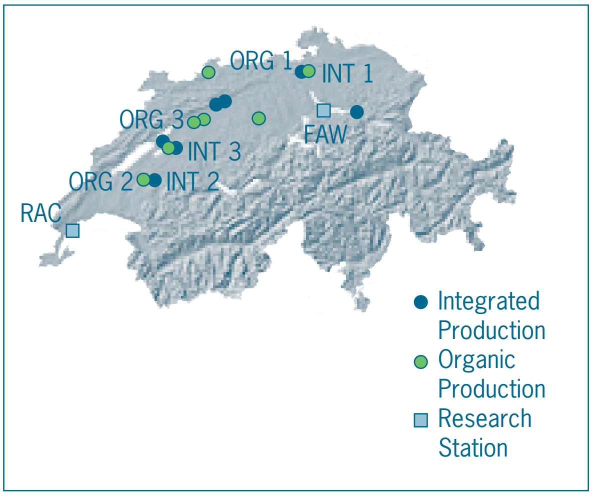
Three integrated and three organic pilot farms were tested:
INT1/ORG1: wholesale distributors, Zurich
INT2/ORG2: direct sale, French-Swiss
INT3/ORG3: retailers / wholesalers, Seeland

Main crops and rotation

Main crops
- head lettuce
- cauliflower
- carrots
- leek
- onions

Rotation length
- short: 3-4 years
- long with arable crops: 6-12 years

Location



Site information

Pedeological information	Bern/Biel		Zürich	
soil type	histosol[2]	eutric cambisol[2]	eutric cambisol[2]	gleyic/calcaric cambisol[2]
clay (%)		1-10/26-54[1]	15-20[2]	30-40[2]
sand (%)		71-94/16-55[1]	40-85[2]	10-70[2]
silt (%)		6-19/20-44[1]	0-50[2]	0-50[2]
organic matter (%)	> 30[1]	1-26[1]	2-5[2]	2-5[2]

Climatic information[3]	Bern/Biel	Zürich
annual average precipitation	1 088 mm (Biel)	1 005 mm (Reckenholz)
annual average sunshine	1 681 hour (Liebefeld 95)	1 501 hour (Reckenholz 95)
annual average radiation	4 325 MJ m^{-2} (Liebefeld 95)	3 858 MJ m^{-2} (Reckenholz 95)
annual average temperature	8.5 °C (Biel)	7.8 °C (Reckenholz)
average latitude	47° 00' N.	47° 30' N.
average altitude	440 m above sea level	450 m above sea level

References:
[1] Organische Böden des schweizerischen Mittellandes, Presler/Gysi 1989
[2] Bodeneignungskarte der Schweiz 1980
[3] Annalen der Schweizerischen Meteorologischen Anstalt 1995

Annex 2. Definitions of parameters

Parameters	Definition	Target
Quality production		
1. Quantity of produce (QNP)	The extent to which good regional yield is realised. QNP = realised yield (kg ha^{-1}) divided by good regional yield (kg ha^{-1}).	All crops should have a yield equal to or higher than good regional yields. QNP ≥ 1
2. Quality of produce (QLP)	The extent to which regional good quality is realised. QLP = realised amount in quality class 1 divided by regional good amount of quality class 1.	All crops should have a quality equal to or higher than regional good quality. QLP ≥ 1
3. NO_3^- content of crop produce (NCONT)	The nitrate content in leafy vegetables in mg kg^{-1} fresh matter.	All leafy crops should have a lower NCONT than the national standard. NCONT < x ppm
Clean environment nutrients		
4. Phosphate Annual Balance (PAB) 5. Potash Annual Balance (KAB)	Phosphate and Potash Annual Balances (PAB/KAB) are phosphate (P_2O_5) and potash (K_2O) inputs divided by phosphate and potash off-take with crop produce in one year.	The value of the target is dependent on the value of the soil reserves (PAR/KAR) (see 13,14) • PAB/KAB > 1 when PAR/KAR is below desired range • PAB/KAB = 1 when PAR/KAR is in desired range • PAB/KAB < 1 when PAR/KAR is beyond desired range
6. Nitrogen Available Reserves (NAR)	Mineral Nitrogen Reserves (NAR) in the soil (0-100 cm) at the start of the leaching season (kg ha^{-1}).	The target values are set such that the EU-norm for drinking water (50 mg NO_3^- l^{-1}) should not be exceeded. NAR < x kg ha^{-1} x = 45 kg ha^{-1} on sandy soils x = 70 kg ha^{-1} for clay soils
Clean environment pesticides		
7. Synthetic pesticides input active ingredients (PESTAS-Synth)	Pesticide input of synthetic pesticides in kg ha^{-1} active ingredient per year.	The use of pesticides in kg active ingredient ha^{-1} should be as low as reasonably possible. PESTAS-Synth < x kg a.i. ha^{-1}
8. Copper input active ingredients (PESTAS-Cu)	Copper input in pesticides in kg ha^{-1} per year.	The use of copper in kg ha^{-1} should be as low as reasonably possible. PESTAS-Cu < x kg a.i. ha^{-1}
Environment Exposure to Pesticides 9. EEP-air, 10.EEP-groundwater, 11.EEP-soil	Emission potential of pesticide active ingredients (a.i.) to the environmental compartments: • air (kg ha^{-1}) • groundwater ppb • soil (kg days ha^{-1})	The potential emission of pesticides should be as low as reasonably possible or fulfil legal standards (EU directive on drinking water) • EEP-air < x kg a.i. ha^{-1} • EEP-groundwater < 0.5 ppb in total and 0.1 ppb (EU countries) • EEP-soil < x kg days ha^{-1}

Parameters	Definition	Target
Nature and landscape		
12. Ecological Infrastructure (EI)	EI is the part of the farm laid out and managed as a network of linear and non-linear habitats and corridors for wild flora and fauna, including buffer strips.	Area with ecological infrastructure should be at least 5% of total farm area EI > 5%
Sustainable use of resources		
13. Phosphorus Available Reserves (PAR) 14. Potassium Available Reserves (KAR)	Phosphate and potash plant available reserves in the soil (kg per unit soil).	PAR/KAR should be within a range that is agronomically desired and environmentally acceptable: $x_p < PAR < y_p$ $x_k < KAR < y_k$
15. Organic Matter Annual Balance (OMAB)	OMAB is the proportion between annual input and annual output (respiration, erosion) of effective organic matter.	The target value is dependent on the actual and desired level of the organic matter content: • OMAB > 1 when actual organic matter content is lower than desired level • OMAB = 1 when actual organic matter content is equal to desired level • OMAB < 1 when actual organic matter content is higher than desired level
Energy Input (ENIN)	Input of direct and indirect (fossil) energy in MJ ha^{-1} used for crop cultivation.	No target established
Farm Continuity		
16. Net Surplus (NS)	Difference between total revenues and total costs (including labour) in € per ha.	Gross revenues should be larger than total costs. NS ≥ € 0
Hours hand weeding (HHW)	The amount of hours needed for hand weeding per ha as indicator of the success of the mechanical and/or chemical weed control.	Hours hand weeding should be as low as possible. HHW < x hours ha^{-1}

Annex 3. Short description of the multi-objective farming methods

Multifunctional Crop Rotation (MCR)
MCR is the major method used to preserve soil fertility and crop vitality in biological, physical and chemical terms. It is also used to sustain quality of production with a minimum of inputs (pesticides, manual and machine labour, fertiliser and support energy).

In MCR, crops are selected and put in order to get maximal positive interaction and minimal external effects for all objectives. A well-balanced mix of crops needs to be chosen. Crops are characterised in their potential role according to different characteristics. Crops are divided into main crops (important from a financial perspective), secondary crops and tertiary crops (the defenders, which put the main crops in an optimal position and defend the rotation against pests and diseases). In addition, an optimal agro-ecological layout of the system in time and space needs to be made to ensure a maximum contribution of the MCR in preventing pests and diseases. MCR forms the basis for the other methods.

Integrated/Ecological Nutrient Management (I/ENM)
I/ENM gives directions in supplying nutrients in the correct amounts and forms, and at the correct time to achieve optimal quality of production; minimise losses to the environment; and keep soil reserves of nutrients and organic matter at adequate levels, agronomically as well as environmentally.

Attention is mainly paid to the macronutrients nitrogen, phosphorus and potassium. Nitrogen, a very mobile nutrient, is treated at a crop level. Phosphorus and potassium are treated at a rotation level as these nutrients are less mobile.

To reach these objectives, the nutrient requirements of the rotation are defined first. Secondly, the contribution of non-fertilisation sources is estimated. External, non-fertilisation sources are deposition, irrigation water and fixation. Internal, non-fertilisation sources (only nitrogen) are green manure, catch crops, crop residues and mineralisation from organic matter in the soil. If these sources are known, the need for fertilisers can be determined. Fertiliser input can be minimised by choosing the correct timing, application technique and fertiliser type.

Integrated/Ecological Crop Protection (I/ECP)
I/ECP supports the Multifunctional Crop Rotation and Ecological Infrastructure Management in achieving optimal quality of production by selectively controlling residual and harmful species with minimal exposure of the environment to pesticides.
The general strategy consists of three steps:
1. maximum emphasis on prevention (resistant varieties, cultural practiceds such as adapting the sowing date and row spacing),
2. a correct interpretation of the need of control (guided control systems, thresholds, signalling systems),
3. the use of all available non-chemical control measures (mechanical weed control, genetic, physical and biological control).

Pesticides are then only necessary as additional measures. Methods with minimum use such as seed treatment, and row or spot-wise application are preferred over applying to the entire field. Appropriate dosages and, when possible, a curative approach (field and year specific), further reduces the input. Finally, pesticides should be carefully selected with respect to selectivity and exposure of the environment to pesticides (EEP).

Minimum Soil Cultivation (MSC)
MSC is an additional method to MCR and I/ENM that sustains quality of production by preparing seedbeds, controlling weeds, incorporating crop residues and restoring physical soil fertility reduced by compaction from machines, specifically at harvest. Soil cultivation should be minimal in order to achieve the objectives with respect to energy use; to maintain sufficient soil cover as basis for erosion prevention; shelter for natural enemies; landscape/nature values; and maintenance of an appropriate organic matter annual balance.

Ecological Infrastructure Management (EIM)
EIM supports MCR in achieving optimal quality of production by providing airborne and semi-soil-born beneficials a place to survive unfavourable conditions, and then recover and disperse in the growing season. In addition, EIM should met the nature/landscape objectives.
Operating EIM implies establishing an area of linear and non-linear elements to obtain spatial and temporal continuity in nature area; and establishing buffer strips to protect these natural areas. Finally, establishing a plan for the long term considering the target species/communities and special ecological elements such as ponds and hay stacks.

Farm Structure Optimisation (FSO)
FSO determines the minimum amounts of labour and capital goods needed to achieve the required net surplus (all revenues - total costs, including labour) ≥ 0.
A region-specific, tested prototype that can meet the quantified objectives also needs a farm economic perspective. The existing farm structure might be an important impediment. To study the perspectives of the prototype, FSO has been developed. FSO examines the farm structure needed to describe an agronomically and ecologically optimal prototype as well as the economical aspects.

The bases for these studies are the existing results of the prototype achieved in an experimental setting. The study considers the perspectives for the near future.

The available results, however, are mostly based on an experimental *(sub-optimal)* scale, with the original *(outdated)* costs for inputs and outputs and the original *(outdated)* versions of the prototype. However, perspectives of integrated and ecological systems can only be estimated if subsequently:

1. inputs and outputs are technically updated considering the latest version of the prototype and possible non-system specific events or effects,
2. inputs and outputs are economically updated considering current or expected costs.

An optimal farm structure is developed considering the rates of land, labour and capital, to achieve the basic income/profit objective of net surplus ≥ 0.

Annex 4. Nutrient content of vegetable crops

Table A4.1 Reference content of nitrogen, phosphate and potash (fresh weight based) in crop produce and residues in the Netherlands for organic and integrated farms

crop	produce dry matter content %	N kg ton^{-1} fresh	P_2O_5	K_2O	crop residues N kg ton^{-1} fresh	P_2O_5	K_2O
Brussels sprouts	15	5.5	2.1	6.0	5.4	1.6	5.7
iceberg lettuce	3.6	1.5	0.5	2.5	2.1	0.4	2.9
celeriac	13.4	2.0	1.6	5.5	2.8	0.9	6.7
fennel	6.3	2.0	0.5	6.0	2.9	0.7	5.0
potatoes	25	3.3	1.1	5.1	4.0	1.5	6.0
barley	8.4	15.0	8.0	6.0	5.4	2.1	14.9
winter wheat	8.4	20.0	8.5	5.1	5.8	1.6	14.9
cauliflower	8.4	2.9	0.9	3.5	3.3	1.1	4.9
ryegrass	12	3.5	1.5	4.0	-	-	-
white clover	13	4.5	1.1	3.7	-	-	-
vetch/grass	12	4.0	1.6	4.0	-	-	-

Table A4.2 Measured content of nitrogen, phosphate and potash (fresh weight based) in crop produce and residues in Italy per system, average of four year (97-00)

crop	produce dry matter content %	N kg ton^{-1} fresh	P_2O_5	K_2O	crop residues dry matter content %	N kg ton^{-1} fresh	P_2O_5	K_2O
I INT1								
melon	10.8	1.8	0.6	4.8	19.9	3.4	1.0	7.1
spinach	10.9	3.1	0.7	5.2	9.1	2.2	0.5	4.6
tomato	7.2	1.8	0.4	3.9	19.1	3.4	0.8	3.9
wheat	87.0	13.4	3.4	4.5	89.1	7.9	1.5	14.6
green beans	8.6	2.6	0.6	3.8	15.7	3.5	0.5	6.1
sugar beet	23.1	1.7	0.4	1.8	23.6	3.6	0.8	12.3
I INT2								
strawberry	7.1	0.8	0.4	1.4	30.8	4.3	0.6	4.5
celery	6.3	1.4	0.5	3.5	8.2	1.9	0.5	2.7
lettuce spring	5.5	1.8	0.5	3.8	6.3	1.4	0.3	6.4
lettuce summer	6.7	2.1	0.5	4.2	7.0	1.7	0.3	4.1
lettuce autumn	6.2	2.0	0.4	4.1	6.6	2.0	0.4	5.3
green beans	9.4	3.0	0.4	3.5	14.7	3.9	0.5	4.6
melon	10.4	2.3	0.6	6.1	18.4	3.1	0.7	6.7
cauliflower	8.5	2.9	0.7	4.3	8.7	2.4	0.5	4.8
I ORG								
strawberry	8.1	0.9	0.4	1.6	41.2	5.1	1.0	6.8
lettuce summer	6.8	2.6	0.7	5.4	7.6	3.2	0.9	7.6
lettuce autumn	6.4	2.1	0.6	4.7	6.9	2.4	0.6	5.8
green beans	9.4	2.7	0.6	3.6	14.0	4.3	0.7	4.8
fennel	7.3	1.9	1.0	8.3	16.6	3.4	1.4	6.1
melon	12.2	2.4	0.9	7.0	18.7	2.8	0.8	5.6

Table A4.3 Reference content of nitrogen, phosphate and potash (fresh weight based) in crop produce and residues in Spain per system

crop	produce dry matter content %	N kg ton^{-1} fresh	P_2O_5	K_2O	crop residues N kg ton^{-1} fresh	P_2O_5	K_2O
ES INT1							
pepper	6.0	1.77	0.68	2.74	5.50	1.68	10.50
sweet corn	22.0	4.03	1.83	3.21	2.42	1.43	5.38
onion	8.5	1.36	0.74	1.80	1.88	0.34	4.77
watermelon	8.3	1.57	0.75	3.12	5.21	2.54	7.98
ES INT2							
watermelon	4.6	1.40	0.61	3.65	3.28	1.29	3.86
tomato	6.5	1.83	0.74	2.78	3.22	1.86	4.86
ES INT3							
Lettuce (Roman) l	3.8	1.29	0.47	3.41	1.29	0.47	3.41
Watermelon	6.3	1.42	0.43	2.85	2.30	0.65	2.66
ES ORG							
Lettuce (Roman) l	3.6	1.25	0.46	3.36	1.25	0.46	3.36
Watermelon	7.2	1.55	0.50	3.21	2.91	0.63	3.63

Table A4.4 Reference content of nitrogen, phosphate and potash (fresh weight based) in crop produce in Switzerland for eight model crops

crop	dry matter content %	N kg ton^{-1} fresh	P_2O_5	K_2O
Brussels sprouts	15	7.1	1.9	4.9
cauliflower	8	3.9	1.2	3.9
lettuce (head)	5	2.0	0.8	2.7
carrot	12	1.6	0.8	3.5
fennel	14	3.9	1.2	5.9
celeriac	11	2.5	1.8	3.9
onion	12	2.0	1.0	2.1
Leek	11	3.6	1.1	2.7

* Reference: Souci, S.W., W. Fachmann und H. Kraut, 1986: Die Zusammensetzung der Lebensmittel. Wiss. Verlagsgesellschaft Stuttgart; pp 1032

Annex 5. Working coefficients

Table A5.1 Working coefficients (%) for nitrogen from crop residues and green manure

Crop/green manure	Incorporation time[1]	N working coefficient (%)[1]
Netherlands		
Iceberg lettuce spring/summer	Before cultivation of the next crop	80
Iceberg lettuce autumn	More than three months before the next crop	0
Barley	Before cultivation of the next crop	0
White clover + stubble	More than three months before the next crop	50
Brussels sprouts	More than three months before the next crop	10-15
Fennel early	Before cultivation of the next crop	80
Fennel autumn	More than three months before the next crop	0
Potatoes	Before cultivation of the next crop	80
Potatoes	More than three months before the next crop	0
Grass	More than three months before the next crop	25
Vetch/grass	More than three months before the next crop	25
Italy		
Lettuce SP-SU-A	Before cultivation of next crop	30-50
Italian ryegrass	Before cultivation of next crop	50
Green beans	Before cultivation of next crop	30
Strawberry	Before cultivation of next crop	30
Fennel	Before cultivation of next crop	30
Vetch	Before cultivation of next crop	50
Melon	Before cultivation of next crop	30
Cauliflower	More than three months before next crop	25
Switzerland		
All crops/cropping plan	After harvest/Before cultivation of next crop	80%
All crops/nutrient balance	After harvest/Before cultivation of next crop	16%
Green manure/non-Leguminosae	Before cultivation of next crop	20 kg ha^{-1}
Green manure/Leguminosae	Before cultivation of next crop	50 kg ha^{-1}
Spain		
Lettuce	Before cultivation of next crop	50
Potato	Before cultivation of next crop	50
Vetch	Before cultivation of next crop	50
Artichoke	Before cultivation of next crop	30
Fennel	Before cultivation of next crop	30
Watermelon	Before cultivation of next crop	30
Cauliflower	Before cultivation of next crop	30
Pepper	Before cultivation of next crop	30
Tomato	Before cultivation of next crop	30
Green beans	Before cultivation of next crop	30

[1] Working coefficient = percentage of total nitrogen in organic material that will be available for the following growing season (12 months) or for the next crop (Switzerland)

Table A5.2 Content nitrogen, phosphate, potash and working coefficients for nitrogen from manure at the different research locations

Manure[1]	Total N-content	Total P-content	Total K-content	N working coefficient spring/summer[2)]	N working coefficient autumn[2)]
Netherlands	kg ton^{-1}	kg ton^{-1}	kg ton^{-1}	%	%
Champost	7.2	5.8	10.3	30-40	
LCM	4.8	2.0	7.6	60-70	
SCM	5.5	2.0	7.6	20-40	15-20
Hydrolysed blood	130	-	-	80	
Italy	kg ton^{-1}	kg ton^{-1}	kg ton^{-1}	%	%
SCHM	22.3	21.8	15	60-70	40-50
SCM	8	6	16	20-30	10-15
Hydrolysed blood	130	-	-	70	60
Linfor	122	-	-	70	65
Fitostim	8	-	-	80	70
Euro pol	152	-	-	80	70
Fertil	125	-	-	70	60
Switzerland	kg m^{-3}	kg m^{-3}	kg m^{-3}	%	
LCM	4.5	1.7	9	55.5-75.7	
compost(mature)	2	1.5	1.5	0-20	
	kg ton^{-1}	kg ton^{-1}	kg ton^{-1}	%	
SCHM	20	25	14	40-60	
SCM	5	3.1	7	30-50	
SHM	5	3.1	7	30-50	
Spain	kg ton^{-1}	kg ton^{-1}	kg ton^{-1}	%	
SCM	4–7	4–7	7–10	20–30	
SCHM	22–30	17–23	11–18	40–60	
SSHM	8–17	3–7	8–18	30–50	
SS compost	8–12	4–10	0.3–1	20–40	

[1)] SCM = Solid Cow Manure, SHM = Solid Horse Manure, SCHM = Solid Chicken Manure, LCM = Liquid Cow Manure, SSHM= solid sheet manure, SS compost = sewage sludge compost

[2)] spring/summer = application of manure in spring or summer, autumn = application of manure in autumn

Annex 6. Ring test for soil analysis and fertiliser recommendations

B. Becu, C. Gysi & B. Schwaninger
Swiss Federal Research Station for Fruit-Growing, Viticulture and Horticulture (FAW), Wädenswil, Switzerland

Objectives

Different countries use different parameters and methods for soil analyses and fertiliser recommendations. It is interesting to know what those differences are and whether these diverse methods lead to different recommendations. Therefore, a ring test for soil analysis and fertiliser recommendation was carried out within the VEG-INECO framework.
This ring test had two main objectives:

1. Comparison of soil analyses carried out by the different methods in the partner countries (Netherlands (NL), Italy (I), Switzerland (CH), Spain (ES)) on the same soil samples.
2. Fertiliser recommendations for different vegetables on four selected soil samples.

Material and methods

Collection of the soil samples
Each of the partner countries took three soil samples at a depth of 0 - 30 cm from vegetable fields representing three different soil types in the main production area (Table A6.1).
These samples were dried at the air temperature of 40°C and sieved to two mm. Only those particles smaller than two mm were used for further analysis.

Soil analysis
The collected samples were then divided into four parts,

Table A6.1 Description of the soil samples

Sample Soil from	1 NL	2 NL	3 NL	4 I	5 I	6 I	7 CH	8 CH	9 CH	10 ES	11 ES	12 ES
Location	West-maas	Nagele	Meterik	Bastoni	Marto-rano	Cenci	Zürich	Schwyz	Bern	Pai-porta	Pilar Horada	Beni-carlo
Soil type	Calcaric Fluvisol	Fluvisol	Anthro-sol	Calcaric cambi-sols	Heysols calci-sols	Calcaric areno-sols	Cambi-sol	Calcaric-gleyic Fluvisol	Histosol	Xeror-thent	Xero-fluvents	Xeror-thent
Vol.% > 2 mm	0.3	0.7	0.4	0.4	0.01	0.3	1	0.1	3	2	3	5

Table A6.2 Strategies of fertiliser recommendation in the different partner countries.

Parameter		Country NL	I	CH	ES
Soil analysis					
P reserve		X	X	X	X
P-available		X		X	
K reserve			X	X	X
K available		X		X	
Mg reserve		X	X	X	X
Mg available				X	
Ca reserve		X	X	X	
Different targets for	different soil types	X	X	X	X
	organic matter			X	X
Fertilisation recommendation					
Classes of nutrient content		7	4	5	5
Correction factor for classes of nutrient content		1.5 - 0	> 1	1.5 - 0	1.5 - 0
Fertiliser recommendation according to individual crops			X	X	X
	groups of crops	X	X		

sent to each partner and analysed according to their specific method. These analyses had to include at least a determination of texture, pH, organic matter, phosphorus, potassium, magnesium and calcium. Each extraction method (volume, weight, proportion and chemical analysis) had to be described. To be able to compare the different extraction methods, all results were recalculated into the same unit, mg phosphorus, potassium, magnesium per kilograms dry soil. These results have been compared on a relative basis by ranking order because the difference in extraction method does not allow for a comparison of the absolute nutrient values. For each country, the analysed soils have been ranked from

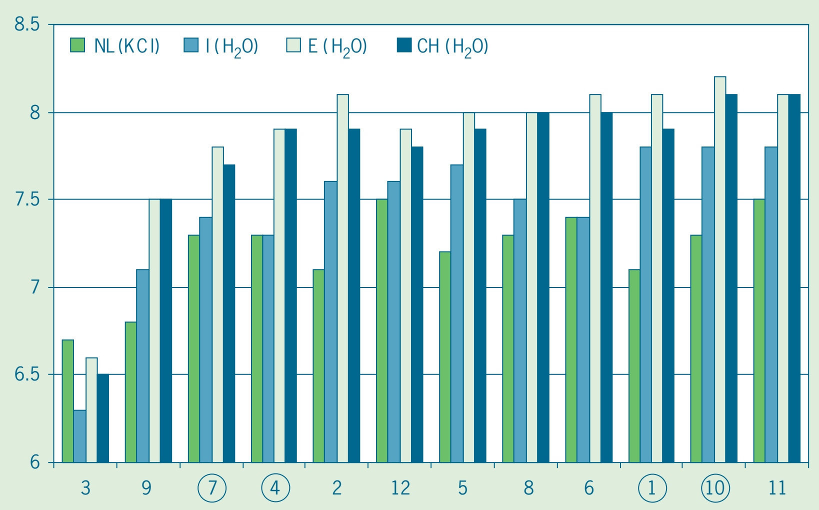


Figure A6.1 Comparison pH from 12 Soil samples analysed by the partners ranked from low to high, x-axis soil sample numbers, y-axis pH

*Table A6.3 Comparative table for soil texture, pH, organic matter (C * 1.7) percentage from 12 soil samples analysed by the Netherlands, Italy, Spain and Switzerland (L: light soil, M: medium, S. heavy; O: organic)*

Sample Soil from	1 NL	2 NL	3 NL	4 I	5 I	6 I	7 CH	8 CH	9 CH	10 ES	11 ES	12 ES
Soil texture												
NL	Loam M	Sandy Loam M	Loamy Sand L	Clay-loam S	Clay-loam S	Loamy Sand L	Loam M	Loam M	Loamy Sand L	Sandy Loam M	Clay-loam S	Clay-loam S
I	Loam M	Sandy M	Loamy L	Clay- S	Clay- S	Loamy L	Loam M	Loam M	Loamy L	Sandy M	Loam M	Loamy Sand L
CH	Clay S	Loamy Clay S	Silty Sand L	Loamy Clay S	Clay S	Silty Sand L	Loam M	Clay-silt S	Organic Soil O	Clay-loam S	Loamy Clay S	Loamy Clay S
ES	Silt Loam M	Loam M	Loamy Sand L	Silty Clay S	Silty Clay S	Sandy Loam M	Loam M	Silt Loam M	Sandy Loam M	Clay-loam S	Clay-loam S	Clay-loam S
pH												
NL (KCl)	7.1	7.1	6.7	7.3	7.2	7.4	7.3	7.3	6.8	7.3	7.5	7.5
I (H_2O)	7.8	7.6	6.3	7.3	7.7	7.4	7.4	7.5	7.1	7.8	7.8	7.6
CH (H_2O)	7.9	7.9	6.5	7.9	7.9	8.0	7.7	8.0	7.5	8.1	8.1	7.8
ES (H_2O)	8.1	8.1	6.6	7.9	8.0	8.1	7.8	8.0	7.5	8.2	8.1	7.9
Organic matter percentage (C * 1.7)												
NL	2.9	2.6	2.7	2.7	2.1	1.9	3.4	4.6	24.6	1.8	2.6	3.2
I	2.1	2.2	2.7	2.4	1.9	1.9	3.1	4.1	26.5	1.5	2.5	3.5
CH	2.2	2.4	4.1	2.1	3.0	3.0	3.7	4.8	22.2	2.9	3.2	3.5
ES	2.5	2.3	2.3	2.5	1.8	1.9	2.9	4.1	20.0	1.5	2.4	2.9

lowest amount of P/P_2O_5 (1) to the highest amount (12). The median from those ranking numbers between the four partner countries was calculated for each soil sample. Then, the results were put into a figure according to increasing median. In this way, the differences are better illustrated.

Fertiliser recommendations

From the soil samples for all of the countries, a recommendation for fertilisers had to be made for the most common soil type for four vegetables: cauliflower, head lettuce, carrot and onion, assuming an early growing period in 1999. A recommendation for phosphate, potassium, magnesium and chalk in kg ha^{-1} for an expected yield had to be given. The main differences in strategies of fertiliser recommendation are listed in Table A6.2 It is obvious that each partner has their own recommended system of fertilisation, which is explained in following example for phosphate:

The Netherlands gave a recommendation for a conventional and an integrated farming system. The amounts of fertilisers from the conventional system are derived from tables (P-Al/Pw) and classified in one of the seven fertilisation groups. In the integrated farming system, the phosphorus application is calculated as followed: if P-water is within a target range (20-30), a balanced fertilisation should be given. If P-water is higher than this target range, no fertilisers should be added. In this new system, also the off-take of phosphate by crops is taken into account to determine the recommendation.

In Italy, the fertilisation strategy is as follows:

1. On soils with a high P-level, an amount of phosphate fertiliser equal to the phosphate off-take by the crop must be added. In that way, the natural nutrient content remains the same.
2. On soils with a normal P-level, an amount of phosphate fertilizer equal to the uptake is used to make up for leaching and retro-gradation.
3. On soils with a low P-level, an amount phosphate fertiliser equal to the uptake + enrichment share is applied to achieve normal capacity of fertility.

Switzerland and Spain make use of correction factors related to the soil type and amount of P in the soil. To calculate the amount of fertiliser, the following formula is used in Switzerland:

*(2 * (F-water) + 1 * (F-reserve))/3*

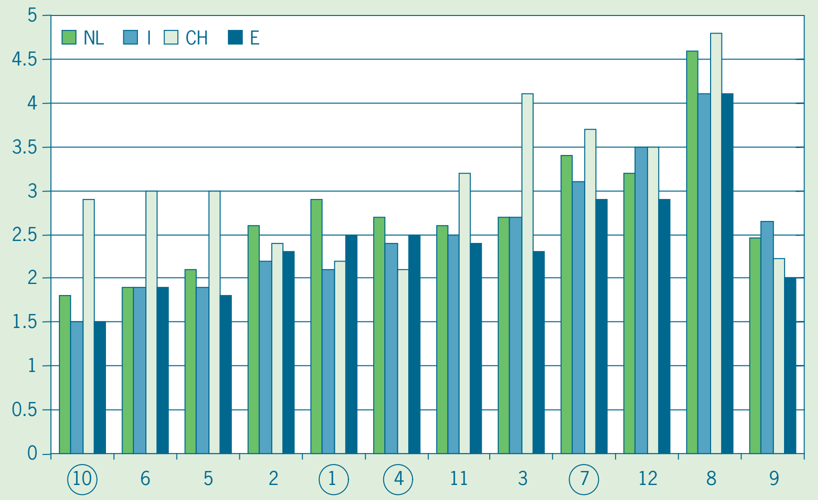


*Figure A6.2 Comparison Organic Matter from 12 Soil samples analysed by the partners ranked from low to high, x-axis soil sample numbers, y-axis organic matter content (%), sample 9 (last sample) * 10*

The F-factors symbolise correction factors, derived from the measured nutrient amounts in the water and NH_4-ac-EDTA extraction. The correction factors are not only related to the absolute amount of nutrients in the soil, but also to the soil texture (light, medium, heavy soil type) and the percentage of organic matter (> 5% organic matter).

Results

Soil texture, pH and organic matter

All countries, except Switzerland (feeling test) determined the soil texture with the density method. Holland estimated the texture classes by transferring the percentage lutum to the texture triangle. Considering the

Table A6.4 Percentages of lutum (Netherlands) and argilla (Italy) to 12 soil samples

Sample Soil from	1 NL	2 NL	3 NL	4 I	5 I	6 I	7 CH	8 CH	9 CH	10 ES	11 ES	12 ES
NL (% lutum[1])	23	19	3	37	49	14	20	21	13	24	21	25
I (% argilla)	15	7	11	25	33	13	11	17	7	3	13	9

[1] lutum fraction is percentage of particles < 2 mm

results (Table A6.3), the texture classes seem to correspond well. Important for the fertilisation recommendation though are the different soil texture groups: light (L), medium (M), and heavy (H). Considering these groups, it is obvious that the results are almost equal, except for S9 and S12. Due to the high percentage of organic matter, Switzerland classified the sample as an organic soil. As the other countries used the density test, the results only showed the mineral fractions. It is evident that when the organic matter is taken into account, S9 also would be classified as an organic soil.

Italy estimated S12 as a much lighter soil (Loamy Sand) than the other partner countries. It is also remarkable that the results of the density test differ between the Netherlands and Italy (Table A6.4).

Most of the soils are alcalic (Figure A6.1). The Netherlands has applied the pH-KCl method, where the other countries used the pH-H_2O method. This explains the relatively lower pH value from Netherlands (0.5 lower compared to the average of Italy, Switzerland and Spain). The pH values from Switzerland and Spain show the best correlation.

Comparing the amount of organic matter (Figure 8.2), the Swiss results are higher, but the average results are comparable. In addition, the analytical results of the organic soil S9 (23.3% organic matter), correspond sufficiently for practical interpretation.

Soil Analysis and Fertiliser Recommendation of phosphate

The following Table (Table A6.5) shows clearly the large variability in results from the different extraction methods. In addition, when the same method is used, such as the

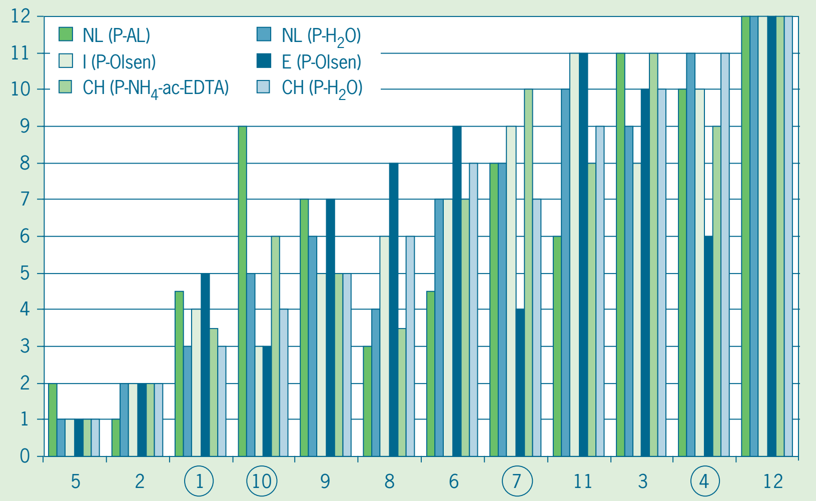


Figure A6.3 Ranking of P-amounts from 12 soil samples analysed by the partners ranked from low to high, x-axis soil sample numbers, y-axis P-ranking

Table A6.5 Absolute P amount (mg/kg dry soil) with specific method of 12 soil samples analysed by the four partner countries and comparative P/ P_2O_5-ranking-number

Sample Soil from	1 NL	2 NL	3 NL	4 I	5 I	6 I	7 CH	8 CH	9 CH	10 ES	11 ES	12 ES
P (mg kg^{-1} dry soil) - Absolute amount												
NL (P-AL)	188	100	659	581	127	188	515	170	445	559	344	1 314
I (P-Olsen)	32	21	96	124	20	85	97	76	44	24	130	193
CH (P-NH_4-ac-EDTA)	58	45	419	114	43	94	369	59	86	91	105	476
ES (P-Olsen)	55	34	129	103	33	108	52	106	104	52	181	226
NL (P-H_2O)	11	7	27	42	7	21	24	15	21	17	41	64
CH (P-H_2O)	4	1	13	14	1	10	9	8	7	4	12	16

Extraction method and original unity

NL (P_2O_5-AL)	mg (P_2O_5 per 100 g dry soil by extraction with ammonium lactate-acetate with pH 3.75
I (P_2O_5-Olsen)	mg (P_2O_5 per kg dry soil by Olsen-extraction
CH (P-NH_4-ac-EDTA)	mg P per kg dry soil by extraction with ammonium acetate EDTA (1:10m weight) with pH 4.65
ES (P-Olsen)	mg P per kg dry soil by Olsen-extraction with Sodium bicarbonate
NL (P_2O_5-H_2O)	mg (P_2O_5 per litre dry soil by extraction in a 1/60 volume extract water (1 l soil = 1.4 kg / 1 l organic soil = 0.8 kg
CH (P-H_2O)	mg P per kg dry soil by extraction with 1:10m weight water, pH variable

Olsen extraction (Spain and Italy), and the water extraction (Netherlands and Switzerland), important differences are indicated. Therefore, comparison on a relative base (ranking order) gives a better overview.

The rankings tend to correspond well. Holland and Spain showed a larger variability in their results (S10, S7). Only Switzerland and Holland determined additionally P/P_2O_5-water to determine the soluble fraction available to plants, which is considered in the fertiliser calculations. The ranking given to those results are almost identical.

- Based on the results of the12 analyses, each country made an evaluation and put each soil in one of the five classes of phosphate content (Table A6.6).

It is obvious that due to a different classification system, these results are highly variable:

- Netherlands evaluated S1 and S9 as very low, whereas the other countries classified them as high to very high. Considering the fertilisation recommendation for phosphate (Table A6.7), the Dutch conventional system advises a large amount of phosphate fertiliser. In integrated farming, no fertilisers are recommended because only Pw is considered and is high in all cases. It is questionable if those extremely low recommendations for the integrated system are realistic in the long term for soils with a low binding capacity and high Pw-value.
- Italy listed all 12 soil samples in class 4, namely 'high', which results in recommendations based only on the phosphate off-take by the crop.
- Switzerland (CH-res) and Spain made almost the same evaluation. Differences such as in S6 are related to different analysis results.
- Switzerland's CH-sol or the fraction available to plants varies greatly, which was also to be expected considering the analysis results. This states that samples more than the soluble fraction influences the recommendations (the Netherlands and Switzerland).

A fertiliser recommendation was made for the soil samples 1, 4, 7, and 10, indicated as being the most common soil type for each partner (Table A6.7).

Table A6.6 Evaluation of soil analysis according to classes of phosphate content for the methods of the Netherlands, Italy, Spain and the two methods of Switzerland (CH-res and CH-sol)

Soil	Class of phosphate content				
	1 (poor)	2 (low)	3 (medium)	4 (high)	5 (very high)
1		NL	CH-sol	I, CH-res, ES	
2	CH-sol	NL	ES	I, CH-res	
3			CH-sol	I	NL, CH-res, ES
4				I	NL, CH-res, CH-sol, ES
5		NL, CH-sol, ES	CH-res	I	
6			CH-res, CH-sol	I, NL	ES
7		CH-sol		I, ES	NL, CH-res
8			NL	I, CH-res	CH-sol, ES
9		NL, CH-sol		I	CH-res, ES
10			NL, CH-sol	I, ES	CH-res
11				I	NL, CH-res, CH-sol, ES
12				I	NL, CH-res, CH-sol, ES

Table A6.7 Phosphate fertiliser recommendation (kg phosphate ha^{-1}) and target values (mg phosphorus kg^{-1} dry soil) for sample Nr. 1, 4, 7, 10 for cauliflower, head-lettuce, carrot, onion

Crop	Target value[1]	Cauliflower				Head-lettuce				Carrot				Onion				Average
Sample	P (mg kg^{-1})	1	4	7	10	1	4	7	10	1	4	7	10	1	4	7	10	
Soil from		NL	I	CH	ES	NL	I	CH	ES	NL	I	CH	ES	NL	I	CH	ES	
NL (conv)	-	150	0	0	50	200	0	50	75	200	0	50	75	150	0	0	50	66
NL (IP)	20-30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I	30-35	0	0	0	0	20	20	20	20	20	20	20	20	20	20	20	20	15
CH	20-40	42	0	30	18	28	0	20	12	42	0	30	18	42	0	30	18	21
ES	30-45	18	0	30	30	12	0	20	20	18	0	30	30	18	0	30	30	18

[1] for medium textured soil

Main points of interest are:

- Very high amounts of phosphate were recommended by the conventional Dutch system. An amount five times as high as the other partners was recommended for head lettuce. The phosphate amounts for head lettuce and carrots would be too high following the Swiss fertiliser guidelines.
- In the Dutch Integrated Farming system, no phosphate was recommended for all of the cases.
- It is expected that the Swiss and Spanish recommendations correspond as they used the same fertilisation strategy. The results showed that the differences in recommendations were related to differences in analytical results.

Soil Analysis and Fertiliser Recommendation for potassium

Table A6.8 shows the absolute results together with the ranking list. K_2O-count from Holland, which is an adapted value for the fertilisation recommendation, and K-soluble

Table A6.8 Absolute potassium amounts (mg/kg dry soil) with specific method of 12 soil samples analysed by the four partner countries and comparative potassium/potash-ranking-number

Sample Soil from	1 NL	2 NL	3 NL	4 I	5 I	6 I	7 CH	8 CH	9 CH	10 ES	11 ES	12 ES
K (mg kg^{-1}) dry soil) Absolute amount												
NL (K-HCl)	199	166	182	357	315	207	340	174	232	382	664	764
I (K-NH_4-ac)	163	127	160	559	352	204	282	183	186	402	924	840
CH (K-NH_4-ac-EDTA)	210	173	182	395	350	247	307	233	206	442	1 050	892
ES (K-NH_4-ac)	156	125	156	335	300	172	238	164	168	355	819	663
NL (K-count)	199	174	290	332	473	241	357	183	133	382	689	755
CH (K-H_2O)	54	31	66	71	44	82	87	92	64	63	252	222

Extraction method and original unity	
NL (K_2O -HCl)	mg K_2O per 100 g dry soil by extraction with 0.1M HCl + 0.4 M oxalic acid
I (K_2O -NH_4-ac)	mg K_2O per kg dry soil by extraction of 2.5 g soil in 50 ml ammonium acetate, pH 7 +/- 0.1
CH (K-NH_4-ac-EDTA)	mg K per kg dry soil by extraction with ammonium-acetate EDTA (1:10m weight) with pH 4.65
ES (K-NH_4-ac)	mg K per kg dry soil by extraction with 1N ammonium acetate
NL (K_2O -count)	K-HCl with correction for lutum fraction, pH and humus fraction (only for sandy and peat soils
CH (K-H_2O)	mg K per kg dry soil by extraction with 1:10m weight water, pH variable

Table A6.9 Evaluation of soil analysis according to classes of potassium content for the methods of the Netherlands, Italy, Spain and Switzerland (CH-res and CH-sol)

Soil	Class of potassium content 1 (poor)	2 (low)	3 (medium)	4 (high)	5 (very high)
1			NL, CH-res, ES	I	CH-sol
2		CH-res, ES	I, NL	CH-sol	
3			ES	I, NL, CH-sol, CH-res	I
4			ES	CH-res	I, NL, CH-sol
5			ES	CH-res	I, NL, CH-sol
6			NL, ES		I, CH-sol, CH res
7			ES	CH-res	I, NL, CH-sol
8			NL, CH-res, ES	I	I, CH-sol
9		NL, CH-res	CH-sol, ES	I	I
10				CH-res, ES	I, NL, CH-sol
11					I, NL, CH-sol, CH-res, ES
12					I, NL, CH-sol, CH-res, ES

from Switzerland, which cannot be compared to the other results, are listed separately.
The strong extraction method from each partner seems to compare better than for phosphate. Also a good correlation between the ranking is listed in Figure A6.4, except for the soluble fraction analysed by Switzerland, which indicates the difference in binding capacity of potassium for each soil type.

Again, the 12 soils have been classified according to their potassium content (Table A6.9):

- The Netherlands, Switzerland (CH-res) and Spain correspond well. The soluble potassium fraction also corresponds better than phosphate.
- Italy evaluated all soils with a very high potassium content, probably due to their low target values (Table A6.10), except for S1 and S2. They, nevertheless, recommended four times more than the Swiss and the Dutch integrated systems.

In Table A6.10, the fertiliser recommendation for potash in kg ha^{-1} is plotted for the four selected soil samples. Main points of interest are:

- Dutch conventional recommendation showed less difference than for phosphate.
- Dutch integrated farming system made recommendations only for S1, where the K-count was within the desired range (20 - 29).

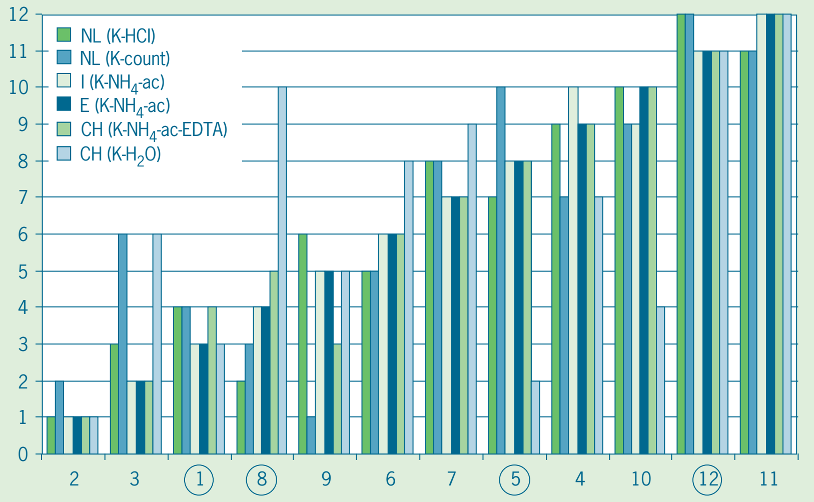


Figure A6.4 Ranking of K-amounts from 12 soil samples analysed by the partners, x-axis soil sample number, y-axis K-ranking

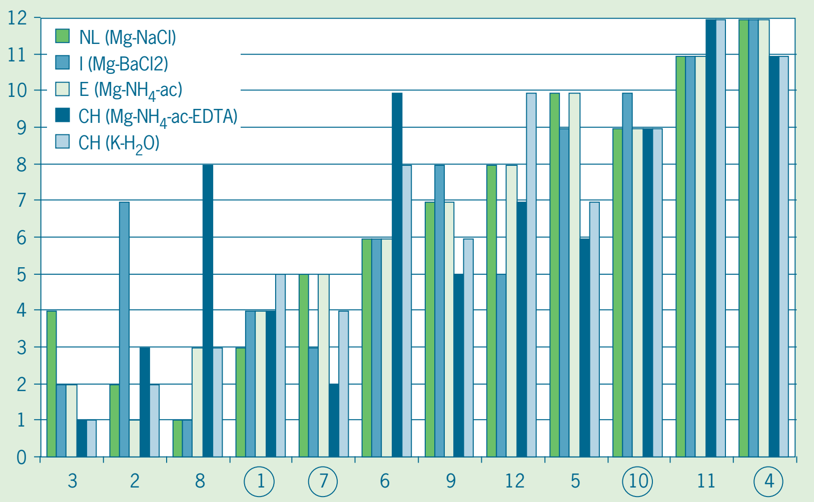


Figure A6.5 Ranking of magnesium amounts from 12 soil samples analysed by the partners, x-axis soil sample number, y-axis Mg-ranking

Table A6.10 Potash fertiliser recommendation (kg potash ha^{-1}) and target values (mg potassium kg^{-1} dry soil) for sample numbers 1, 4, 7, 10 for cauliflower, head-lettuce, carrot, onion

Crop	Target value[1]	Cauliflower				Head-lettuce				Carrot				Onion				Average
Sample	K (mg kg^{-1})	1	4	7	10	1	4	7	10	1	4	7	10	1	4	7	10	
Soil from		NL	I	CH	ES	NL	I	CH	ES	NL	I	CH	ES	NL	I	CH	ES	
NL (conv)	-	300	200	200	200	250	150	150	150	300	200	200	200	250	150	150	150	200
NL (IP)	160-240	70	0	0	0	123	0	0	0	210	0	0	0	90	0	0	0	41
I	120-180[2]	50	0	0	0	55	0	0	0	175	0	0	0	75	0	0	0	22
CH	180-300	72	36	18	36	48	24	12	24	88	44	22	44	80	40	20	40	41
ES	150-300	216	162	180	90	144	108	120	60	264	198	220	110	240	180	200	100	162

[1] for medium textured soil
[2] except soil 4 (102-144)

If K-count was higher than this range, no fertilisation would be recommended. The recommendation in Spain is a factor four higher than the Swiss, Italian and integrated Dutch potassium input. For those large differences, it is questionable whether the Italian and Spanish potassium recommendation could be reduced, or if the Dutch and Swiss K-fertilisation is sufficient to maintain the natural balance.

- The important differences were between Switzerland and Spain, where the recommendations for P corresponded rather well due to their similar systems.

Soil Analysis and Fertiliser Recommendation of magnesium

Table A6.11 and Figure A6.5 show the comparative results of the magnesium/magnesium oxide analysis. Clearly there is great variability in absolute magnesium amounts (mg/kg dry soil), which can be explained by the application of different extraction methods. The correlation of the ranking tend to be rather good, except for the Swiss magnesium reserve, where the differences are larger (S8, S7 and S9) and S2 from Italy (Figure A6.7).

Table A6.11 Absolute magnesium amounts (mg/kg dry soil) with specific method of 12 soil samples analysed by the four partner countries and comparative Mg/MgO-ranking-number

Sample No. Soil from	1 NL	2 NL	3 NL	4 I	5 I	6 I	7 CH	8 CH	9 CH	10 ES	11 ES	12 ES
Mg (mg kg^{-1} dry soil) - Absolute amount												
NL (Mg-NaCl)	95	82	102	433	275	157	117	79	177	238	371	178
I (Mg-BaCl2)	190	240	110	570	265	210	170	105	260	310	520	205
CH (Mg-NH^4-ac-EDTA)	337	316	127	1116	492	616	269	531	345	560	1240	519
ES (Mg-NH^4-ac)	107	89	91	559	328	180	134	92	219	293	486	234
CH (Mg-H_2O)	15	9	6	26	18	18	15	12	15	25	36	26

Extraction method and original unity	
NL (MgO-NaCl)	mg MgO per kg dry soil by extraction with 0.5M NaCl
I (Mg-$BaCl_2$)	mg Mg per kg dry soil by extraction of 2.5 g soil in 50 ml $BaCl_2$ + trie-thane-amine, pH 8.1
CH (Mg-NH_4-ac-EDTA)	mg Mg per kg dry soil by extraction with ammonium-acetate EDTA (1:10m weight) with pH 4.65
ES (Mg-NH_4-ac)	mg Mg per kg dry soil by extraction with 1N ammonium acetate
CH (Mg-H_2O)	mg Mg per kg dry soil by extraction with 1:10m weight water, pH variable

Table A6.12. Evaluation of soil analysis according to classes of magnesium content for the methods of the Netherlands, Italy, Spain and the two methods of Switzerland (CH-res and CH-sol)

Soil No.	Class of magnesium content 1 (poor)	2 (low)	3 (medium)	4 (high)	5 (very high)
1			CH-res, CH-sol, NL, I, ES		
2		CH-sol, NL, ES	CH-res		I
3		CH-sol, ES	CH-res, I		NL
4			CH-sol		CH-res, NL, I, ES
5			CH-sol	CH-res.	NL, I, ES
6				CH-sol, ES	CH-res, NL, I
7			CH-res, CH-sol, NL	I, ES	
8	NL	CH-sol, ES	I	CH-res	
9		CH-res	CH-sol		NL, I, ES
10			CH-sol	CH-res	NL, I, ES
11					CH-res, ES CH-sol, NL, I,
12				CH-res	CH-sol, NL, I, ES

The differences in evaluations (Table A6.12) are more related to different analysis results, than to application of diverse target values.

Main points of interest are:

- The recommendation for magnesium does differ extremely. In the Netherlands, magnesium fertiliser is recommended for clay soils only when there is a deficiency. Therefore, it is not recommended to apply magnesium in all cases for the conventional as well for the integrated farming systems.
- Generally, Italian soils are believed to have sufficient magnesium, therefore, a magnesium application is never recommended.
- Although Switzerland and Spain make use of a correction factor, the results do not correspond. According to this advise, the magnesium input would be twice as high in Switzerland.
- In places where Switzerland has the second lowest recommendation for potassium, it has the highest magnesium recommendation, which contradicts their high target values. For S4 and S10, they are the only ones that recommend applying magnesium.

Soil Analysis and Fertiliser Recommendation of Chalk

Only Italy ($CaCO_3$ total/active) and Switzerland carried out this analysis (Table A6.14 and Figure A6.6). The results correspond well. Due to the high pH-values, a Chalk dose was not recommended for any of the samples

Conclusion

The ring test showed us clearly that all partner countries used different parameters and methods. The results from absolute analyses sometimes indicated large differences (phosphorus, magnesium), but a good correlation between the partner countries was seen considering the ranking of analysed nutrient content for each of the soil samples. This indicates that the high variability in use and amount of fertilisers is caused by applying different fertilisation strategies; that is different calculation techniques and target values. The strategies are far from standardised, which causes inconsistent differences in the recommendations.

In the results from the ring test, the important differences were between the Dutch conventional and integrated farming systems. In the Dutch integrated production, the recommended input decreases from an average high (K)/extreme high (P) input, to almost no fertiliser input. Italy recommends based on their system generally higher amounts, also for soils with a high nutrient content. Their recommendation system will be reviewed in the

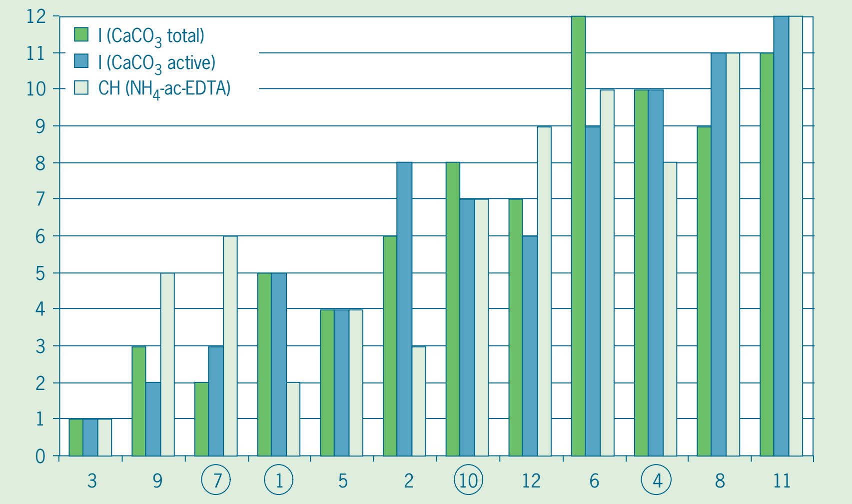


Figure A6.6 Ranking of Ca-amounts from 12 soil samples analysed by the partners, x-axis soil sample number, y-axis Ca-ranking

Table A6.13 Magnesium oxide fertiliser recommendation (kg magnesium oxide ha^{-1}) and target values (mg magnesium kg^{-1} dry soil) for sample number 1, 4, 7, 10 for cauliflower, head-lettuce, carrot, onion

Crop	Target value[1]	Cauliflower				Head-lettuce				Carrot				Onion				Average
Sample	Mg (mg kg^{-1})	1	4	7	10	1	4	7	10	1	4	7	10	1	4	7	10	
Soil from		NL	I	CH	ES	NL	I	CH	ES	NL	I	CH	ES	NL	I	CH	ES	
NL (conv)	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NL (IP)	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
I	100-150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CH	200-400	33	18	30	24	22	12	20	16	33	18	30	24	33	18	30	24	23
ES	80-120	27	0	18	0	18	0	12	0	27	0	18	0	27	0	18	0	10

[1] for medium textured soil

near future, which would implicate a lower fertiliser input. The Spanish and Swiss systems are very much related to each other, but also here differences in recommendation of potassium and magnesium should be noted. It is also questionable whether the high Italian and Spanish potassium recommendations could be reduced, or if the Dutch and Swiss K-fertilisations are sufficient to maintain the natural balance.

To develop a well-defined and consistent fertilisation system within the European Union, the different strategies and target values should be reviewed.

Table A6.14 Absolute $CaCO_3$ amounts (%) with specific method of 12 soil samples analysed by the four partner countries and comparative Ca/$CaCO_3$-ranking-number

Sample Soil from	1 NL	2 NL	3 NL	4 I	5 I	6 I	7 CH	8 CH	9 CH	10 ES	11 ES	12 ES
% $CaCO_3$ Absolute amount												
I ($CaCO_3$ total)	5	5	2	14	4	39	3	13	3	12	37	10
I ($CaCO_3$ active)	2	4	<1	6	2	4	2	7	<1	3	9	2
CH (NH_4-ac-EDTA)	4	5	1	8	6	9	7	10	7	7	10	9

Extraction method and original unity	
NL	not determined
I ($CaCO_3$ total)	method Scheibler
I ($CaCO_3$ active)	method Drouineau G. F.
CH (NH_4-ac-EDTA)	mg Ca kg^{-1} dry soil by extraction with ammonium-acetate EDTA (1:10m weight) with pH 4.65
ES	not determined

VEGINECO

EU. FAIR PROGRAM