VEGINECO
EU. FAIR PROGRAM

Final report on the VEGINECO project

VEGINECO Project Report No. 1

The Netherlands   Italy   Spain   Switzerland

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W. Sukkel & A. Garcia Diaz (eds.)

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Introduction

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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. Because 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.
Because 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 'ecology 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 agro-chemical-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 (EC 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 organic 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 organic 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 Southwestern 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 Southwestern 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.), Switzerland
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 protyping methodology is included in the manual on crop rotation. In addition to these methodological manuals, other publications include workshop proceedings and this final report on the Vegineco project. The workshop proceedings focus on project results in general and their implications for policy and certification. This final project report concentrates on the results of the prototyping methodology, in terms of application and development, and how well the tested systems performed.

2 Development of 'Prototyping Methodology' in Outdoor Vegetable Farming Systems

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2.1 Prototyping methodology

The systematic and comprehensive development and evaluation of integrated and organic farming systems is an important area of research in arable farming. Over the last 20 years, integrated and organic arable systems have been developed on experimental farms throughout Western Europe (Vereijken and Royle, 1989; Vereijken, 1994). During the last 10 years, substantial experience has also been gained in developing these prototype systems in innovative pilot farms, in co-operation with commercial farms (Vereijken, 1995).
The methodology of designing, testing, improving and disseminating these systems for arable farming was worked out in detail during a 4-year EU concerted-action project, involving leading European research teams (Vereijken 1994, 1995). The project ended in 1996.
The methodology, known as 'prototyping', 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.
This approach turned out to be of great importance for arable farming, but it has been put to limited use in vegetable farming. The Dutch work (Sukkel et al., 1998) in this area is one of the few examples of research into farming systems for outdoor vegetable production. It is both a challenge and a necessity to transplant this methodology to vegetable production and start farming systems research aimed at fully integrating all the different objectives. Only then will it be possible to evaluate the full potential of the new systems.

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 2.1).
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.

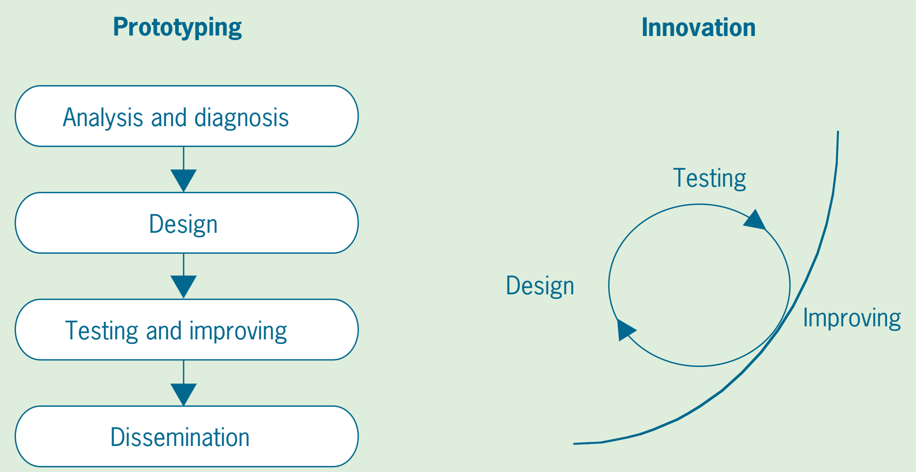

Figure 2.1 Prototyping methodology and the process of testing and improving

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.

2.2 Results of the theoretical part of protyping methodology, as applied in the Vegineco project

2.2.1 Analysis: State-of-the-art of European vegetable farming

Some statistics
A statistical analysis was made of the total surface, crops, area per crop, trade value per crop, trade channels and import/export flows of vegetables. When possible, this analysis was also carried out for the regions under investigation by the partners in the project.

Outdoor vegetables only occupy a small surface area (between 1-4%) of the total agricultural land in the regions shown in Figure 2.2). On average, the area of open field vegetables is about 3-4 ha per farm. In the Netherlands, this acreage per farm is larger than in the other countries. Under ‘acreage per crop’, two types of vegatable crops can be distinguished: crops for industrial processing, which are often grown on a large scale on arable type farms, and fresh crops for market that are grown on a smaller scale.
There is a very wide diversity of crops in vegetable farming (Figure 2.3). Not all crops are classified in the same way in every country. For example, the acreage of Dutch outdoor vegetables excludes potatoes (183 000 ha), onions (17 000 ha) and processing peas (6 000 ha).

Farm types
Throughout Europe, there is great diversity among farm types that grow outdoor vegetables. In general, three types of vegetable-producing farms can be distinguished:
1. Small farms (<10 ha), specialised in outdoor

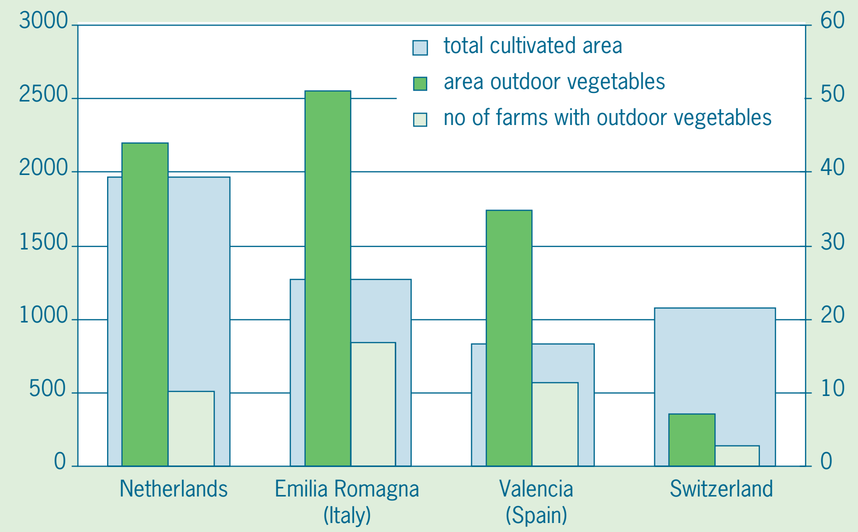

*Figure 2.2 Left axis: Total agricultural area under cultivation (*1000 ha) and area of outdoor vegetables (* 100 ha); Right axis: number of farms involved (*1000)*

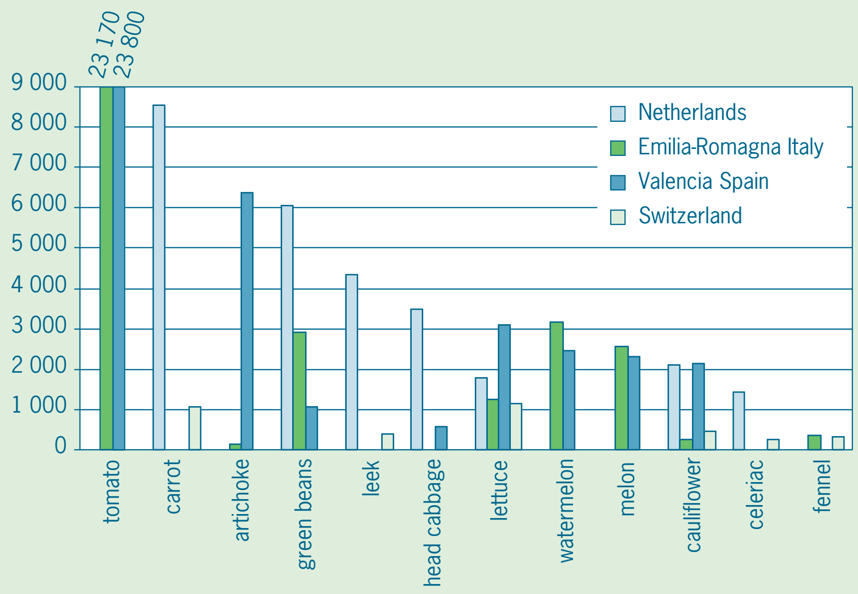

Figure 2.3 The major crops per partner in terms of area (ha), based on national statistics from 1995-1997 (the Dutch sample excluded potato, peas, onions, and chicory roots)

vegetables. These labour-intensive farms grow a wide variety of crops and are oriented towards producing fresh market produce. They are mostly family operated and are very intensive in terms of land use and inputs such as fertilisers and pesticides. A small group specialises in one or two crops, in the Netherlands, for example, Brussels sprouts or leeks.

2. Larger farms (10-50 ha) with either arable or citrus/fruit-tree acreage (Valencia) combined with outdoor vegetables. This is an expanding group. The well-mechanised vegetable crops can be produced without intensive labour.
3. The remaining farms are those that combine indoor and outdoor vegetables (Switzerland and Valencia) or those combining highly mechanised fresh market or industrial vegetable crops with arable farming (Emilia-Romagna and the Netherlands).

Due to the traditional orientation towards local markets, Swiss farms grow a very large number of crops and are therefore in a somewhat different position to farms in the other partner countries.

Farm economy and developments

Vegetable growers are currently facing a rather weak economic situation. Their average income is low, the costs of labour in Italy, Switzerland and the Netherlands are high, land rent is expensive in the Netherlands, and prices are generally fairly low, especially when there is open competition on the international markets as in the Netherlands, Spain and Italy. Internal quality demands are intensifying and cosmetic quality demands are constantly high. The predominant response from farmers is to reduce costs by inceasing efficiency. This is mainly achieved by specialisation, enlarging the scale of the operation, and mechanisation. These demand-driven changes also have consequences for farmtype development. In general, there is a shift from the small-scale fresh market family farm to specialised and/or large-scale farms. A parallel development is the incorparation of vegetable crops in arable crop rotations.

Environmental and agronomic problems

The intensive use of land, overfertilisation and a high input of pesticides are generally considered to be problematic, causing high emissions of nutrients and pesticides into the environment.

Except for Switzerland, problems caused by nitrogen leaching into the ground and surface water are clearly evident and well documented, as is the emission of pesticides in the Netherlands. Although the emission of pesticides is also viewed seriously in Italy and Spain, there is little documentation on its effects there.

There is ongoing concern about the sustainability of production in terms of soil fertility (especially biological and physical soil fertility) and the options for controlling soil-borne pests and diseases in the long term. Of particular concern, due to the one-sided agrochemical approaches, is the growing resistance of pests, diseases and weeds to pesticides.

Efficient large-scale agriculture has decreased bio-diversity in the main growing areas by removing flora and fauna habitats and corridors. The old landscapes formed by small-scale farming are rapidly disappearing. Even where small fields are maintained (as in Valencia, Spain), the hedges that used to separate them have largely been removed.

Policy and legislation

All countries have developed, or are developing, policy or legislation to counteract the negative effects of current farming practices.

- For *pesticides and fertilisers,* legislation has been introduced in the Netherlands and Spain to reduce input and emissions or, in Italy, to counteract the unwanted negative side effects of their use. In the Netherlands, Spain, Italy and Switzerland restricting measures have been incorporated into the production guidelines for ‘integrated’ production.
- Subsidy policies are being formulated to encourage *conversion to organic farming* in the Netherlands, Italy, Spain and Switzerland.
- In Switzerland, to qualify for subsidies, restriction clauses regarding production methods and farm management, which have to be met.
- In Spain, there are subsidies for co-operatives to help them to employ technicians whose task is to impart knowledge about integrated farming practices.

Market and label developments

The governments of Switzerland, the Netherlands, Spain and Italy are encouraging the development of organic farming by introducing subsidies to help farms convert to this style of production. In Switzerland and the Netherlands this development is being stimulated further by large grocery/supermarket chains who are actively incorporating organic production into their product range.

The development of integrated production labels started in the early nineties, stimulated, in the Netherlands and Spain, by either the auctions or co-operatives, in the Netherlands also by other groups in society (e.g. consumer groups), or, in Italy and Spain, by the government. A comparable development began earlier in Switzerland and has led to the present situation whereby almost all vegetable growers produce under the IP label. Parallel government subsidies, available to enterprises whose production processes are more or less the same as the guidelines for IP production, are in place to stimulate this trend further.

Driven by concerns about food health and safety, another important development is market and consumer awareness of the internal quality of produce. Where quality chain approaches are applied, this will lead to controlled and certified quality and the reduction of hazards throughout the chain.

Table 2.1 Themes and common parameters used in the Vegineco project

Parameters	*Definition*	*Target*
Quality of production		
Quantity of produce (QNP)	The extent to which good yield is realised per region. QNP = realised yield (kg ha^{-1}) divided by the good yield (kg ha^{-1}) figure for that region.	All crops should have a yield equal to or higher than regional good yields. $QNP \geq 1$
Quality of produce (QLP)	The extent to which good quality is realised in that region. QLP = realised quality class 1 levels divided by average quality class 1 level for that region.	All crops should have a quality equal to or higher than the average good quality level for that region. $QLP \geq 1$
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		
Phosphate Annual Balance (PAB) and Potash Annual Balance (KAB)	Phosphate and Potash Annual Balances (PAB/KAB) are P_2O_5 and K_2O inputs divided by P_2O_5 and K_2O withdrawals resulting from crop production in one year.	The target level is dependent on soil-reserve levels (PAR/KAR) PAB/KAB > 1 when PAR/KAR is below the desired range, PAB/KAB = 1 when PAR/KAR is within the desired range and PAB/KAB < 1 when PAR/KAR is above the desired range
Nitrogen Available Reserves (NAR)	Mineral Nitrogen Reserves (NAR) in the soil (0-100 cm) at the start of the leaching season.	Target values are set at a level that does not exceed the EU norm for drinking water (50 ppm NO_3): NAR < x kg ha^{-1} X = 45 kg ha^{-1} for sandy soils X = 70 kg ha^{-1} for clay soils
Clean environment pesticides		
Synthetic pesticides, input of active ingredients (PESTAS-Synth)	Input of synthetic pesticides in kg ha^{-1} of active ingredients per year.	The use of pesticides in kg of active ingredients per ha should be as low as is reasonably possible. PESTAS-Synth < x kg a.i. ha^{-1}
Copper input in 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 is reasonably possible. PESTAS-Cu < x kg a.i. ha-1
Exposure of the Environment to Pesticides: EEP-air, EEP-groundwater, EEP-soil	Potential of the active ingredients in the pesticide to emit substances into the environmental compartments air, groundwater and soil.	The emission potential of pesticides should be as low as is reasonably possible, but at least within legal standards (EU directive on drinking water) EEP-air < x kg ha^{-1} EEP-groundwater < 0.5 ppb (EU countries) EEP-soil < x kg days ha^{-1}
Nature and landscape		
Ecological Infrastructure (EI)	EI is the part of the farm that is laid out and managed as a network of linear and non-linear habitats and corridors for wild flora and fauna, including buffer strips.	EI > 5%

Table 2.1 Themes and common parameters used in the Vegineco project (continued)

Parameters	*Definition*	*Target*
Sustainable use of resources		
Phosphate Available Reserves (PAR) and Potash Available Reserves (KAR)	P_2O_5 and K_2O reserves in the soil (kg per unit of soil) that are available to plants.	PAR/KAR should be within an agronomically desirable range that is environmentally acceptable $xp < PAR < yp$ $xk < KAR < yk$
Organic Matter Annual Balance (OMAB)	OMAB is the difference between annual input and annual output (respiration, erosion) of effective organic matter.	To preserve the organic matter content, input should be equal to or larger than output. $OMAB \geq 1$
Energy Input (ENIN)	Input of direct and indirect (fossil) energy (in MJ ha^{-1}) used for crop cultivation.	No target established
Farm Continuity		
Net Surplus (NS)	Difference between total revenues and total costs (including labour) per ha.	Gross revenues should be larger than total costs. NS ≥ € 0
Hours spent hand weeding (HHW)	Amount of hand weeding used as an indicator of the success of mechanical and/or chemical weed control.	The hours spent hand weeding should be as low as possible. HHW < x hours ha^{-1}

Summary of trends
In summary, the important trends in outdoor vegetable farming for the coming period are:

- scale enlargement,
- specialisation,
- better mechanisation,
- uptake of vegetables by larger arable farms,
- increasing demand for, and the guarantee of, safe and healthy products,
- more IP labels and the increasing importance of organic production,
- control systems for quality–production chains,
- stabilised, or further decreases in the (already) low nature and landscape values,
- the need to create all-round sustainable farms.

The rate of change in each aspect differs among the partner countries, however the general picture remains the same.

2.2.2 Design: Objectives, parameters and methods

Based on the analysis of shortcomings in current farming and future perspectives regarding the main objectives (themes), future-oriented farming systems were devised. To quantify them, the objectives were expressed as a set of parameters/indicators. The main parameters used or developed in the Vegineco project can be found in Table 2.1 and a brief description of each parameter is given in Annex 2.

To design, test and improve farming systems, each parameter was given a target value, thereby establishing a well-defined, documented and clear framework. The target levels were future oriented, region- or system specific, and were derived from legislation, scientific evidence or expert knowledge. The desired level per tested system can be found in the reports on specific countries given later in this report.

The next step was to design a suitable set of farming methods. 'Methods' are defined here as coherent strategies on the major aspects of farming. To realise their objectives, these methods mostly require further development.
For each method, not only is a general strategy needed, but also a mixture of methods and techniques has to be fixed. The challenge in this process is how to overcome apparently conflicting objectives. When this has been achieved, the 'new' method is a coherent, safe and flexible, multi-objective strategy, utilising a diversified set of techniques (toolbox) depending on the specific farm conditions and the growing season (see Annex 3).
To achieve the objectives, the focus in the project was

mainly on the following farming methods: Multifunctional Crop Rotation (MCR), Integrated/Ecological Nutrient Management (I/ENM), Integrated/Ecological Crop Protection (I/ECP), and Ecological Infrastructure Management (EIM). The development of the methods used in the Vegineco project, and the results achieved, are treated in depth in corresponding manuals, published as part of the Vegineco project.

2.3 New approaches

'Prototyping' methodology was first applied to arable farming. For further development and in order to adapt it to outdoor vegetable farming a number of modifications were made. The main changes, described in the following paragraphs, involve new approaches to the quantification of production quality, the evaluation of pesticide use, the quantification of energy input, and the quantification of nature and landscape values.

2.3.1 Quality production

In outdoor vegetable farming, the main factors in the economic result are the quantity and quality of the produce. Quantity and quality are closely related to important objectives such as food supply and basic income/profit levels and are influenced by all the farming methods we use.

Quantity of produce

In vegetable farming, the quantity of produce is usually expressed as a unit of weight per surface unit or as a number of pieces per surface unit, depending on the way the product is marketed. In addition, the quantity produced is frequently expressed as the weight or number of pieces within certain size or weight classes. As yields are expressed in these different ways in different countries, it makes it very difficult to compare them. To overcome this problem, all yields were expressed in weight units of marketable quantity per surface unit. By marketable quantity, we mean 'the quantity that is actually fit to be sold'.

Quantifying yield is one thing, but how to interpret its value is another. In the case of integrated/organic farming systems, most of the time there was no zero reference in the experiment — no conventional system to measure the yields against. Therefore a reference had to be devised. The criterion followed in the Vegineco project was the reference: *Regional Good Yields and Quality.* An estimation of 'regional good yields and quality' was made from available data and expert knowledge. It is important to note that the values obtained were *not year-specific, but indicated the average performance.* A yield and quality reference could also be made more farm- or system-specific by making it a yield quality target based on a combination of factors, such as ambition, what is realistic and what is usually achieved in practice.

To evaluate yield quality, the quantity achieved and what is considered a good quantity for that region were combined in one index, 'Quantity of Produce' (QNP). Quantity of Produce is the extent to which regional good yield is realised.

QNP = realised yield (kg ha^{-1}) divided by regional good yield (kg ha^{-1}).

Using this QNP has a number of advantages:

- results from different systems are comparable,
- results from different crops are comparable,
- results for different crops can be summarised on farm level.

Quality of produce

Quality is hard to define because the subjective element can be quite significant. It can be defined in categories/classes and the percentage of produce in each (vegetable crops), and by using quality parameters (content over the bulk product in arable crops), or by the price obtained as a result of the quality.

In the Vegineco project, nationally used quality classes were used as much as possible for quality classification. Realised quality was expressed as the quantity of top- or first-class quality produced.

As with quantity, regional good quality was used as a reference.

Combining realisation and reference, the parameter 'Quality of Produce' (QLP) is defined as:

QLP = realised amount of Class 1 quality, divided by the 'regional good amount' of Class 1 quality.

The resulting figure gives an indication of the extent to which regional good quality has been achieved.

2.3.2 Evaluation of the use and effects of pesticides

Pesticide use

The purpose of pesticides is to control pests, diseases, and weeds. However, these substances also pose a risk for the environment. Pesticides can be described as 'the only group of toxic chemicals which are intentionally dispersed in the environment' (The Pesticides Trust UK, information leaflet).

The use of pesticides is currently often quantified as the 'number of treatments', as 'active ingredients per kg' (PESTAS), or as a relative number expressing the ratio 'used dose to recommended full-field dose'. These parameters, however, only quantify use and cropping technique. As 'pesticide input in active ingredients per kg' is easy to assess, and is often used in fixing policy and label target levels, this measure was used as a testing parameter in the Vegineco project.

Not all pesticides fall easily within the definition 'active ingredients'. Organic pesticides such as *Bacillus thurigiensus* — the concentration of which is measured in International Units — are difficult to express in terms of active ingredients. Moreover, active ingredients, such as mineral oil, copper or sulphur, which have a lower environmental effect and a higher active ingredient concentration in their formulations, are usually applied in a much higher dose per ha than synthetic pesticides. To overcome this problem, the units of use of the different pesticide groups were quantified as follows:

1. Synthetic pesticides and complex toxic molecules of natural origin (pyrethrines, azadirachtine, rotenone) were quantified in kg of active ingredients per ha (PESTAS-Synth).
2. Copper compounds were quantified as kg copper per ha (PESTAS-Cu).
3. Sulphur compounds were quantified as kg sulphur per ha.
4. Bacillus thuringiensus was quantified in numbers of international units.

Groups 1 and 2 were the main evaluation parameters used in the Vegineco project.

Pesticide emission

Only a fraction of the pesticides come into direct or indirect contact with the organisms they are meant to eliminate. Inevitably, in use, most of the pesticides become part of the abiotic environment. They partly volatilise into the air, run off or leach into surface- and groundwater, are taken up by plants or soil organisms or remain in the soil. The environment, thus, gets exposed to a certain pesticide load. The combination of pesticide properties and environmental conditions determines the 'persistence' of the compounds (adsorption, degradation, photolysis, etc.). The major cause of pesticide loss — levels of up to 80-90 % have been reported (Taylor and Spencer, 1990) — is volatilisation. This occurs within a few days after application. A recent study in the Netherlands, undertaken within the framework of evaluating the crop protection policy, estimates that some 50% of the total pesticide used volatilises (Anonymus, 1996). What happens to pesticides in the atmosphere is largely unknown.

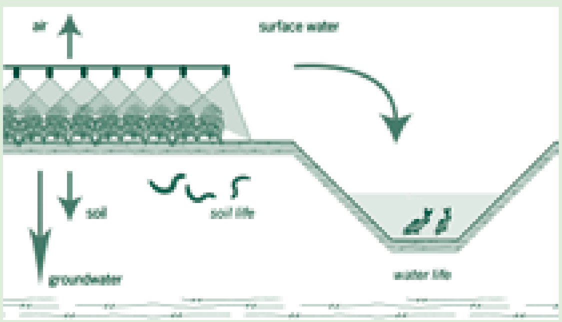

Figure 2.4 The main emission routes and ecological effects of pesticide use

However, it is very probable that winds and other atmospheric systems carry and distribute disturbing levels of pesticides worldwide (Schomburg and Glotfelty, 1991; Gregor and Gummer, 1989; Atlas and Schauffler, 1990; Simonich and Hites, 1995).

In order to quantify the amount of active ingredients that are dispersed to the different environmental compartments, PPO has developed a concept called 'Environment Exposure to Pesticides' (EEP; Wijnands, 1997). EEP is quantified by taking into account the physical properties of the active ingredients (DT50, VP= vapour pressure, and Kom = bonding to organic matter) and the amount of active ingredients used (see Intermezzo).

This concept fits into the strategy of integrated farming systems. In the development of these systems, the use of this instrument follows a strategy that aims at minimising any potential effect of pesticides on biota. The exposure of the environment to pesticides (EEP) should therefore be minimised, an effect that can be furthered by minimising the pesticide requirements of farming systems (e.g. by integrated crop protection), and by carefully selecting the pesticides used to minimise their effect on the environment. The EEP approach was used in the Vegineco project, because it is a basic instrument on which to base preventative measures regarding pesticide levels. An annual analysis was made of the highest scoring pesticides in use, and, as a first step in replacing them, alternatives were sought.

Ecological risks

Pesticides unavoidably cause ecological effects, since no pesticide is only toxic to the species that it is meant to control. The presence of pesticides in the abiotic environment is, in fact, a potential threat for all biota, also non-target ones. The magnitude and differentiation of this threat is only very partially known and quantified. While it is relatively well known that pesticides are toxic for humans and some mammals, much less is known about their effects on other biota, their so-called ecotoxicity. However, it is virtually impossible to evaluate a substance's ecotoxicity accurately, since the reactions of thousands of different species would have to be examined, each of which might react differently when exposed to the substance being studied. To gain an accurate picture, not only would direct toxicity have to be assessed, but also the mid- and long-term effects on, for instance, fertility, vitality, and population dynamics.

Ecological risks and human toxicity are not factors that are explicitly taken into account in the testing and improving procedures used in Vegineco systems. The main focus is on preventing emissions. In some cases, however, information about ecological risks is taken into account as an additional criterion for selecting pesticides.

Intermezzo: Environments Exposure to Pesticides (EEP)
EEP calculates per pesticide application the potential pesticide emission to the compartments air, soil and groundwater. Calculation of this potential emission is based on the amount applied active ingredient and physical pesticide properties.

The EEP basic data are:
DT50 = half life time of pesticide in soil, a measure of the persistence in the soil
K_{om} = the partitioning coefficient of the pesticide over the dry matter and water fraction of the soil/organic matter fraction of the soil to organic matter
VP = vapour pressure; a measure for the volatilisation in Pascal

Derived from this basic data is:
F = the F value, a measure of the fraction of the active ingredient that leaches
$F = exp(-[(A \times f_{om} \times ln2 \times K_{om}) / DT50 + (B \times ln2) / DT50 + C])$

In which:
A = 392.5 l kg^{-1} $days^{-1}$; B = 68.38 days; C = 1.092 and f_{om} = 0.0146 (van der Zee en Boesten, 1991)

emission% = the translation of vapour pressure to the percentage of the active ingredient that volatilises
The emission percentages are:

> 10 mPa	95%
1 – 10 mPa	50%
0.1 – 1 mPa	15%
0.01 – 0.1 mPa	5%
< 0.01 mPa	1%

EEP calculation formulas for an application of one pesticide are given below. The $\sum_{1-n}$ refers to pesticides with more than one active ingredient. Then, the calculations should be done first per active ingredient and then added per parameter to make a total for the application.

EEP-air [kg ha^{-1}] = $\sum_{1-n}$ *(a.i. input$_m$ x emission%$_m$ /100)*

In which:
a.i. $input_m$ = input of active ingredient m x active ingredient concentration of active ingredient m in a pesticide [kg ha^{-1}]
emission$\%_m$ = emission percentage of active ingredient *m* (see above)

EEP-groundwater [ppb] = $\sum_{1-n}$ *(a.i. input$_m$ * F$_m$ / prec surplus)*

In which:
a.i. $input_m$ = input of active ingredient *m* x active ingredient concentration of active ingredient *m* in a pesticide [kg ha^{-1}]
F_m = F value of active ingredient m (see above)
prec surplus = precipitation surplus [m^3]

EEP-soil [kg days ha^{-1}] = $\sum_{1-n}$ *(a.i. input$_m$ x DT50$_m$ / ln2)*

In which:
a.i. $input_m$ = input of active ingredient *m* x active ingredient concentration of active ingredient *m* in a pesticide [kg ha^{-1}]
$DT50_m$ = soil half life of active ingredient *m*

EEP values per application can be summed per parameter to calculate EEP values on crop, field or farm level.

2.3.3 Energy input

In the Vegineco project, the main objectives were to achieve a clean abiotic environment and the sustainable use of resources. Energy is one of the inputs. Non-renewable fossil energy is also potentially polluting, because of CO_2 production and its effects on global warming. For this reason the parameter energy input was examined within the Vegineco project.

System bounderies
In order to quantify energy use, the system boundaries have to be clear.
Energy input was quantified according to the following criteria:

1. To determine system boundaries, the unit that was used was 'the field', so everything that happened to the product after it left the field (storage, transport, handling) was not accounted for.
2. Direct (machine operations) as well as indirect energy input were quantified.
3. The processes needed to produce durable means of production for manufacturing inputs in the vegetable production process were not included.
4. Energy inputs for buildings and infrastructure were not taken into account.

Input data were primarily based on inputs supplied by the *Eidgenössische Forschungsanstalt für Agrarwirtschaft und Landtechnik* (Gaillard et al, 1997).

Calculation
To calculate the energy input at either crop-, field- or system level, the following steps were taken:
1. The indirect energy input values for machinery (expressed per energy use per hour of machine use) were based on weight, the energy value per kg of steel, the lifespan and intensity of use.
2. The direct energy input values per hour were calculated for all machine operations. This calculation is based on the power (kW) needed, the fuel use per kWHour, the load of the machine, and the energy value per unit of fuel. The load is dependent on the type of machine (2 weeldrive, 4 weeldrive, etc.) and on the type of operation (soil cultivation, transport, etc.).
3. The total direct and indirect energy input in machine operations and labour was calculated by multiplying the hours of machinery and labour input by the direct energy use per hour for labour, or the direct and indirect energy use per hour for machinery use. The calculation of the activity time per machine operation is based on the width of the implement, the forward speed of the machine and the extra time needed for turning and refilling.
4. The indirect energy input in (other) durable inputs (plastics, irrigation material, etc.) was calculated, based on the weight of the input, the durability of the input, and the energy value per kg of input.
5. The energy input in consumables was calculated by multiplying the energy per unit consumable with the number of used units of the consumable.
6. Finally, the direct and indirect energy input for machinery, the direct labour, and indirect consumables were summarised, so that the total energy input per ha or per unit product could be calculated.

Direct energy input in terms of fuel, especially for machine operations, can be measured directly at farm level by directly measuring the total fuel use. However, the model approach, mentioned above, was chosen, because it allowed individual techniques to be judged in terms of energy use.

Example
As an example of testing using the parameter 'energy input', the Vegineco partners calculated the energy input of the cultivation of lettuce in one of their systems. From Table 2.2, it becomes clear that, in this case, the differences between systems (countries) are mainly due to direct and indirect (in Spain, other equipment) energy use for irrigation. Direct energy for irrigation is used for pumping up the water and indirect energy is caused by the use of plastic (PET) tubes. In this case, the recycling of the plastic is not accounted for. Smaller differences between systems are caused by using fertilisers and the energy input for sowing and planting. The last factor is mainly influenced by the number of

Table 2.2 Energy input in lettuce cultivation (MJ ha^{-1})

Category	The Netherlands		Switzerland		Italy		Spain	
	Summer integrated	Summer organic	Spring integrated	Spring organic	Summer integrated	Summer organic	Winter integrated 1	Winter integrated 2
Total machinery	*17 220*	*16 914*	*15 959*	*15 168*	*16 421*	*14 320*	*16 488*	*18 710*
Direct	10 631	10 220	9 622	9 240	9 989	8 369	9 658	10 665
Indirect	6 590	6 693	6 337	5 928	6 432	5 951	6 831	8 045
Other equipment	*0*	*0*	*0*	*0*	*0*	*0*	*14 105*	*14 105*
Energy input labour	*289*	*290*	*404*	*401*	*651*	*602*	*469*	*231*
Total consumables	*21 233*	*14 540*	*19 243*	*18 263*	*23 243*	*18 619*	*38 492*	*24 717*
Fertilisers	9 040	1 340	6 179	4 488	3 222	0	6 671	209
Pesticides	593	0	174	0	50	0	1 752	217
Plants and seeds	11 600	11 600	12 891	13 775	13 485	13 819	9 063	10 150
Water	0	1 600	0	0	5 200	4 800	21 007	13 542
Total energy input ha^{-1}	38 742	31 744	35 606	33 832	40 315	33 540	69 555	57 763

Table 2.3 Parameters and target values for the evaluation of the quality of on-farm nature values

Nature and landscape	
PWE Percentage of Woody Elements	Percentage at farm level (scale 1:5000) = percentage at landscape level (scale 1:25000). At landscape level, the presence of larger woody elements in 250 by 250 meter squares is scored, at farm level the presence of individual trees in 50 by 50 meter squares is scored. For the landscape level, maps around 1970 were used. Target values can be adjusted, if rural development plans for the area differ from the actual landscape.
CoLE Connectivity Elements in Landscape	Desired connectivity is reached if L ≥ ½N N = Node: a landscape element of sufficient size (>50 m^2) to provide shelter, food and the possibility for reproduction (depending on the species). L = Link: suitable habitat for groups of target species to move from one area to another. A distinction is made between woody links and herbal links.
CiLE Circuitry Elements in Landscape	Desired circuitry is reached if the number of L ≥ N
BTP Biotopes	50% of existing biotopes in the 6.25 km^2 surrounding the farm must also be present on the farm.
Environment	
BZI Buffer Zone Index	Length of buffer zones per length of ditches, watercourses or woody elements between 1 and 2. The index is 1 for elements at the border of the farm, and 2 for internal elements.
BZW Buffer Zone Width	The average width of the buffer zones are 4 m. For the calculation of this parameter, buffer zones wider than 4 m are fixed at 4 m.
Agro-ecological layout	
EII Ecological Infrastructure Index	The percentage of the farm which is managed as a network of linear- and non-linear biotopes for flora and fauna, including buffer strips ≥ 5%
FSI Field Size Index	Width of the fields <125 m. FSI = (A1*(W1-125)/At) . A1 is the area of the farm with fields wider than 125 m, W1 the average width of that part of the farm, and At the total area of the farm. Every 25 units corresponds with a 10% shortfall.
BTS Biotope Target Species	The number of target species present in a biotope.Twenty target species were chosen for each biotope. These 20 species can be divided into 4 groups corresponding to a specific stage in the succession of the vegetation.

plants per hectare. In general terms, how the energy input is divided among the main farm–input categories is comparable with the data found in literature elsewhere.

2.3.4 Methodology and parameters on ecological infrastructure management

There is a common concern about the decline of nature and landscape values in agricultural areas. However, there are different accentuations in the framework from which the different countries view nature on farms. The Italian and Spanish interest is dictated more by agronomy. Their the main motivation for improving and preserving nature on farm properties is as a means of combating natural enemies. In the Netherlands and Switzerland, the aim of on-farm nature is more to increase biodiversity. Other motives, common to all the countries, are to increase the attractiveness for humans and to improve physical conditions (e.g. reduce erosion, improve wind-shields). In general, every country has the same set of motives for increasing on-farm nature, but the priorities

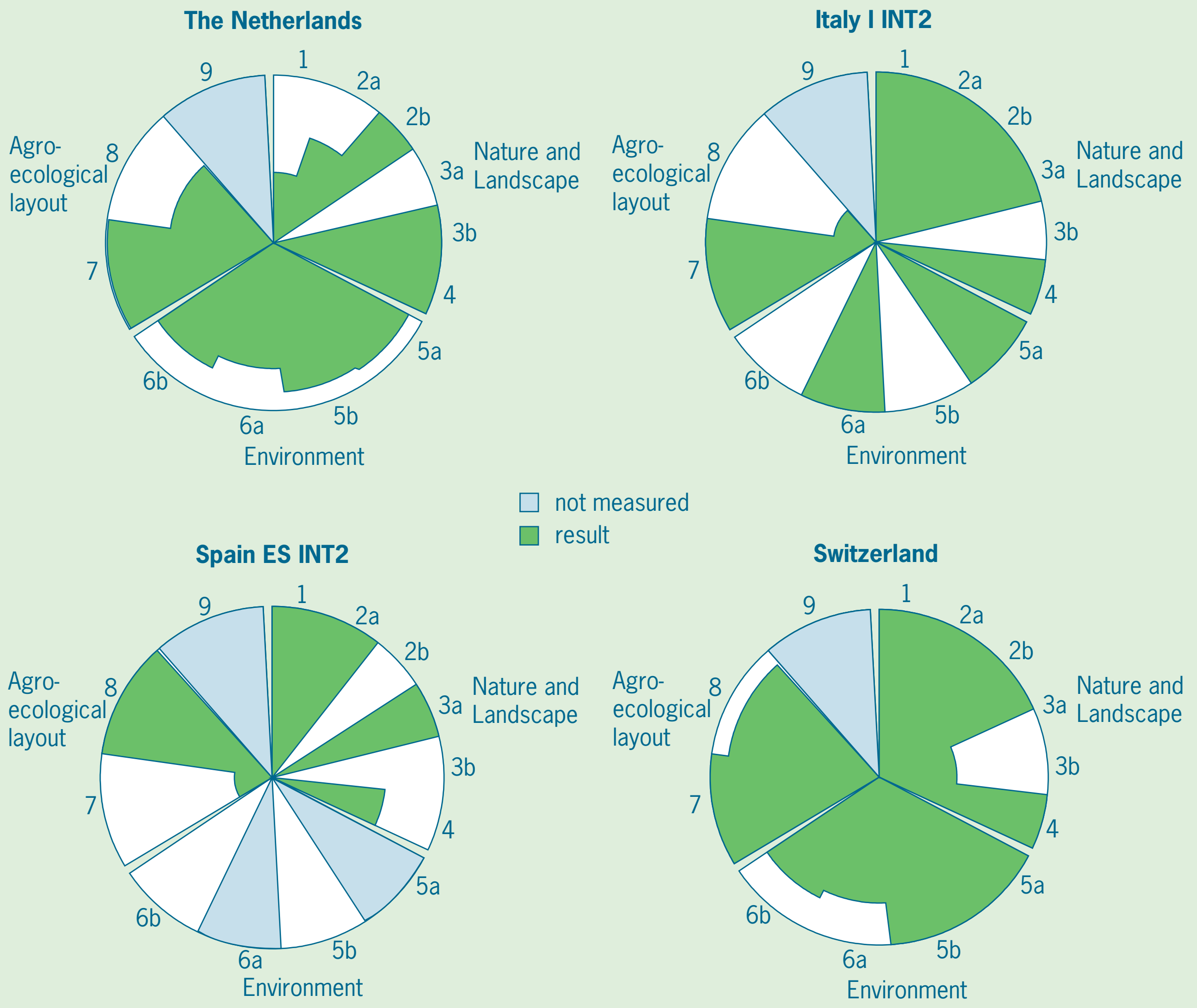

Figure 2.5 Representation of the realisation of on farm nature parameters per country

are different. In the Netherlands, Switzerland and Italy there are subsidies to encourage the improvement or preservation of on-farm nature, and in Spain, around the large cities, there is a strong need to combine agronomic and recreation (landscape) functions.

The Netherlands presented a methodology for the quantification of the potential quality of on-farm nature. For the Dutch, historical, cultural and present landscape values play an important role in the layout of on-farm nature. From this motivation, parameters have been developed to quantify the potential quality of on-farm nature in relation to its surroundings. However, even where measures to improve the quality of on-farm nature are put in place, it can take a long time before the effects become visible. This is why the parameters are focused more on creating conditions to exploit fully the potential nature quality on a specific farm (or region). There is also a need for parameters estimating the extent of improvements in quality and how far they are from reaching their maximum potential (scoring, for example, aspects of biodiversity). These parameters are also necessary, of course, to check the efficacy of parameters that are more focused on creating the circumstances for achieving quality potentials. However, this aspect was somewhat outside the scope of the Vegineco project.

Nine parameters were developed, divided into three themes: nature and landscape, environment, and agro-ecological layout (see Table 2.3). Although parameters proposed for linking the farm to the landscape (PWE, CoLE, CiLE and BTP) have recently been developed, they have yet to prove their suitability in different landscapes. PWE was developed to provide a guideline for the extent to which woody elements on a farm reflect the landscape in which the farm is situated. The same holds for BTP. CoLE and CiLE were derived from landscape ecology, where connectivity and circuitry are used to describe the

functioning of networks (Forman and Godron 1986). In this methodology, they are used to involve farms in creating corridors designed to connect nature areas. The introduction of specific stepping-stones on the farm may improve the connectivity and circuitry of existing networks. Moreover, when new landscape elements are introduced on a farm, the positioning has to be evaluated in terms of how it connects with the connectivity and circuitry of existing networks.
BZI and BZW are based on pesticide drift-reduction studies, which show that by introducing 4-meter zones, drift can be reduced to zero (Huisman et al., 1997).
EII is the only parameter which was also used in the original prototyping methodology (Vereijken 1995). FSI was developed to express the extent to which the agro-ecosystem of a specific farm can be stabilised. Expert judgement indicates that the optimal field size for predators to reach the centre of the field is 125 meters.
BTS has only been implemented for the management of dyke grassland vegetation so far. Similar methods for other biotopes are being developed.

For all parameters (except BTS), it is hypothesised that when the target values have been achieved, the preconditions will have been created to ensure a certain basic level of agricultural landscape quality. Ultimately, the quality will largely depend on how the different elements are managed. This can be evaluated using the BTS parameter.

Prototyping on-farm nature management provides a tool for analysing and evaluating the achievements of nature management on a farm. This provides the farmer or researcher with clues about how to improve the functioning and the quality of the nature on the farm and in the surrounding area. It is important to emphasise that the methodology presented here evaluates whether the conditions are present for a basic level of quality for agricultural landscape. The actual quality achieved largely depends on how the different elements are managed. Parameters for evaluating the latter will be developed in analogy with the BTS parameter. The parameters for evaluating the quality of on-farm nature have been tested on a selected number of the systems present in the Vegineco partner areas (see Table 2.4 and Figure 2.5).

2.4 Testing and improving

Testing implies that the shortfall between target and actual results is analysed in terms of the methods linked to the parameters in question. The agronomic database and the qualitative observations during the growing season are indispensable for analysing the shortfall between actual and target results. In this phase, detailed knowledge was generated about the different production techniques, their compatibility with other farming methods, their

Table 2.4 Realisation of on-farm nature parameters and target values for a selection of systems

	Parameter	Netherlands target	Netherlands realised	I INT1 target	I INT1 realised	ES INT2 target	ES INT2 realised	Switzerland target	Switzerland realised
	Nature and landscape								
1	Percentage of woody elements	30%	13%	14%	40%	44%	45%	9%	23%
2a	Connectivity of woody elements	50%	33%	25%	25%	28%	100%	33%	50%
2b	Connectivity of herbal elements	5%	133%	25%	100%	28%	0%	33%	50%
3a	Circuitry of woody elements	100%	0%	14%	100%	20%	100%	30%	14%
3b	Circuitry of herbal elements	100%	100%	14%	0%	20%	0%	30%	14%
4	Biotopes	3	4	2	4	3	2	4	8
	Environment								
5a	Length of buffer zones/ length of ditches	1	0.91	1	1	-	-	1.48	1.48
5b	Length of buffer zones / length of woody elements	1	0.89	1	0	1	0	1.57	1.57
6a	Width of buffer zone next to ditches	4 m	3 m	4 m	4 m	-	-	4 m	3 m
6b	Width of buffer zone next to woody elements	4 m	3.3 m	4 m	0 m	4 m	0 m	4 m	3.2 m
	Agro-ecological lay out								
7	Ecological infrastructure index	5%	4.9%	5%	12%	5%	1.1%	5%	8.2%
8	Field-size index	<125 m	230 m	<125 m	313 m	<125 m	<125 m	<125 m	139 m
9	Biotope target species	-	-	-	-	-	-	-	-

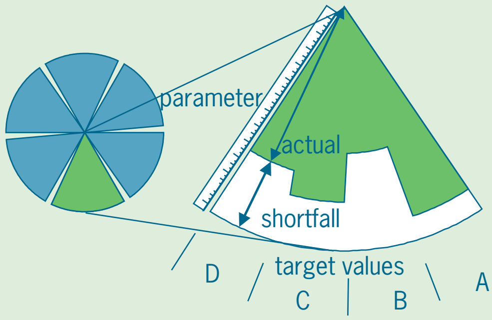

Figure 2.6 Schematic representation of target realisation and shortfall

efficacy in relation to the objectives, and the (potential) conflicts with other methods and objectives. This information is directly used to improve the prototype.
The prototype is made more effective by improving the set of methods in a targeted way. This implies using safe, efficient, acceptable and manageable integrated farming methods capable of achieving the target result. The prototypes have been improved from year to year.
The following sections focus on the performance of tested vegetable farming systems in different European regions, although the methods used will not be explained in detail. These methods have been published as a series of four manuals, one on each key farming method: crop rotation, nutrient management, crop protection and ecological infrastructure management.
Performance is presented in terms of the level at which the parameters have been realised, compared with the desired (target) levels of these parameters (see Figure 2.6). This is followed by a commentary on the remaining shortfalls. Where possible, an additional comparison was made with standard practice performance.

3 A practical case in the Southwest of the Netherlands

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3.1 Introduction

The Dutch integrated vegetable systems are located at Westmaas in the south-west clay region of the Netherlands. Approximately 18% (7 466 ha in 1996) of the Dutch outdoor vegetable surface is located in this region. The main vegetable crops in this region are onions, chicory, winter carrots, Brussels sprouts, celeriac, and to a smaller, but growing, extent, iceberg lettuce, and various other vegetable crops such as fennel, cauliflower and broccoli. Most of the farms are specialised vegetable farms (mainly in Brussels sprouts) and arable farms with vegetable crops. In the south-west region, specifically, but also nation wide, there is a growing tendency to include vegetable crops in arable rotations. Either specialised farms rent land from arable farms, or arable or organic farmers start to grow vegetable crops. This could be a beneficial tendency in that it extensifies the existing intensive vegetable rotations. Research on the integrated and organic system variants at Westmaas is trying to find answers to the specific sustainability issues that accompany this development.

3.2 Crops and Rotations

Two types of extensive integrated vegetable systems and one extensive organic vegetable system were tested at one location. The crop choice in both systems was based on the possibilities offered by the region and the soil. Moreover, the same main crops were used in both systems. The basis of the integrated systems at Westmaas is a 4-year arable rotation, including cereals and potatoes as arable crops, and with either Brussels sprouts or iceberg

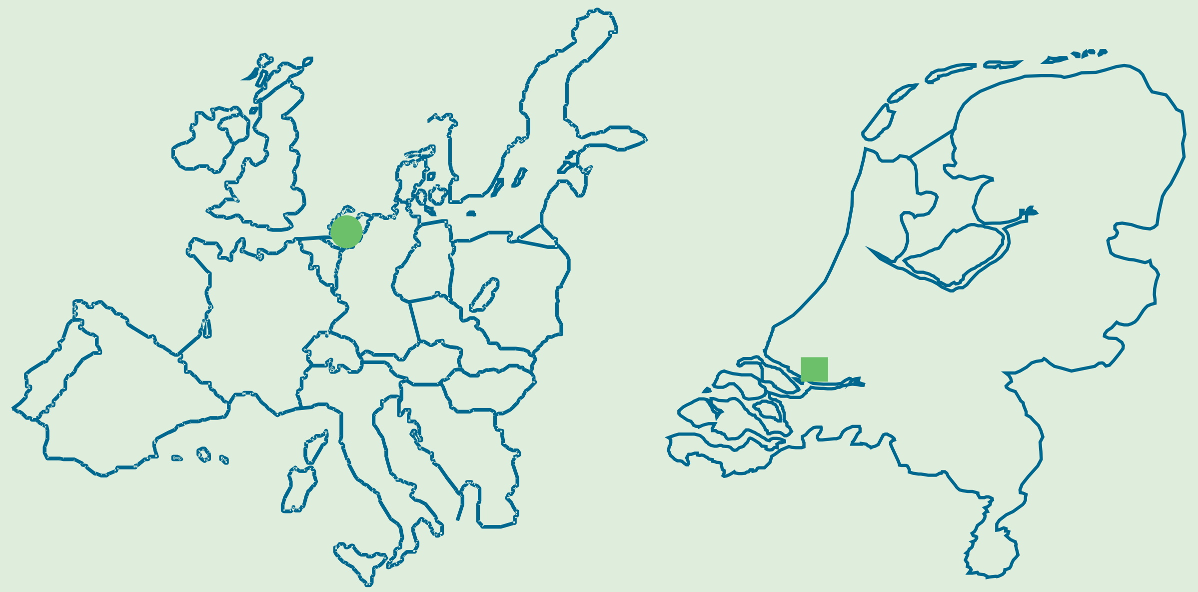


Figure 3.1 Location of the experimental integrated and organic vegetable farming systems in the Netherlands

Table 3.1 General scheme of integrated and organic farming systems in the Netherlands

Year/ block	Integrated NL INT 1 Brussels sprouts systems (4 variants; 4 parcels/variant)	NL INT2 Iceberg lettuce systems (3 variants; 4 parcels/variant)	Organic NL ORG Organic system (1 variant; 12 parcels)
1	potatoes	potatoes	potatoes
2	Brussels sprouts	fennel/celeriac/cauliflower	iceberg lettuce
3	winter wheat/spring barley	winter wheat/spring barley	grass/clover
4	fennel/celeriac/iceberg lettuce	iceberg lettuce	Brussels sprouts
5			fennel
6			barley/clover

lettuce as the main vegetable crop. The second vegetable crop is either celeriac, fennel or cauliflower. This set-up has led to seven system variants that covered two cropping plans, with the main vegetable crops and the range of cultivation types (periods) within the vegetable crops.
The organic system has a 6-year rotation with includes the same main crops as in the integrated systems.
Per rotation block, two parcels were available to test the different cultivation periods per crop.

3.3 Results

3.3.1 Results overview

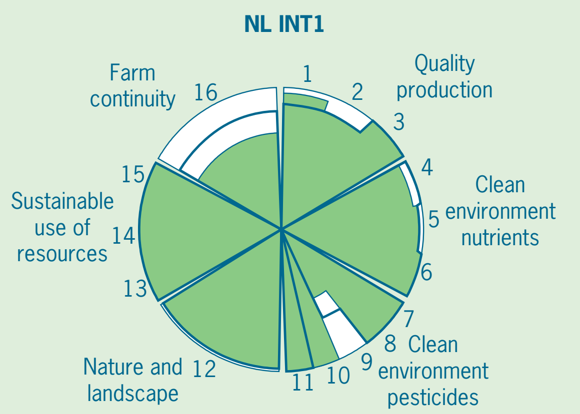
Figure 3.2 and Table 3.2 give the relative overall performance of the systems, compared with the desired level of performance. The desired level is that for an all-round sustainable farm. The results of the last testing year (2000), and the average results over 4 years, are indicated below.
The main shortfall in the integrated systems could be found in the theme's environment pesticides, farm continuity, and, to a small extent, in production quality.

The apparent shortfall for 2000 in the 'environment nutrients' theme was caused by a year effect. The average achievements for this theme were close to target. For the organic system, the main shortfall could be found in production quality and in the potash balance in the theme 'environment nutrients'. We will focus on the specific themes below.

It can be rather discouraging to look at shortfall, compared with an ideal situation. When possible, therefore, an additional comparison was made, using estimations of the average performance in practice. This gives an impression of the progress that might be expected in average practice in the future. The estimations of average practice are based on statistical data, data from projects with practicing farmers, and on expert knowledge.

3.3.2 Farm continuity

The results under 'farm continuity' are quantified with the system parameter 'net surplus', which is defined as total revenues minus total costs. For net surplus we focus on the underlying costs to get a picture of the main factors that determine costs. Figure 3.3 shows the economic performance of the three farmtypes that were tested. The economic calculation is based on a farm size of 47 ha for NL INT1 and 28 ha for NL INT2 and NL ORG. The gross revenues are yield times realised price. Fluctuating product prices mainly influenced the fluctuation in the gross revenues. Unfortunately, the average price level in the testing period was very low. This had a negative influence on the economic performance. The costs were included in the costs for own labour (valued against a standard hourly rate) and the interest on capital goods. If these last two cost categories are not included in the total costs, then one arrives at the entrepreneur income (in the case of 100% own capital). The net revenues for the integrated farm types were negative, which resulted in an income per 100 costs of 80 for the NL INT1 and 84 for the NL INT2. This result is



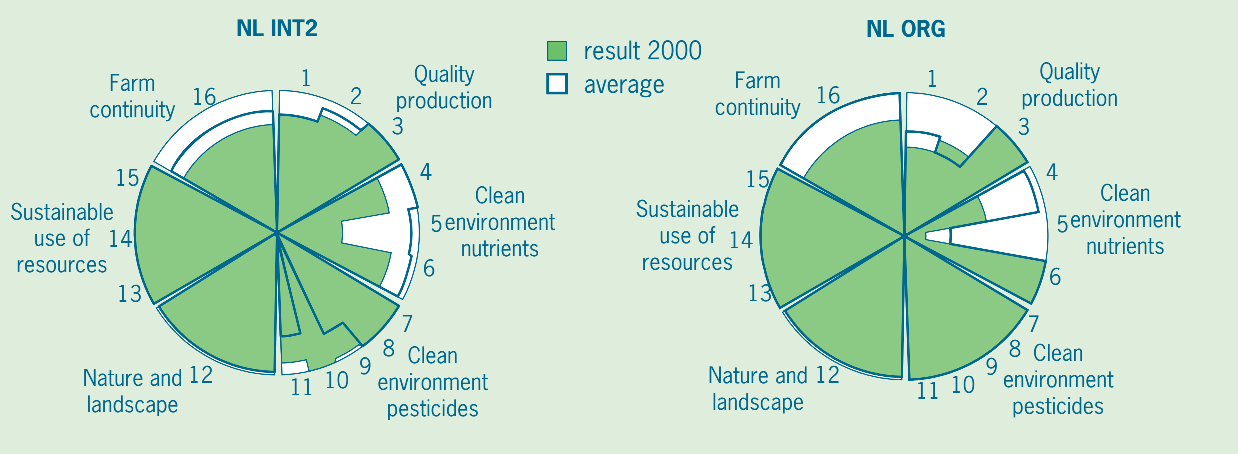


Figure 3.2 Relative realisation (2000 = coloured and average = thick line) of the parameter targets for the systems tested in the Netherlands

comparable to average practice (agronomic statistics and expert knowledge). The organic farm had higher costs per ha (Figure 3.3), but net revenues were still positive because of the high prices paid for organic produce. The compilation of the costs (Figure 3.4) shows that, for these types of farms, the main cost categories are labour (25-32%) and seeds and plants (16-19%). The 4-year average labour input per ha was 139 hours ha^{-1} for NL INT1, 219 hours ha^{-1} for the NL INT2 and 264 hours ha^{-1} for the NL ORG. The differences in input per hour are related to the highly mechanised harvest of Brussels sprouts and the extra labour input for hand weeding in the organic system. The 4-year average input for hand weeding was 9 hours ha^{-1} for the integrated systems and 41 hours ha^{-1} for the organic system. The input needed for hand weeding in the organic system has increased over the years. Together with increasing labour prices, serious attention needs to be given in the coming years to finding ways of dealing with the number of hours spent hand weeding.

3.3.3 Quality production

The results under 'quality production' were quantified by the parameters 'quantity of produce' (QNP), 'quality of produce' (QLP), and the 'nitrate content of leafy crops' (NCONT).

Quantity and quality

Most crops in the integrated systems performed equally well or better with respect to quantity than the regional good yields (GAP, Figure 3.5). The performance of wheat, barley, potato, fennel and celeriac has been stable over the years. The quantity and quality results for iceberg

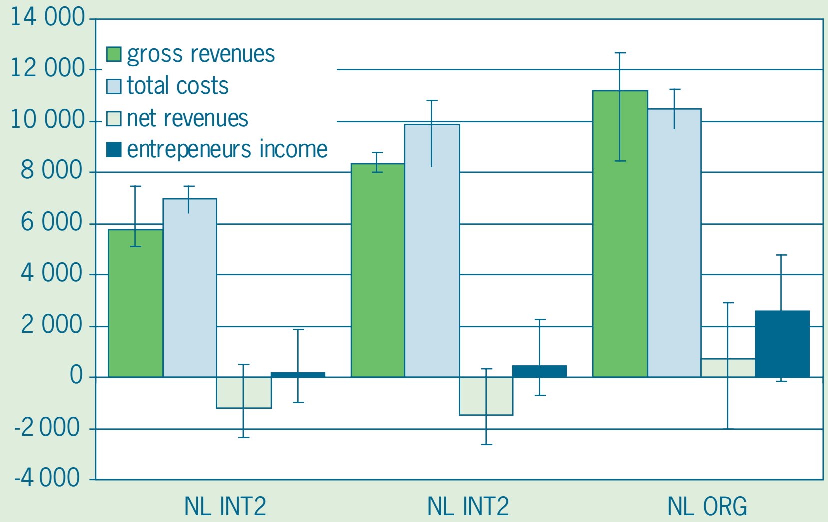


Figure 3.3 Four-year average economic performance of the three tested farm types (€ $farm^{-1}$)

Table 3.2 Absolute target values and realisation (for 2000 and the average for 1997-2000) per parameter

Theme	No	Parameter	Desired results [1]	NL INT1 2000	NL INT1 97-00	NL INT2 2000	NL INT2 97-00	NL ORG 2000	NL ORG 97-00
Quality Production	1	Quantity of produce	1.0 (GAP)	0.96	0.88	0.83	0.83	0.62	0.73
	2	Quality of produce	1.0 (GAP)	0.88	0.90	0.88	0.93	0.71	0.62
	3	N-content produce	< 2500 ppm	952	896	554	966	234	658
Environment Nutrients	4	P_2O_5-balance	1.0	1.06	0.99	1.20	1.00	1.42	1.05
	5	K_2O balance	1.0	1.03	1.02	1.4	1.06	1.85	1.68
	6	N-available reserves	<70 kg ha^{-1}	32	41	83	73	41	47
Environment Pesticides	7	Pesticide a.i. input	6.0; 4.1; 0 kg ha^{-1}	2.5	2.3	2.3	2.2	0	0
	8	Pesticide copper input	0 kg ha^{-1}	0	0	0	0	0	0
	9	Pesticide emission air	0.45; 0.42; 0 kg ha^{-1}	0.66	0.59	0.43	0.51	0	0
	10	Pesticide emission gr. water	0.5; 0.5; 0 ppb	0.01	3.90	0.01	5.17	0	0
	11	Pesticide emission soil	240; 144; 0 kg d ha^{-1}	167	199	156	183	0	0
Nature, landscape	12	Ecological infrastructure index	>5%	4.9	4.9	4.9	4.9	4.9	4.9
Sustainable use of resources	13	Available reserves of P_2O_5	20<Pw-count<30	24	28	29	30	23	28
	14	Available reserves of K_2O	20<K-count<29	22	24	23	24	25	25
	15	Organic matter balance	>1.0	1.42	1.54	1.61	1.73	1.43	1.39
Farm Continuity	16	Income per € 100 cost	> € 100	63	80	75	84	80	106

[1] If the target values are the same for all systems, then one value is mentioned; if there are system-specific target values, three values are mentioned

Table 3.3 Nitrate content in the integrated systems for iceberg lettuce and fennel

System	Crop	Nitrate content (mg kg^{-1} fresh matter) 1997	1998	1999	2000	Average
Int	iceberg lettuce	647	692	566	844	687
Int	fennel	1 870	1 093	930	942	1 209
Org	iceberg lettuce	804	175	626	403	502
Org	fennel	1 547	729	917	65	815

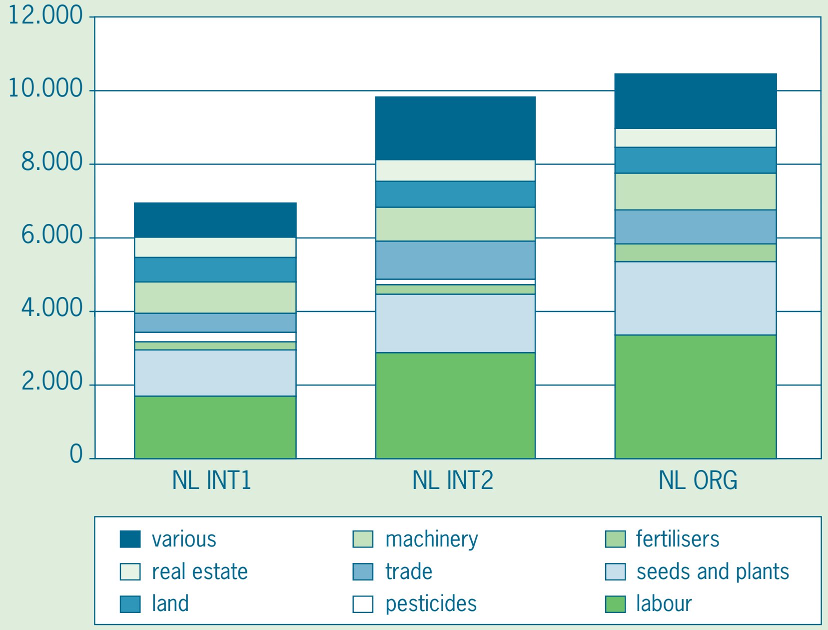


Figure 3.4 Production costs per ha per cost categories for the three tested farm types (€ ha^{-1})

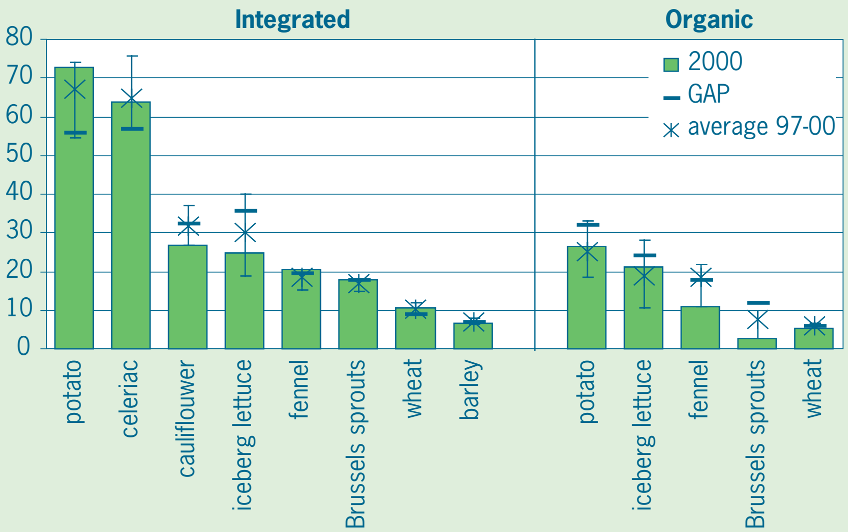


Figure 3.5 Realised quantity per crop in the integrated and organic systems for 2000 (tonnes ha^{-1}); the average is compared with the target quantity

lettuce, and to a smaller extent the quality of Brussels sprouts, have been very variable between years and between cultivations within those years. This variability is partly a characteristic of these crops (susceptibility to weather conditions, pests and diseases), but it is also partly due to insufficient crop protection strategies. The strategy applied in iceberg lettuce and Brussels sprouts was aimed at low pesticide input and emission, but this could not always prevent quantity and/or quality losses.

Yields in the organic systems were much lower than in the integrated systems (Figure 3.5). This was mainly due to fungal diseases in potato, iceberg lettuce and Brussels sprouts. Disease control with 'bio-chemicals' was not used in the organic system. The 4-year average yield for fennel was almost the same in both the integrated and the organic systems. This was mainly due to the absence of noxious organisms for this crop. In some cases, in iceberg lettuce and Brussels sprouts, a secondary reason for lower quantities was insufficient nitrogen availability.

Nitrate content

Iceberg lettuce and fennel are the crops that produce high nitrate contents. As shown in Table 3.3. These crops never exceeded the maximum level of 2500 ppm.

3.3.4 Environment nutrients

The results under 'environment nutrients' were quantified under the system parameters 'nitrogen available reserves at the start of the leaching season' (NAR), and the 'annual balances of phosphate and potash (PAB/KAB).

Nitrogen

The nitrogen fertilisation strategy was aimed at providing optimal nitrogen availability to the crops during crop production and minimising the amount of available nitrogen in the soil at the start of the leaching season. For some crops, the nitrogen availability appeared to be very close to the limits necessary for an optimal crop production.

The nitrogen balance is relatively stable (see Figure 3.6). The variation in off-take and surplus was mainly caused by the flooding of the fields in 1998, which meant that a number of crops could not be harvested. The average nitrogen surplus realised per system was 50 to 70 kg ha-1 lower than the indicative values in average practice.

The available nitrogen reserves (NAR), which represent the leaching risks of nitrogen to the groundwater were, at system level, lower than, or close to, the target level of 70 kg ha-1 (see Figure 3.7). In spite of satisfactory performance at this level, the NAR for individual crops was above target. Lettuce, fennel and early potatoes in the organic system also showed high NAR levels. The wide variation between years for iceberg lettuce and fennel were partly caused by the possibilities for growing a successful catch crop after cultivation. In combination with a catch crop, the

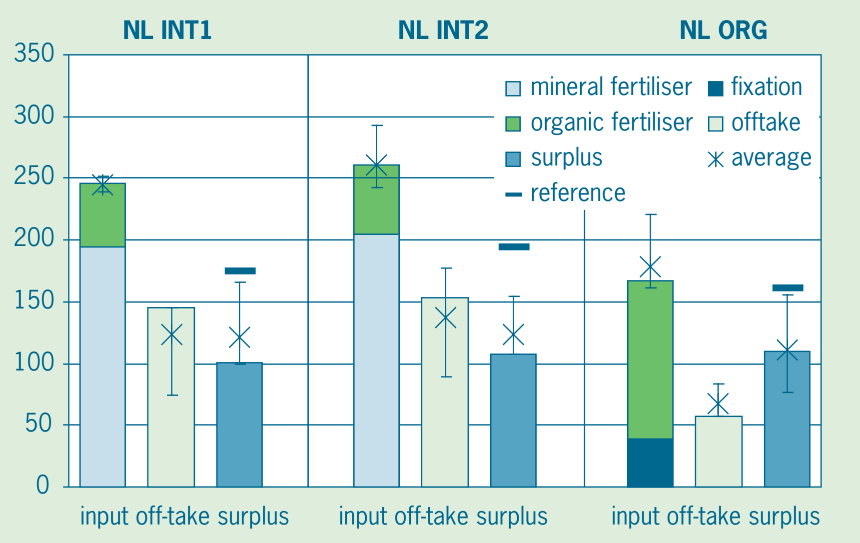


Figure 3.6 Nitrogen balances for the three tested systems (kg ha-1)

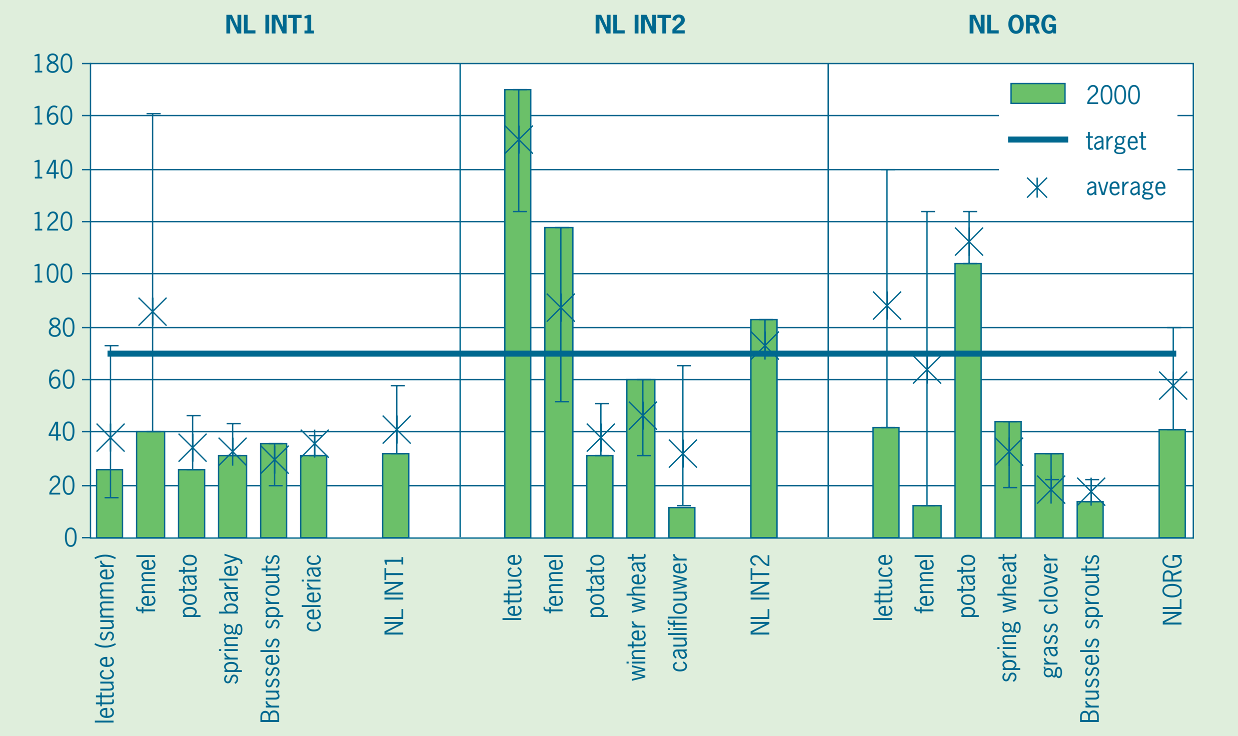


Figure 3.7 Available nitrogen reserves (NAR) per crop and system (kg ha-1)

NAR for lettuce and fennel was 25 - 50% lower than in situations where there was no catch crop. This was the case, for example, after autumn cultivations of fennel and iceberg lettuce, when it was too late in the year to grow a catch crop. The variation between crops, and between cultivation periods within a crop, meant that the performance of a system was very dependent on the crop composition of that system. If a large share of crops like fennel and iceberg lettuce were present in the crop mix, and if there were autumn cultivations of these crops, there would be high NAR at the system level.

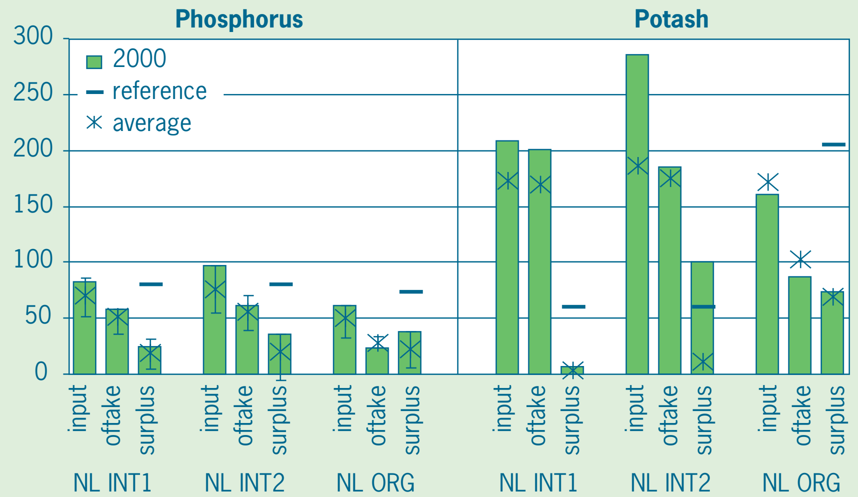


Figure 3.8 Phosphorus (kg P_2O_5 ha^{-1}) and Potassium (kg K_2O ha^{-1}) balances per system

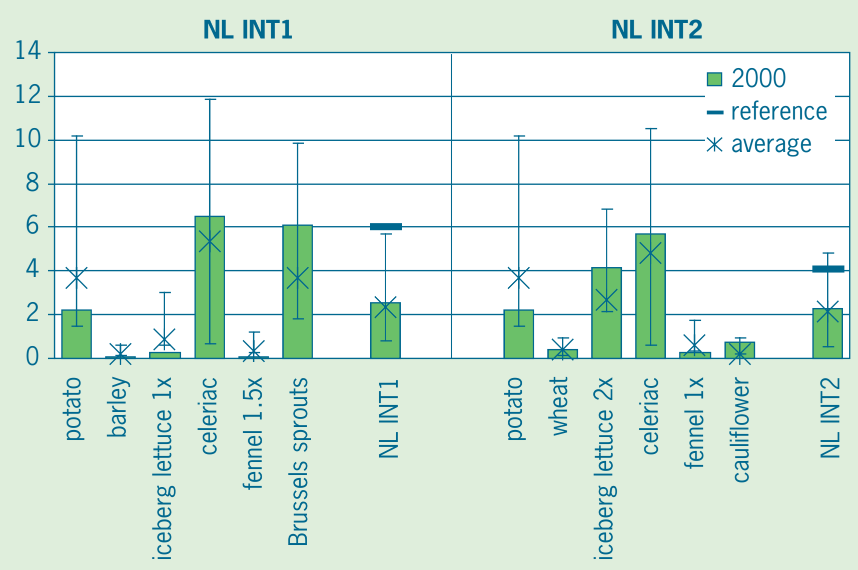


Figure 3.9 Active ingredient input per crop and per system

Phosphate and Potash

Phosphate and potash balances at system level cannot be evaluated without taking the phosphorus and potash reserves into account. For all systems, phosphorus and potash reserves were within the desired range (agronomically sufficient and environmentally acceptable, see Figure 3.10). In this case, the strategy at system level was aimed at an input that equaled off-take for potash and an input that equaled off-take + 20 kg ha^{-1} of unavoidable losses for phosphate. This balance was based on the total cropping plan. The yearly phosphate and potash fertilisation was crop based and directed at the crops with high demands for phosphorus and potash. For example, phosphate fertilisation preceded early crops and potash was applied before potatoes. In the integrated systems, this strategy was applied successfully for both potash and phosphate (see Figure 3.8). The 4-year average surplus in both systems was close to 20 for P_2O_5 and to zero for K_2O. There were no indications that the phosphorus and potash fertilisation strategy had a negative influence on production quality.

Because of the exclusive use of organic fertilisers, such a balance, for either phosphate or potash, is difficult to realise in an organic system. Priority was given, and achieved, to balancing phosphate in the organic system. The K_2O surplus — 70 kg ha^{-1} — was above the desired level. In all systems, the actual surplus was considerably lower than the surplus estimations in average practice.

3.3.5 Environment Pesticides

The results under 'environment pesticides' were quantified by the system parameters 'pesticide active ingredient input' (PESTAS) and 'environment exposure to pesticides' (EEP), a measure for the three environment compartments: air, soil and groundwater.

Pesticide input

The targets for pesticide input at system level (50% reduction of the input in average practice) were amply reached (see Figure 3.9). However, the inputs of active ingredients varied significantly between different crop cultivations. Celeriac, Brussels sprouts and iceberg lettuce contributed strongly to the inputs of active ingredients. For iceberg lettuce, this was mainly due to the break-through brought about by the cultivation of the resistant strain Bremia lactucae, and to aphid control. For celeriac, it was due to the absence of a good prevention strategy for Septoria apiicola and to the non-availability of low input, but effective, pesticides for this disease. No pesticides were used in the organic system.

Pesticide emission

In both system variants, the realisation for EEP-air was close to the target (reducing emission by 70% of the levels found in current practice) due to low pesticide inputs and a careful selection of pesticides (see Table 3.4). More than 65% of emissions to the air came from Fluazinam, used against Late Blight in potatoes, and thiomethone, used for aphid control in Brussels sprouts. There are no better alternatives available at the moment. The leaching risks in EEP-groundwater, as quantified in the year 2000, (see Table 3.4) amply meet the target of 0.5 ppb. From 1997 to 1999 the target level was greatly exceeded, because of the use of maneb fentinacetate to protect celeriac crops against Septoria apiicola. In 2000, this product was replaced by chlorthalonil, which significantly lowered the risk of leaching.
Regarding emission risks to the soil (accumulation) the target of a reduction in emissions of 70% of that in conventional practice was almost met. The highest emission, (50%) in EEP-soil, came from the use of Fluazinam (Shirlan) on potato crops.

3.3.6 Nature and landscape

The results under 'nature and landscape' are quantified in system parameters that indicate the presence of the right circumstances for the development of an attractive landscape and varied nature. The methodology for quantifying the potential for on-farm nature values is still being developed. The Dutch experimental systems (both organic and integrated) were on too small a scale to test and improve the resulting methodology. Instead, the total farm level — the total number of farms included in the experimental system — was used to test the methodology and quantify the results.
The methodology developed and the resulting improvements in nature and landscape are described in the Vegineco publication: Manual on ecological infrastructure management. The main improvements were that an extra 4.9% of the farm surface was gained for ecological infrastructure to connect nature elements and to act as buffer zones to protect them.

3.3.7 Sustainable use of resources

The parameter used for this topic in the Vegineco project was 'energy input', and also a number of soil-fertility parameters. At the time of the project, energy input was a new parameter, and it had only been established at crop level (see Section 2.4). The soil-fertility parameters used to quantify system performance were 'available phosphate and potash reserves' (PAR/KAR) and the 'organic matter balance' (OMAB).

Phosphate and potash reserves

The response of available phosphorus and potash reserves in the soil to fertilisation is slow, and the year to year variation of these parameters can be substantial. For this reason, the 4-year project period was too short to make a valid judgement of the effect of the fertilisation strategy on the level of these parameters. At the start of

Table 3.4 Realisation of parameters related to pesticide use and emission

	no.of applications no ha^{-1}	a.i. input kg ha^{-1}	EEP-air kg ha^{-1}	EEP-ground-water ppb	EEP-soil kg days ha^{-1}	EYP-surface water no. appl. > 10
NL INT1						
Conventional: 2000	21.8	11.9	1.5	6.23	801	13
Realisation: 1997	12.9	3.3	0.6	5.98	250	10
Realisation: 2000	10.1	2.5	0.7	0.01	167	6
Vegineco target	-	5.9	0.5	0.50	240	0
% reduction in 2000-conventional	54	79	57	99.9	79	54
NL INT2						
Conventional: 2000	19.0	8.1	1.4	8.01	479	9
Realisation: 1997	9.8	2.6	0.7	7.96	217	6
Realisation: 2000	8.2	2.3	0.4	0.01	156	4
Vegineco target	-	4.0	0.4	0.50	144	0
% reduction in 2000-conventional	57	72	69	99.9	67	58

the experiment, the levels of reserves of available phosphorus and potash were within the desired range. The fertilisation strategy was aimed at maintaining these levels. During the project period, the levels of available phosphorus and potash reserves stayed within, or just above, the desired range (see Figure 3.10) In the year 2000, however, the level of available reserves was lower than in the other years. Taking into account the year-to-year variability of these parameters, there is no conclusive evidence of a decrease in available nutrient reserves.

Balance of organic matter

The strategy for organic input was to compensate at least the estimated losses of effective organic matter in the soil. Such losses are difficult to assess, but an estimation was made using the standard figure for respiration in clay soil, which is 2.5% of the total organic matter in the plough layer. The input of effective organic matter in both systems more than met the target (see Table 3.11). The biggest input of effective organic matter was from the residues of vegetable crops and the straw from cereal crops. A surprising, but substantial, input in these vegetable systems came from the peat pots used during planting.

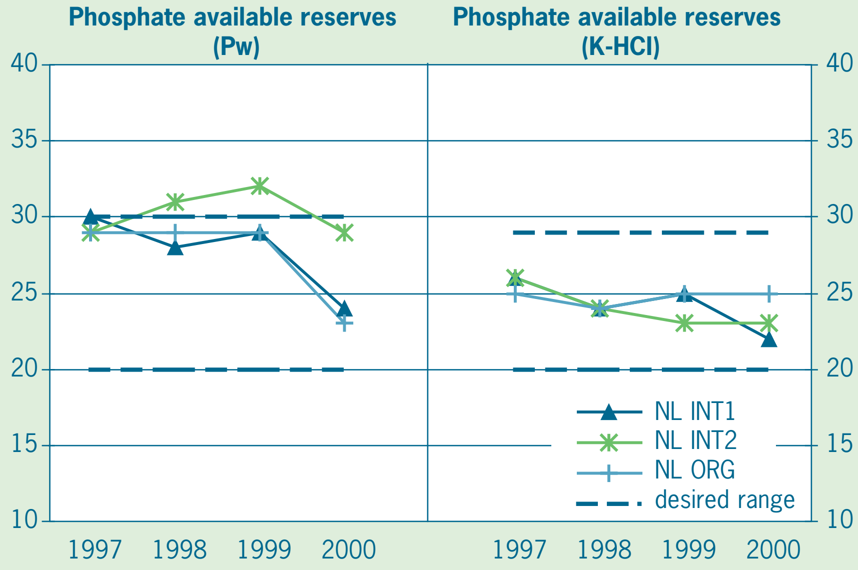


Figure 3.10 Available phosphate (Pw) and potash (KHCl) reserves, averaged over all fields from 1997 to 2000

3.4 Discussion and conclusions

Comparing the performance of the tested integrated and organic farming systems with the all-round

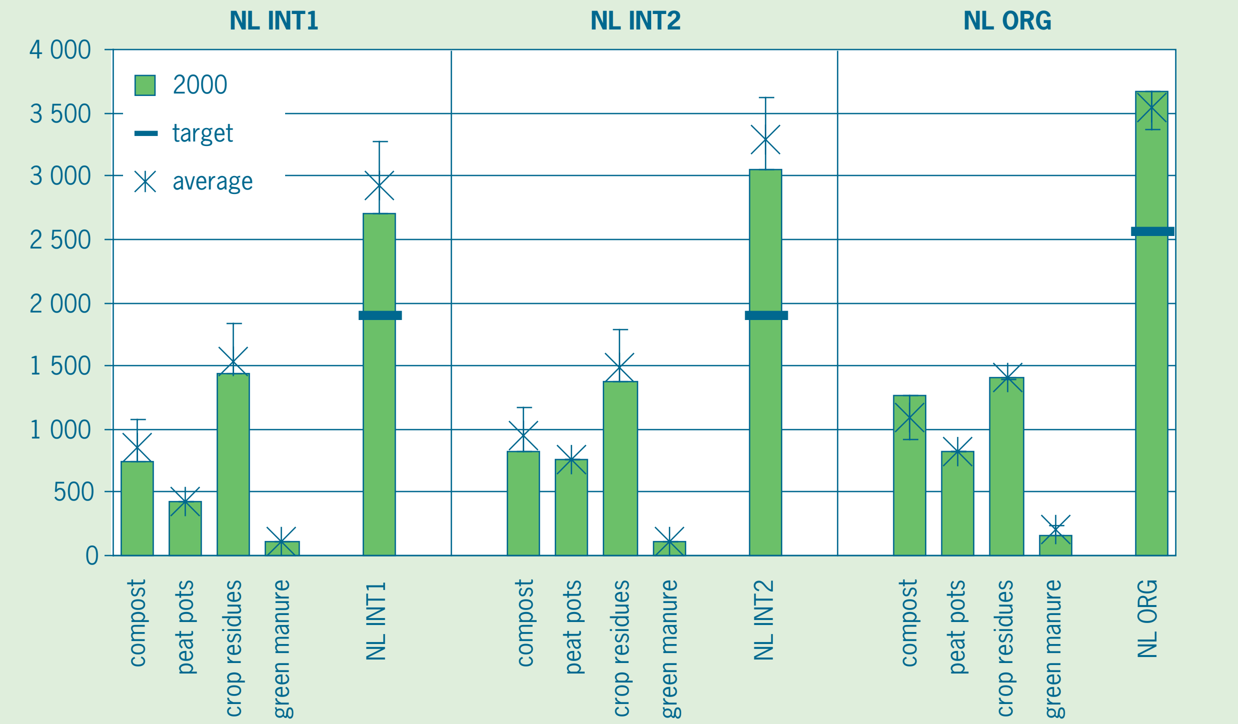


Figure 3.11 Balance of organic matter in the three systems tested (kg ha-1)

sustainable target system, the following conclusions can be reached:

1. The economic performance of the integrated systems is insufficient.
2. For specific crop/disease combinations, chemical crop protection still leads to high emissions of pesticides.
3. The quality of production in the organic system is insufficient.

Comparing the performance of the tested integrated farming systems with that of conventional practice, the following picture arises:

1. Large reductions can be made in the use and emission of nutrients and pesticides.
2. Yields and economic results are comparable to average practice.
3. Cost reductions of pesticide or fertiliser inputs can be substantial compared to the same cost categories in conventional practice, but they are marginal compared to the total costs.

To improve and implement integrated farming systems, a key factor that needs to be addressed is the shortfall in economic performancein this system. Farmers are reluctant to convert to integrated farming, because this requires investments in knowledge and machinery. Their income is already very low and the risks of yield losses in vegetable production are high.
Possible options to encourage farmers to take this step are cost reductions, increases in yields, price increases, or a basic reward for acting in the public interest. The last two options are outside the scope of this research, but they could be an important aid to furthering sustainable vegetable production.

The necessary improvement in the performance of the systems tested is dependent on technical innovations. The availability of resistant varieties, the improvement of techniques and mechanisation, better knowledge of the epidemiology of pests and diseases and, as a last option, a broad spectrum of low emitting and safe pesticides could contribute to further improvements in sustainability. The basic choice of not using 'bio' pesticides in the organic system might have influenced production quality in the Dutch organic system, and whether 'bio'-pesticides should be used or not remains questionable. The focus for organic farming systems has to be on prevention rather than control, but the development of indisputable means of 'biological' control could help to solve the problems that remain.

4 A practical case in Emilia-Romagna (Italy)

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4.1 Introduction

Italy has developed three farm systems, two integrated systems and one organic, all of them located in the eastern part of the Emilia-Romagna (ER) region, on loam and clay soils. About 55 000 ha of outdoor vegetables are cultivated in ER. The main vegetable crops grown on a large scale in this region are tomatoes for the food industry; potatoes, onions, melons and outdoor vegetables for the frozen foods industry; and other outdoor vegetables of minor importance. Fresh market crops such as strawberries, lettuce, celery, fennel and green beans are also important, but are generally cultivated on a smaller scale. In ER, there are three main kinds of outdoor vegetable farms: specialised farms (2-3 ha) growing vegetables for the fresh market, larger farms (15-20 ha) growing vegetables for industry in addition to arable crops; and farms (8-10 ha) growing vegetables for the fresh market in addition to arable crops. During the last year of the project, integrated and biological products gained in importance on the market. For this reason, a lot of effort was devoted within the project to verifying and improving the application of these farm practices on outdoor vegetable farms that, until then, had not followed the year 2078 guidelines for integrated and organic production. Economic factors such as low revenues and excessive bureaucratic restrictions had hitherto acted as a deterrent to following the guidelines on these farms.

4.2 Crops and Rotations

Three types of rotations, two aimed at fresh market crops (integrated and organic systems) and one for the integrated production of arable crops and outdoor vegetables for industry, were tested in ER. The choice of crop in the three systems was based how important they were on the market and how likely they were to perform well enough to create a sustainable agronomic rotation scheme.

4.2.1 Integrated systems

The integrated farm systems 'integrated fresh market' (I INT2) in Cesena, and 'integrated industry' (I INT1) in Ravenna, determined which two rotations to choose because these two farm types typically differ in size and specialization (although melon and green beans are common to both systems).

4.2.2 The organic system

In this system, a rotation similar to I INT2 was designed. The only difference was that fennel was included, instead of celery. The rotation of this system (I ORG) was changed at the end of the first year (by eliminating cauliflower and spring lettuce) because it was found to be too intensive to meet the targets set for nutrient management. The final rotation scheme is shown in Table 4.1.

4.3 Results

Overview of results

For the integrated systems (see Figure 4.2 and Table 4.2), the most important remaining shortfall can be found

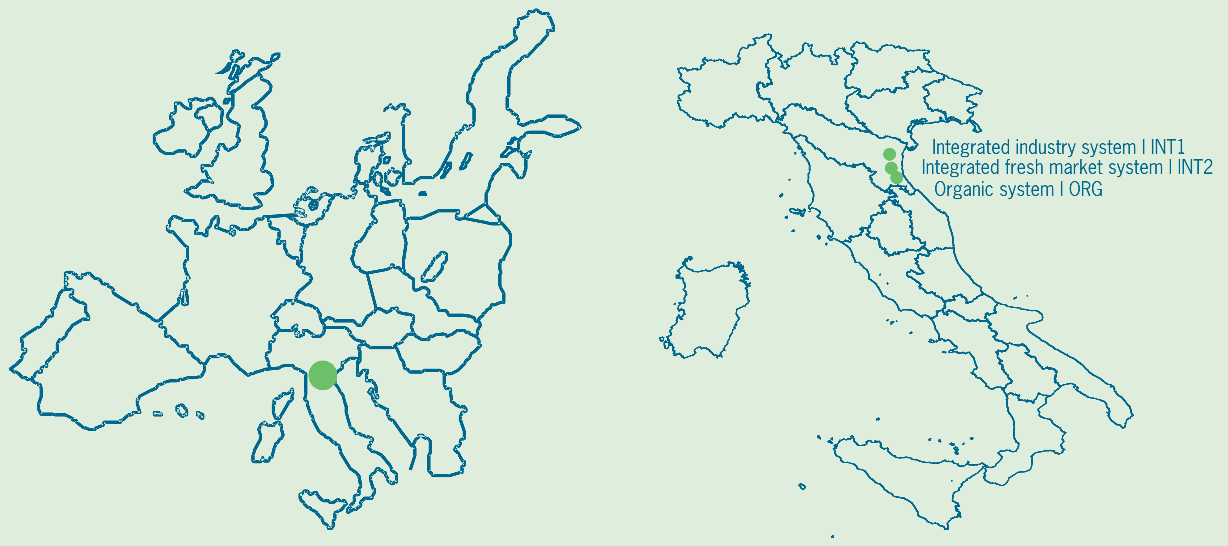


Figure 4.1 Location of the experimental integrated and organic vegetable farming systems in Italy

Table 4.1 The general scheme for organic and integrated rotation types in Italy

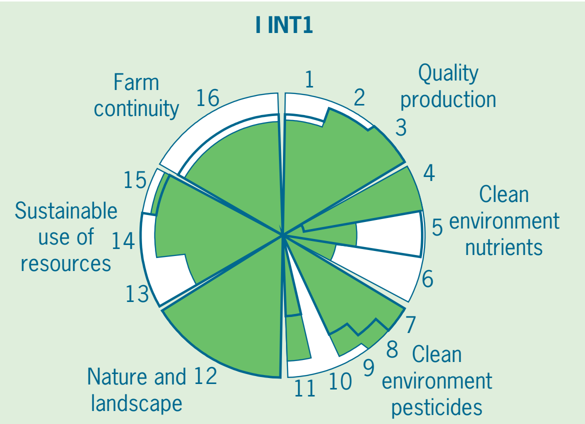
Year/ block	I INT1 Integrated Industry	I INT2 Integrated Fresh Market	I ORG Organic Fresh Market
1	Spinach (h) Tomato Wheat (pl/s)	Lettuce, spring Lettuce, summer Lettuce, autumn	Green beans Fennel
2	Wheat (h) Green beans	Green beans Strawberry (pl/s)	Melon
3	Sugar beet	Strawberry (h) Celery	Strawberry (pl/s)
4	Melon Spinach (pl/s)	Melon Cauliflower	Strawberry (h) Lettuce, summer Lettuce, autumn

Catch crops are excluded, pl/s = year of planting/sowing, h = year of harvest

in the income per 100 costs (farm continuity; 16) and the risks of nitrate leaching, as quantified by the available nitrogen reserves (environment nutrients; 6).
In I INT1, the emission of pesticides to groundwater (environment pesticides; 10) was far too high. In the course of the four test years, great progress was made within most of the parameters 'environment nutrients' and 'pesticides', with no negative effects on farm continuity and quality production.
In the organic system, inspite of the progress made, the main shortfall was nutrients. Soil reserves of phosphorus and potash (parameters 13 and 14) as well as the phosphorus balance and available nitrogen reserves were all too high.
In the following paragraphs we will focus on the results for the different themes.

4.3.1 Farm continuity

The results under 'farm continuity' were quantified by using the system parameters 'net surplus' or 'income per € 100 costs'. The target was met in the organic system, but in the two integrated systems the income did not cover the total costs (see Table 4.3).
During the final years of the project, good quality production was achieved in I INT2 (except for celery in 1999), but the gross margin (income–total cost) was still



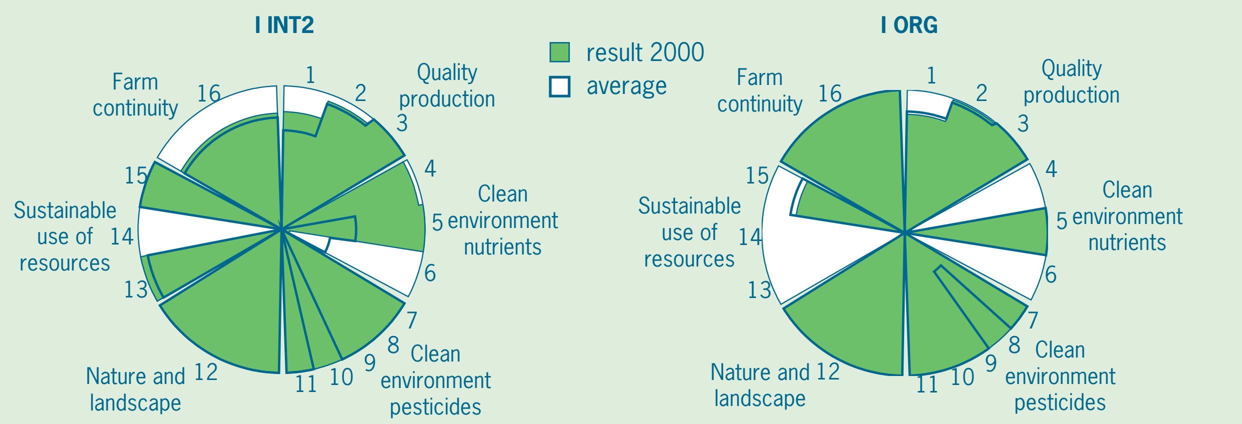


Figure 4.2 Relative realisation (for year 2000, and on average) of the parameter targets for the organic and integrated systems in Italy

Table 4.2 Absolute target values and their realisation (in 2000, and in 1997- 2000) per parameter

Theme	No	Parameter	Desired results[1]	I INT1 2000	I INT1 97-00	I INT2 2000	I INT2 97-00	I ORG 2000	I ORG 97-00
Quality	1	Quantity of produce	1.0 (≥GAP)	0.81	0.85	0.82	0.69	0.83	0.85
Production	2	Quality of produce	1.0 (≥GAP)	0.95	0.95	0.95	0.93	0.99	0.97
	3	N-content of produce	<2500 ppm	166	554	560	928	495	689
Environment	4	P_2O_5-balance	1.0; 1.0; ≤1.0	1.00	1.85	1.03	3.01	1.95	2.72
Nutrients	5	K_2O-balance	1.0; ≤1.0; ≤1.0;	0.48	0.98	0.14	0.74	0.27	0.61
	6	Available N-reserves	<45; <70; <70; (kg ha^{-1})	73	115	136	116	146	207
Environment	7	Input of a.i. from pesticides	<3.1; <5.4; <0.5 (kg ha^{-1})	1.40	2.09	3.61	3.22	0.03	0.37
Pesticides	8	Input of copper from pesticides	<1.0; <1.0; <0.5 (kg ha^{-1})	0.24	1.12	0.21	0.61	0.38	0.83
	9	Pesticide emission into air	<0.35; <1.07; <0.20 (kg ha^{-1})	0.37	0.43	0.52	0.75	0.01	0.09
	10	Pesticide emission into gr. water	<0.5 ppb	8.99	9.17	0.00	10.12	0.00	0.00
	11	Pesticide emission into soil	<130; <299; <25 (kg days ha^{-1})	145	186	95	185	0	3
Nature, landscape	12	Ecological infrastructure index	≥5%	11.1	11.1	8.3	8.3	9.5	9.5
Sustainable use	13	Available P_2O_5 reserves	30-35; 35-40; 35-40	21	30	35	42	156	181
of resources	14	Available K_2O reserves	120-180; 144-216; 144-216;	108	132	388	419	480	545
	15	Balance of organic matter	≥1.0	0.94	0.90	1.13	1.32	0.77	0.81
Farm continuity	16	Income per € 100 costs	≥ € 100	80	85	81	78	147	106

[1] If the target values are the same for all systems, one value is mentioned; if there are system-specific target values, then three values are mentionend

negative. In this farm type, significant cost reductions could be realised, if hand labour could be reduced. However, to reduce costs by using more machinery is not very practicable for farms as small as these, and, in general, small-scale mechanisation is not available.
In I INT1, the economic result is similar that of I INT2 system. The input and costs of machinery (also involving third parties) are more important than hand labour costs. The economic results of this system could probably be improved by enlarging the scale of the farm (to reduce machinery costs ha^{-1}). Green beans, tomato (except in 2000) and spinach were very profitable, but the melon crop (except in 1997) brought large losses due low production and a market crisis for this crop.
The positive net surplus in the organic system is mainly due to good market trends for biological products. The average price of organic produce is 30-40% higher than produce from the conventional and integrated systems. Melon was overvalued, even, by 400%, compared to conventional and integrated produce. This market situation remained constant during the four years of the Vegineco project and future perspectives are good because the demand for these products is increasing and there is keen interest from the GDO.

4.3.2 Quality production

The results under 'quality production' were quantified by the system parameters 'quantity of produce' (QNP), 'quality of produce' (QLP), and the 'nitrate content of leafy crops' (NCONT).

Quantity and quality

In the organic system (I ORG), the quantity and quality of the production was generally satisfactory. The crops that

Table 4.3 Financial results of the farm models

	Dimension	I INT2 2000	I INT2 4-year average	I ORG 2000	I ORG 4-year average
Surface farm	Ha	4	4	4	4
Gross revenues	€	80 040	69 783	120 964	97 492
Total direct costs	€	93 334	84 147	75 540	85 009
Labour income	€	-13 294	-14 391	45 424	12 484
Net surplus	€	-19 034	-19 774	38 429	5 252
Labour input	Hours	5 387	4 585	4 503	5 324
Income per 100 costs		81	79	147	107

Table 4.4 Actual quantity (in tonnes fresh matter ha-1) per crop in the organic and integrated systems in 1997, 1998, 1999 and 2000, compared with target quantity

Crop	1997		1998		1999		2000		Target	
	Yield ton/ha	Quality %class 1	Yield ton/ha	Quality %class 1	Yield ton/ha	Quality %class 1	Yield ton/ha	Quality %class 1	Yield ton/ha	Quality %class 1
I INT1										
Tomato	65.9	5	85.6	5	71.4	5	62.2	4	55.0	5
Wheat	-	-	7.9	78	7.4	74	5.4	74	8.0	80
Greenbeans	7.4	90	5.2	89	3.4	100	4.3	100	8.0	90
Sugarbeet[1)]	33.0	17	46.5	18	54.7	18	59.4	17	50.0	16
Melon	32.4	60	20.1	77	18.6	73	22.2	79	30.0	85
Spinach	-	-	18.2	98	16.5	97	13.1	98	14.0	90
I INT2										
Lettuce early	0.5	100	26.0	100	31.0	75	25.8	98	28.0	100
Lettuce sommer	3.5	100	16.4	90	27.0	76	21.1	79	32.0	100
Lettuce autumn	3.8	100	21.2	99	21.7	68	14.8	100	28.0	100
Greenbeans	0.0	0	5.3	86	7.6	88	4.9	86	8.0	90
Strawberry	-	-	24.9	73	27.6	71	31.7	77	30.0	80
Celery	44.8	90	35.3	92	0.0	0	54.7	100	55.0	90
Melon	27.3	76	29.5	69	21.0	66	25.2	81	30.0	75
Cauliflower	19.3	100	16.7	91	14.4	99	26.0	97	25.0	85
I ORG										
Lettuce early	13.5	100	-	-	-	-	-	-	25.0	100
Lettuce summer	31.4	100	21.3	100	31.1	90	30.8	95	28.0	100
Lettuce autumn	18.8	100	12.3	100	11.3	59	14.1	100	25.0	100
Greenbeans	6.5	95	7.6	93	5.8	100	5.8	90	7.0	90
Strawberry	14.0	85	12.3	100	20.4	90	10.3	99	18.0	90
Fennel	20.3	64	20.4	100	17.8	99	24.2	95	20.0	70
Melon	34.1	77	62.4	77	51.0	71	48.4	84	30.0	80
Cauliflower	33.8	94	-	-	-	-	-	-	30.0	90

[1)] quality sugarbeet expressed as sugar content instead of % class 1

suffered poor harvests were autumn lettuce, due to problems with Bremia lactucae, and strawberry, because of spring frosts during flowering in 1997 and 1998 and a high percentage of dead plants in 2000. This unexpected loss of strawberry plants was caused by crop residues from the preceding catch crop, which produced toxic substances while decomposing. Melon was the crop that achieved the best results for QLP and QNP during the project. A contributory factor was that this crop adapted itself very well to organic farm practices.
In the integrated fresh market system (I INT2), QNP values were below target levels, mainly because previous farm management had negative effects on the soil structure and on weed control options. However, production quality improved during the testing years. QLP values remained at a reasonable level, but lower than the target. In all three cycles, lettuce was problematic during the first year, despite a normal input of fertilisers. It was not possible to adapt green beans and celery to the integrated systems of the project.

Throughout the testing period, both crops had difficulties in reaching their targets for QNP. Celery was particulary susceptible to disease (Septoria apiicola), so badly, in fact, that the crop was completely lost in 1999.
In the Integrated Industry System (I INT1), tomato and spinach produced consistently high QNP and QLP values, as did sugar beet in 1999 and 2000. QNP

Table 4.5 Nitrate content (ppm) for some crops, target value (maximum) is 2500 ppm

System	Crop	1997	1998	1999	2000
I INT1	Spinach	-	1049	446	166
I INT2	Celery	2526	1871	158	365
I INT2	Lettuce	303	987	462	754
I ORG	Fennel	133	898	565	395
I ORG	Lettuce	1335	1161	432	596

values were low for melon and green beans, however, due to unfavourable weather conditions which caused irregular growth and flower abortion.

Nitrate content

The nitrate content was assessed for leaf vegetables.

The target was fixed at 2500 ppm. However, during the project, only in the first year two crops (summer lettuce in I ORG, and celery in I INT2) did have a level higher than the target. In all other situations, the nitrogen content values were below target.

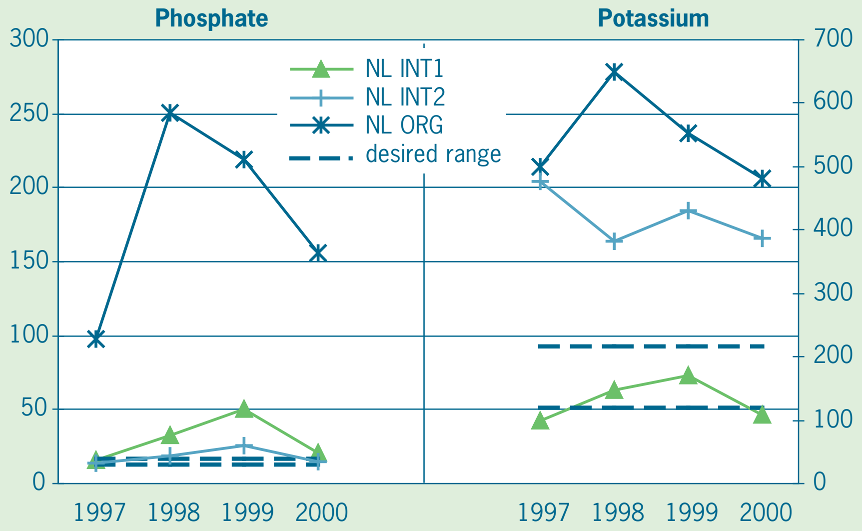


Figure 4.3 Available phosphate and potash reserves in the soil in relation to the desired range present (mg P_2O_5 kg^{-1} soil and mg K_2O kg^{-1} soil)

4.3.3 Sustainable use of resources

The parameters on this topic used in the Vegineco project were 'energy input' and a number of soil-fertility parameters. Energy input was a new parameter, developed within the project, and so it had only been established at that point at crop level. The soil-fertility parameters used to quantify the performance of a system were 'available reserves of phosphate' and 'available reserves of potash' (PAR/KAR) and the 'balance of organic matter' (OMAB).

Phosphate and potash reserves

A desired range of soil reserves was defined for the Italian test areas, taking into account availability and the agronomic and

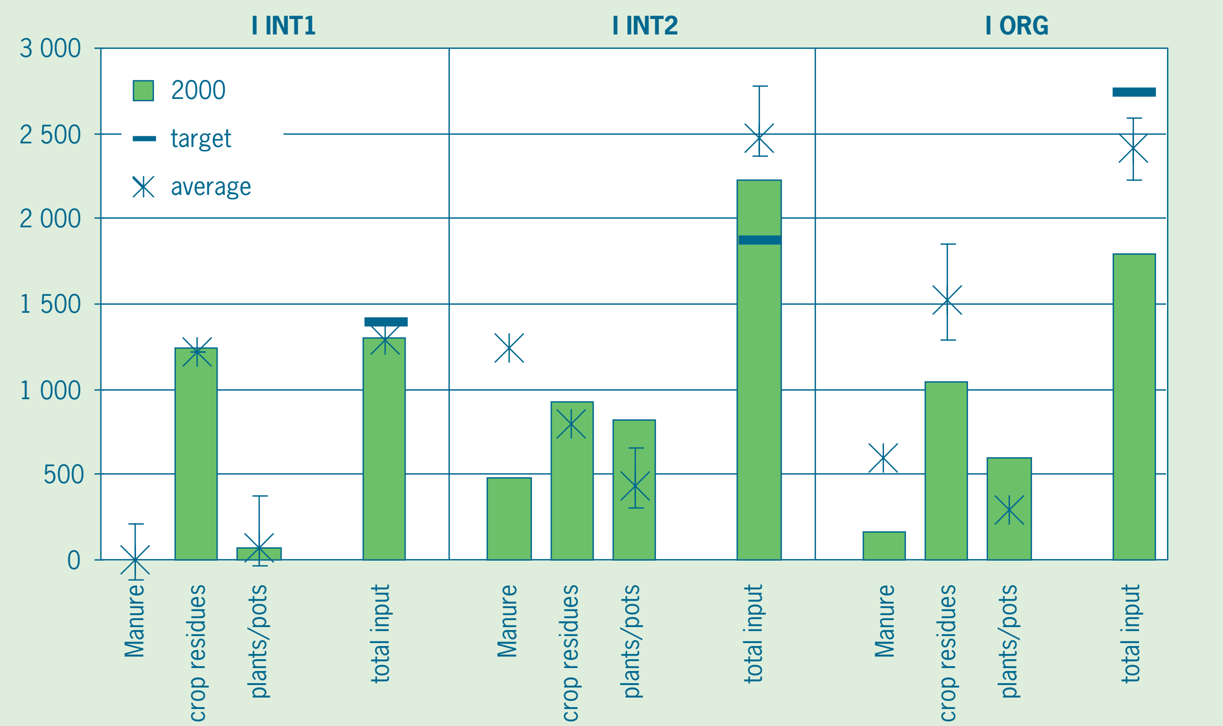


Figure 4.4 Input of effective organic matter (kg ha^{-1}) from different sources compared with the target (= estimated loss of organic matter)

environmental consequences. The fertilisation strategy aimed at achieving these target ranges in the long term. In practice, the soil analysis data (see Figure 4.3) actually taken for these two elements varied greatly. However, the general picture is one of very high soil reserves of both phosphorus and potash in the organic system and very high soil reserves of potash in I INT2. In I INT1, both phosphorus and potash reserves were approximately within the desired range. The high level of soil reserves in the organic system was due to a history of fertilisation with organic manure as is frequently the case in outdoor vegatable production. Consequently, surpluses of phosphorus and potash should be lower than zero in the organic system, and the potash surplus should be lower than zero in I INT2. In I INT1, phosphorus and potash fertilisation could balance (input = off-take). The extent of the success of this strategy can be found in the paragraph on 'environment nutrients'. Because nutrient reserves were expected to decline slowly and as the measurements varied greatly, it was virtually impossible within the testing period to measure the effect of this strategy on soil fertility.

Organic matter balance

Relatively little is known about the optimal content of organic matter in soil, and its composition (type, activity). There are no practice- oriented analytical techniques to establish the compostion of organic matter in soil. With these restrictions, the target set for organic matter content in soil was in line with a strategy to keep it at

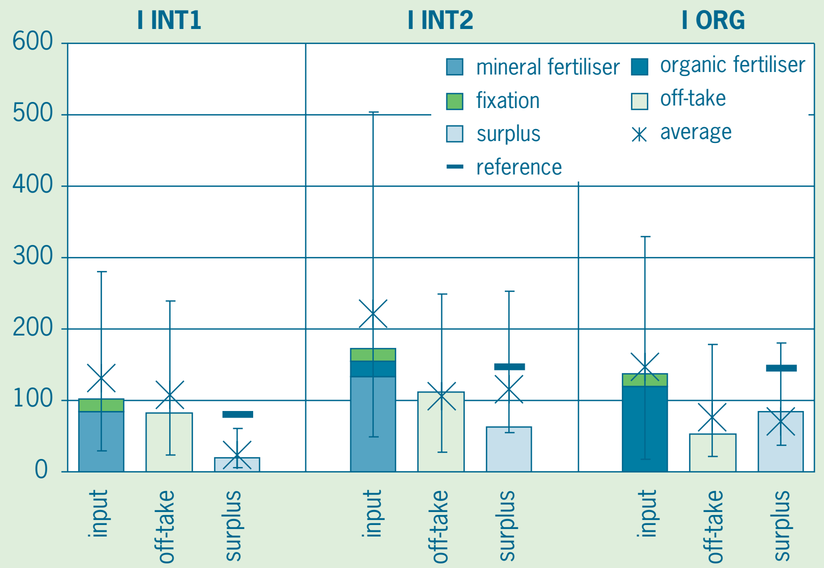


Figure 4.5 Nitrogen balance (excluding deposition) for organic and integrated systems in Italy (kg ha-1)

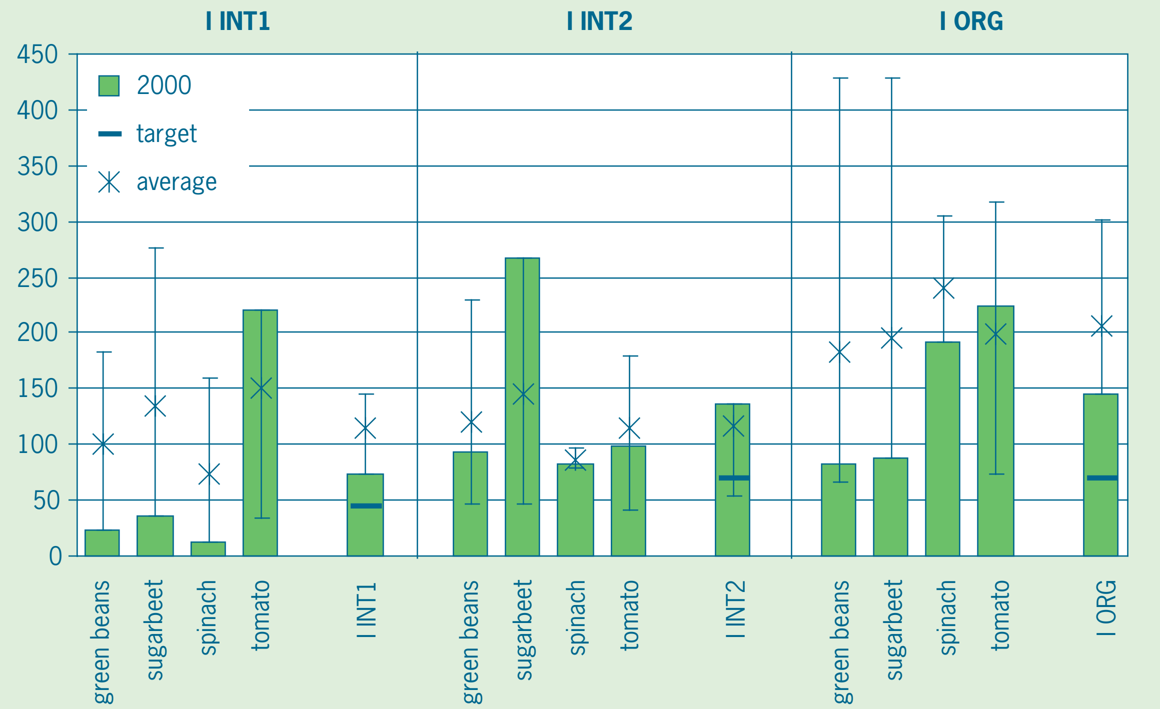


Figure 4.6 Available nitrogen reserves at the start of the leaching season (NAR) per crop and per system (kg ha-1)

least on the same long-term level. This meant achieving a balance between the input of effective organic matter and the estimated loss of organic matter through respiration. The results of this strategy can be found in Figure 4.4. In particular, in the organic system, the necessity of reducing the phosphorus and potash input and the need to reduce uncontrolled nitrogen mineralisation conflicted with this target (see next paragraph).
The objective of maintaining the organic matter content in the soil was not completely reached in I INT1 and I ORG. In I INT2, a surprisingly high input of effective organic matter came from the peat pots in which the seedlings were planted (see Figure 4.4). In I ORG, the low input of effective organic matter from manure was due to the use of commercial organic fertilisers, which had a good N-P-K ratio, but a low organic-matter content.

4.3.4 Environment nutrients

The results under 'environment nutrients' were quantified by the system parameters 'available nitrogen reserves at the start of the leaching season' (NAR), and the 'annual balances phosphate and potash' (PAB/KAB).

Nitrogen

During the first year, there was a large surplus in the nitrogen balance, especially in the fresh market systems. From the second test year onwards, strategy changes (see I/ENM manual) and the use of actual off-take data (from analysis) led to big improvements in the nitrogen balance. Compared with the average conventional and integrated farm, the total reduction of nitrogen input and surplus was considerable (see Figure 4.5). The adoption of a restrictive fertilisation strategy did not seem to influence production quality. The project was too short, however, to permit definitive conclusions in this respect. Even though the nitrogen surplus was reduced, the risks from nitrate leaching were still too high. Measurements of nitrate concentrations in the soil solution for I INT2 showed autumn levels of over 300 ppm. In the last test year, available nitrate reserves exceeded the target level in all the systems (see Figure 4.6). During the course of the project, the NAR levels, in particular, were strongly reduced in I INT1 and I ORG. The contributory factors here were surely the reduction of the nitrogen surplus and the use of catch crops. Nevertheless, the nitrogen fertilisation strategy needs to be improved further. One possible step towards further progress in this area might be to improve the temporal match between crop demands for nitrogen, and nitrogen availability in the soil. One of the obstacles, though, will be the high rate of mineralisation, as observed in I INT2 and I ORG.

Phosphate and potash

The evaluation of the reserves of nutrients in the soil in the different systems resulted in the following range of desired balances per system:

- I INT1 system: PAB = 1 → P surplus = 0; KAB = 1 → K surplus = 0
- I INT2 system: PAB = 1 → P surplus = 0; KAB $<$ 1 → K surplus $<$ 0
- I ORG system: PAB $<$ 1 → P surplus $<$ 0; KAB $<$ 1 → K surplus $<$ 0

The high surplus in phosphate fertilisation at the start of the testing period was strongly reduced for all systems. Compared to avarage practice, however, the actual phosphorus surplus in the tested system is considerably lower. Taking into account some unavoidable losses and the natural fluctuations in phosphorus off-take, the remaining surplus in I INT1 and I INT2 was acceptable. For the organic system, it was hardly possible to achieve a phosphorus surplus lower than zero, because of the fixed amounts of nitrogen, phosphorus and potash in organic fertilisers. For Potash fertilisation, in all systems again showed a large reduction in the potash surplus during the course of the testing years. Figure 4.7 shows that, in I INT2 and I ORG, the potash surplus was in line with the strategy. For I INT1, a negative surplus was achieved on average, also in 2000, whereas a zero surplus would have been more appropriate. This was mainly due to strongly fluctuating analysis data for soil reserves and crop content. In contrast to phosphorus surplus values, potash surplus in average farming practice was not excessively high.

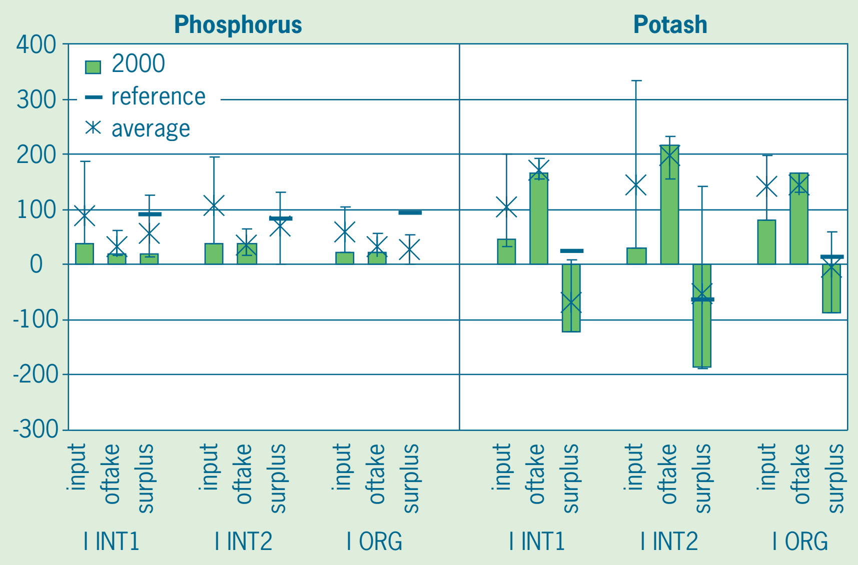


Figure 4.7 Phosphate (kg P_2O_5 ha^{-1}) and potash (kg K_2O ha^{-1}) balances

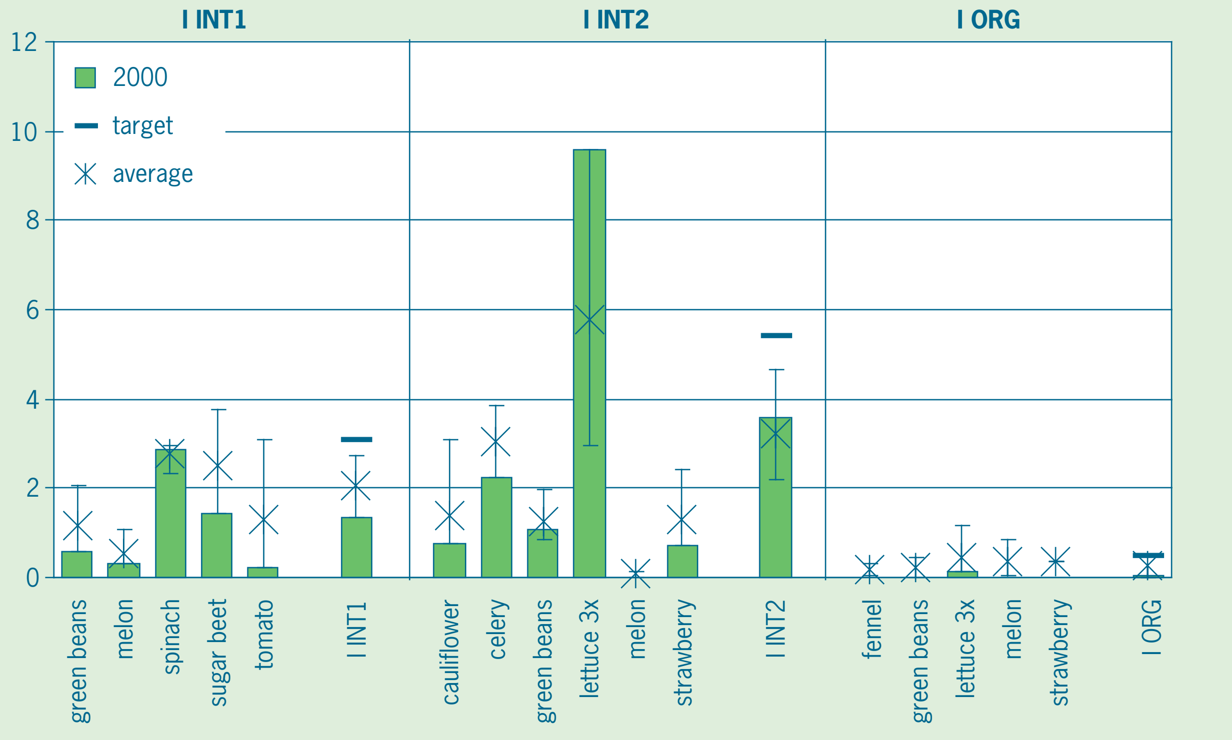


Figure 4.8 Input of active ingredients (kg ha-1) from synthetic pesticides per crop and per system

4.3.5 Environment Pesticides

The results under 'environment pesticides' were quantified by the system parameters 'pesticide active ingredient input' (PESTAS) and 'environment exposure to pesticides' (EEP) for the three environment compartments: air, soil and groundwater.

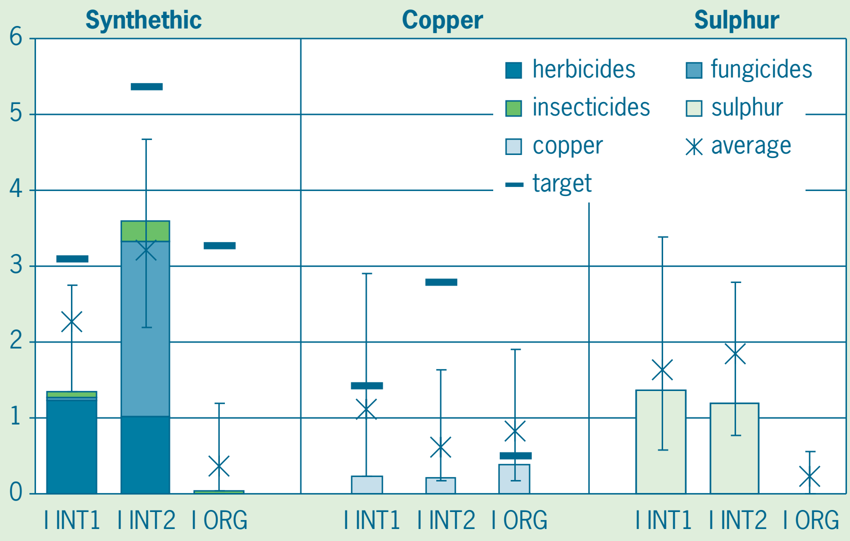


Figure 4.9 Input of active ingredients (kg ha-1) per system for synthetic pesticides, copper and sulphur

Input of active ingredients in pesticides

Inputs of active ingredients can vary significantly between different crop cultivations (see Figure 4.8). The targets per system for synthetic pesticides are based on reducing the input in average practice by 50%, a target that was more than met. By using integrated crop protection strategies, over a number of years, a general reduction of the input was achieved. The input increase in I INT2 in 2000 was entirely due to the break through in lettuce production by using strains resistant to Downy Mildew. The pesticide input in lettuce was a very large part of the total pesticide input in I INT2 (see Figure 4.8). Not only were synthetic pesticides used, but also copper- and sulphur-based pesticides (see Figure 4.9). The copper input was reduced to a level at which there was no risk of copper accumulation.

The chemical control of weeds has been eradicated in Italy, and herbicides have been replaced by mechanical and physical treatments. However, this has resulted in more unwanted hours of hand weeding. In the integrated

Table 4.6 Actual exposure of the environment to pesticides (EEP) per year and the input of synthetic pesticides in the integrated systems

Parameter	Dimension	System	1997	1998	1999	2000	Average	Target	Practice
PESTAS-Synth	kg ha^{-1}	I INT1	2.7	2.1	2.1	1.4	2.1	3.1	6.2
		I INT2	4.7	2.4	2.2	3.6	3.2	5.4	10.7
EEP-air	kg ha^{-1}	I INT1	0.4	0.4	0.5	0.4	0.4	0.4	1.2
		I INT2	1.3	0.7	0.5	0.5	0.7	1.1	3.6
EEP-groundwater	ppb	I INT1	8.26	9.38	10.06	8.99	9.17	0.50	16.02
		I INT2	35.01	2.97	2.52	0.00	10.12	0.50	92.12
EEP-soil	kg days ha^{-1}	I INT1	190	199	210	145	186	130	432
		I INT2	418	120	107	95	185	299	998

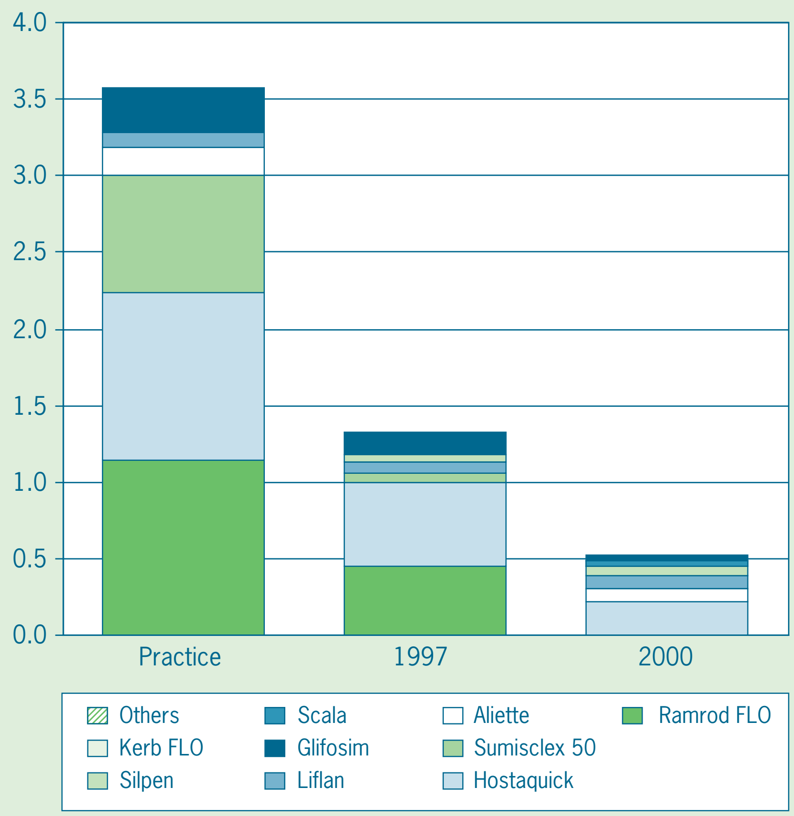


Figure 4.10 The effect of the various pesticides on EEP-air in the practice situation, at the starting year and the final year of the project of I INT2

systems, the impact of herbicides has been reduced by integrating mechanical weed control better and by applying low dosages of chemical treatment containing a better choice of active ingredients.
The concern in disease control has turned more towards using crop varieties that are resistant or tolerant to the main diseases that plagues them (lettuce/downy mildew, melon/powdery mildew, sugarbeet/*cercospora* and spinach/downy mildew). Other developments paralleling the reduced use and lower doses of herbicides are close observation (strawberry/powdery mildew, celery/*septoria,* sugarbeet/powdery mildew), and the use of forecasting models (tomato/downy mildew, sugarbeet/*cercospora*) and damage thresholds (sugarbeet/*cercospora*).
The focus in pest control is to introduce resistant varieties (melon/aphids, lettuce/aphids), and to apply pesticides less frequently. The lower frequency is based on close observations (melon/aphids, greenbeans/aphids, lettuce/aphids) and on setting damage thresholds (sugar beet/*conorrhinchus*, strawberry/aphids, wheat/aphids). In the organic system, thanks to the abundance of natural elements like shrubs, pest control by natural enemies has proved to be a particularly important development.

Pesticide emission

In addition to minimising the use of pesticides, an effort was also made to reduce pesticide emission by carefully selecting the pesticides used. The target for emission to the air (EEP-air) and soil (EEP-soil) was to reduce emission in the practice situation (with a comparable crop composition) by 70%. The EU drinking-water directive of 0.5 ppb was used as a target for emission to groundwater.
The targets for EEP-soil and EEP-air were more than met. Although the emission risks in I INT1 with respect to groundwater were above target, a strong reduction was

achieved compared to the risks in average practice. The high EEP-groundwater levels caused by the input of herbicides on spinach, was the main problem in this system. However, there is no suitable alternative herbicide available at present.
Comparing the integrated systems with average practice (see Table 4.6), large reductions were evident in both the input of active ingredients and in emissions.

The reduction in the use and emission of pesticides was brought about by different aspects of the strategies employed. Important elements of these strategies were close observation, applying traps and damage thresholds, using resistant or tolerant cultivars, crop rotation, pesticide selection, localised applications and no-chemical control methods (especially natural control).
Figure 4.10 shows an example of the combined effect of the different strategies applied and the choice of pesticides on the emission of pesticides to the air in the Integrated Fresh Market System (I INT2).

4.3.6 Nature and landscape

The target set for the surface of the ecological infrastructure (EI) was amply met in all systems. The lay-out of the EI has been evaluated in detail in both I INT1 and I ORG. Various elements of nature and landscape were already present in these two systems. The evaluation of the situation showed that, with minor changes, their protection and potential for providing food and shelter to various species could easily be improved. An example is to improve the circuitry of herbal elements by connecting ecological strips between two fields with other strips at the head and the end of each field. Detailed results of the evaluation of EI can be found in the method manual on 'nature management on farms' that resulted from this work.

4.4 Conclusions

The results obtained in the three farm systems during the four years of the project lead to a number of considerations.

- The rotation adopted, played an important role in meeting objectives such as correct reserve soil management, reducing fertiliser input and improving the natural equilibrium. To apply this on a vast scale, however, it is necessary to link the technical results to a positive financial result. This has been achieved in the organic system, mainly due to good production quality in combination with high product prices. In the integrated systems, markets are poor and there is no premium price to develop farming strategies in practice.
- Reducing the use of fertilisers: in general much progress has been made, and further improvements are possible. However, the targets for minimising nitrate leaching will be diffcult to reach completely. Conflicting objectives such as increasing organic soil matter, while reducing inputs of phosphorus and potash, where there are high reserves of these two elements in the soil, are important thresholds for further improvement.
- It has been proved possible to drastically reduce the input and emission of pesticides. However, because of the knowledge level required, it is necessary to ensure that farmers are given sufficient technical assistance to reduce the risk of damage from disease, pests and weeds. Good market conditions (e.g. high prices) can also compensate against major risks from low production or decreased quality.
- Natural landscape management to create a better balance between parasite–predator and agriculture–landscape was reasonably successful in the project, but further improvements can be made.
- To reduce labour costs in small-scale farm types and to apply inputs better, (small scale) mechanisation needs to be improved.

5 A practical case in the Valencian Community (Spain)

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5.1 Introduction

The Valencian Community (VC) has always been one of Spain's vegetable growing areas. In 1998, with a final value of € 276.5 million, vegetable crops were second in economic value to the citrus crop. Vegetable crops occupy an area of about 34 610 ha. One, very important social aspect of Valencian horticulture is that a lot of hand labour is used, accounting for 50% of the production costs. It is widely accepted that vegetable and citrus crops are complementary, since the periods of low activity of the two types of crop do not coincide. In periods of low activity in citrus crop, most of the hand labour can be used for vegetables. In this way, the availability of hand labour can be stabilised throughout the year and the costs of facilities can be fixed. Outdoor vegetable crops are more important in the centre and north of the VC, while in the south, there is a continuous expansion of greenhouse cultivation.

As far as production is concerned, the most important crops are tomato, potato, onion, watermelon, artichoke, lettuce, melon, pepper and cauliflower. The southern part of the VC is perhaps the most important area in Europe for tomatoes, together with Murcia, Almería and the Canary Islands.
To gain an accurate understanding of vegetable crop production in the VC, it is very important to realise how small the farms are in this region. The average size is about 4.5 ha. Very little machinery is available to lighten the burden of the tasks that have to be carried out on these farms, and weeding poses a particular problem. This is why so much hand labour is needed. The move towards citrus and other fruit orchards, in combination with vegetables, has been made to reduce the need for hand labour to some extent. The Regional Government has been heavily promoting integrated production for the last ten years, so that nowadays most producers employ technicians specialised in integrated management. It is an ongoing process of change. The main problem in setting up integrated management techniques in commercial farming is how to meet high demands for visual quality, in situations, sometimes, where there are few alternatives to conventional farming methods.
In Spain, organic farming occupied 269 465 ha in 1998, of which 12 179 ha was in the VC, but only 2 019 ha nationally, and 90 ha in the VC, were dedicated to vegetables. Most of the organic produce is exported.

5.2 Systems, crops and rotations

Five integrated farming systems were set up, extending from the North of the VC in Benicarló (ES INT2 system), to the South, in Pilar de la Horadada (ES INT1). These are two of the most important areas for vegetable crops. An organic system was also established (ES ORG) in Paiporta, in addition to the integrated system ES INT3, so that both systems could be adequately compared. The crop rotation that was set up used those crops that were most frequently grown in the different areas, taking into account their botanical characteristics. The rotations carried out in these four systems during the year 2000 are shown in Figure 5.2. In two of the systems (Almenara and Elche) it was not possible to carry out the project adequately due to structural and staff problems, so the results there were not taken into account. A fact that

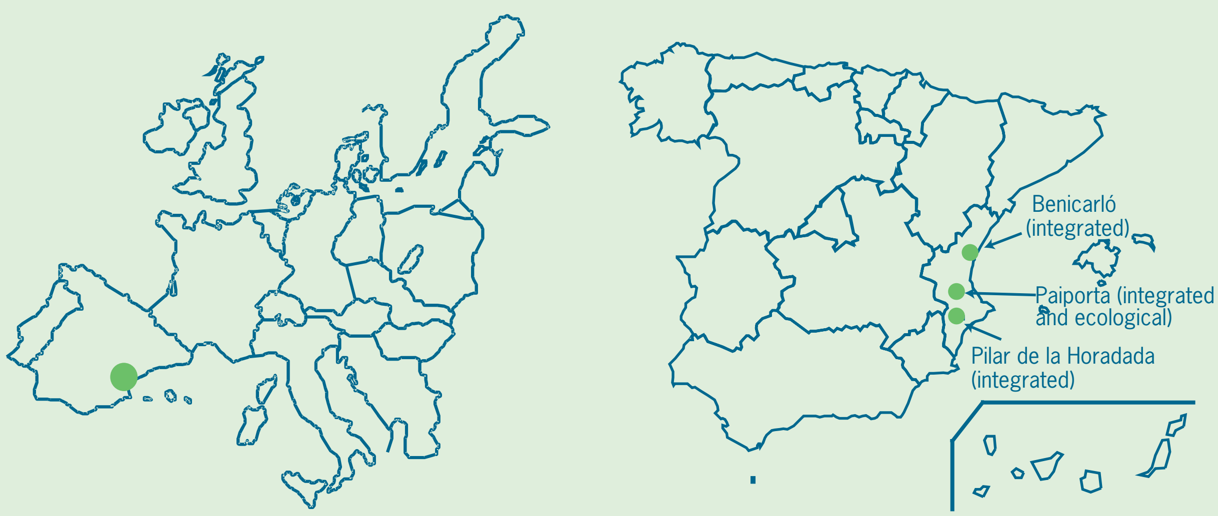

Figure 5.1 Location of the experimental integrated and organic vegetable farming systems in Spain

ES INT1, Pilar de Horada

Year	Winter			Spring			Summer			Autumn		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	vetch oats								little gem			little gem
	little gem		sweet corn					broccoli			lettuce	
	lettuce		onion						celery			
	celery			watermelon					vetch-oats			

ES INT2 Benicarlo 2000

Year	Winter			Spring			Summer			Autumn		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
		lettuce			watermelon				cauliflower			
		vetch-oats					artichoke					
	artichoke							tomato				
			green bean						lettuce			

ES INT3/ES ORG Paiporta 2000

Year	Winter			Spring			Summer			Autumn		
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	artichoke						green beans				onion	
	onion				watermelon				cauliflower			
	potato								fennel			
	green manure (oats)						seed artichoke					

Figures 5.2 Crop rotations for the integrated and organic systems in Spain

Figure 5.3 Relative realisation of the parameter targets for the integrated and organic systems in Spain, in the year 2000

clearly emerged, however, was that not every farm was prepared to work with an integrated farming system, and that a transition period might be necessary.

There are some important differences between the three areas in the study. The ES INT1 area enjoys a much warmer climate than in the other systems, with mild winters and hotter summers. The direct consequence of this, and lower crop diversity, is the higher incidence of pests. Irrigation in Pilar de la Horadada usually makes use of river water. In Benicarló and Paiporta, however, where there are more citrus orchards, irrigation water is usually taken from wells, so the nitrate content in the water is higher, specially at Paiporta where it is around 100 mg $N\text{-}NO_3^- l^{-1}$. ES INT2 is situated on different soils from the other systems. Here, the soils are shallow (<50 cm) and very stony. However, the soil texture was average in all four systems.

Four-year rotations were planned, although rotations of this length had been carried out in Spain since the mid-eighties. At first, nine or ten crops were included in the rotation. This was later modified in ES INT3 and ES ORG by reducing the minimum number of crops per rotation to eight. The crops included in the different rotations were artichoke, potato, onion, tomato, pepper, cauliflower, broccoli, sweet corn, celery, fennel, green bean and watermelon. A green manure crop was also included in all systems (vetch-oat, vetch-barley, and oat and corn grown as green manure).
In two cases (ES INT1 and ES INT2), the fields used for the project belonged to farmers, whereas ES INT3 and ES ORG were set up at an experimental station (Caja Rural Valencia Foundation). Weekly data were taken on each system.

5.3 Results

Results overview

An overall look at the pie charts (Figure 5.3) indicates that the main shortfalls in both systems occurred in the themes 'nature and landscape' and 'sustainable use of resources'. The parameters of these two themes are closely related to the initial agricultural conditions of the systems, and so it is necessary to correct them over time.

In the year 2000, it was difficult to meet the target for 'quantity of produce' (QNP) in ES INT1and ES INT2. Pests and bad market conditions were the main reasons in the ES INT1 system, and, in Benicarló, diseases and climatic accidents. In 1999, the QNP values were 0.81 in Pilar de la Horadada and 0.75 in Benicarló. In ES INT3 and ES ORG, however, the quantity of produce was very close to that obtained in Good Agricultural Practices (GAP). The best results under this theme, in all systems, were obtained in the nitrate content of produce and the quality of the yield.

The bad results obtained in the 'net surplus' (NS) of ES INT1 and ES INT2 were directly related to poorer production in the year 2000. In 1999, NS was 0.97 in ES INT1, and 0.81 in ES INT2. Particular note should be made of the fact that, in spite of the many hours spent on hand weeding, and the lower yields compared with those of ES INT3, good financial results were obtained for the organic system. Farm continuity is also threatened in ES INT1, ES INT3 and ES ORG, due to the many hours spent on hand weeding.

Of the environmental parameters, either nutrients or pesticides showed a big improvement during the project. It was only the sixth parameter, 'nitrogen reserves' that was very far from target, probably because of an excess of nitrogen input and/or lack of rain during the period before soil sampling. The shortfalls in environment pesticides occurred in the tenth parameter, 'EEP-groundwater', particularly in ES INT3, due to a bad selection of insecticides, and in ES ORG, in PESTAS-Cu. In ES INT2, the targets of the parameters in this theme were completely met.

It should be noted that the graphs in Figure 5.3 relate to data from the year 2000, reflecting, therefore, an eventual situation in the Vegineco Project that, for Spain, began in the middle of 1998. In the following sections, all the parameters are analysed in depth and figures are given for each year.

5.3.1 Farm continuity

As in conventional farming, the most important element in the economic evaluation of the Vegineco fields was obviously the time spent on hand labour. This is an obstacle that is difficult to solve because of the small commercial-field size and the low level of mechanisation. New research to develop adequate machinery is necessary in this area. In the Vegineco fields, harvesting, planting and hand weeding were the main tasks involving hand labour. In the integrated and organic systems, the most important crop costs, after hand labour, are in order of costs: seeds and plants, opportunity costs, and the combined costs of pesticides and fertilizers. The higher expenditure on pesticides and fertilizers in conventional farming is usually partly offset by increased hand labour for hand weeding in the integrated systems (Table 5.1). Therefore, the differences in net surplus between conventional farming and the integrated systems of the Vegineco project were mainly due to differences in the quantity of yields. Both the integrated and the conventional systems usually show negative financial results since gross revenues are lower than crop costs. To solve the market problems, some co-operatives in the VC are working successfully with contract crops, programming a calendar agreed with their customers, thereby 'integrating' marketing in the farming system. The only system to meet the financial targets is ES ORG. This is because the costs of extra hand-weeding hours are compensated for

Table 5.1 Absolute target values and realisation (2000 and average)

Theme	No	Parameter	Desired results	ES INT1		ES INT2		ES INT3		ES ORG	
				2000	98-00	2000	98-00	2000	98-00	2000	98-00
Quality production	1	Quantity of produce	1 (≥GAP)	0.75	0.80	0.64	0.82	1.32	1.09	1.38	1.08
	2	Quality of produce	1 (≥GAP)	0.94	0.81	0.95	0.98	1.01	0.95	1.00	0.96
	3	N-content in produce[1)]	1 (<2500 ppm)	1	1	1	1	1	1	1	1
Environment Nutrients	4	P_2O_5 balance	0.0	0.0	1.0	0.0	1.7	0.0	1.1	0.0	1.1
	5	K_2O balance	0.0	0.0	0.3	0.1	0.9	0.1	0.5	0.1	0.5
	6	N-reserves in autumn	<70 kg N ha^{-1} (0 - 100 cm)	186	147	238	306	252	331	223	274
Environment Pesticides	7	Pesticide a.i. input	13.4; 3.9; 6.4; 0.64 kg ha^{-1}	2.7	5.1	1.41	3.3	2.2	3.9	0.22	0.3
	8	Copper input	1.6; 0.3; 1.2; 1.2 kg ha^{-1}	0.15	0.3	0.47	0.8	1.3	1.6	1.16	1.23
	9	Pesticide emission to air	1.8; 0.44; 0.83; 0.14 kg ha^{-1}	0.35	1.55	0.20	1.20	0.44	0.80	0.04	0.18
	10	Pesticide emission to groundwater	0.5; 0.5; 0.5; 0.025 ppb	0.7	71.0	0.02	55.4	32.9	23.5	0.01	0.004
	11	Pesticide emission to soil	381; 235; 408; 67 kg day ha^{-1}	223	420	120	393	271	321	3	1.4
Nature Landscape	12	Percentage nature	≥5%	3	-	0.5	-	2	-	2	-
Sustainable Use of Resources	13	Available P_2O_5 reserves	30-45 mg P kg^{-1}	153	160	216	231	87	93	87	99
	14	Available K_2O reserves	150-300 mg K kg^{-1}	1010	942	659	764	353	495	353	533
	15	Balance of organic matter	>1.0	0.7	1.1	0.9	1.7	1.2	1.9	1.1	1.7
Farm Continuity	16	Income per € 100 costs	>100	79	88	53	67	101	89	335	286
	17	Hours of hand weeding	70; 70; 70; 200 hours ha^{-1}	292	253	86	61	143	145	370	356

[1] The results were always under 2500 ppm

by the higher market prices gained for organic produce.

For net surplus, as the project only began in mid 1998 in the Valencian Community, the only complete-year data collected were those for the years 1999 and 2000. Figure 5.4 gives a summary of the economic evaluation (the data for conventional farming were collected from farms situated in the different areas where the project was performed). The normal yields for conventional farming are estimated is being 20% lower than the GAP optimum. The costs per hour of hand labour are € 6.00 hour-1 for unspecialised tasks, and € 7.20 hour-1 for specialised work. The differences in the net surplus between conventional and integrated systems are mainly related to differences in yield. However, it is not only lower yeilds that cause negative financial results in the conventional and integrated farming systems, but also low prices and a high amount of hand labour that is required. If yields could be brought close to the optimum and if prices were not too low, it would still be possible to achieve a positive financial result, irrespective of the costs of hand labour. The reasons for the shortfalls in yields are analysed in the next section on quality production. In ES ORG, the financial results were always excellent, because organic produce fetches a high price on the market.

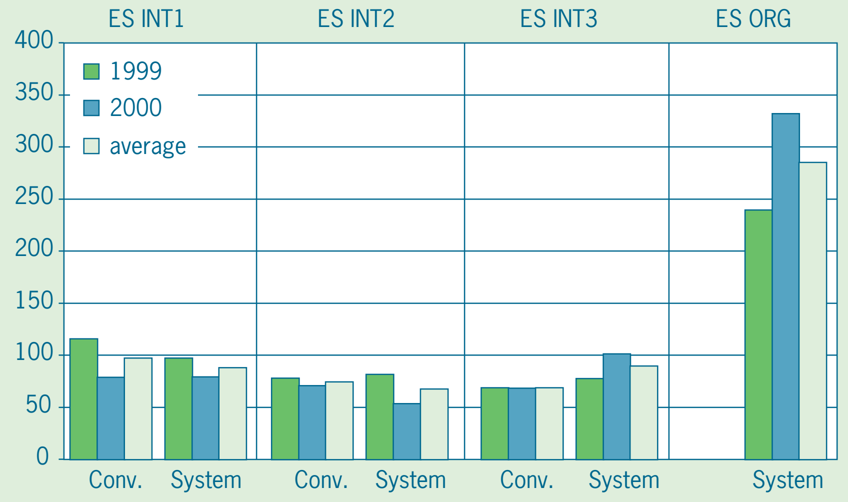

Figure 5.4 The cost/revenue balances of integrated and organic systems (revenues per € 100 costs) compared with conventisnal ones

In Table 5.2, we can see that the costs of pesticides were higher in

Table 5.2 Economic results of integrated and organic systems compared with conventional ones

SYSTEM		ALLOCATED COSTS						FIX COSTS			TOTAL INPUT	TOTAL OUTPUT	NET SUR-PLUS
		Pest.	Fertilizers min.	org.	Seeds & plants	Irrig. water	Hand labour	Others	Deprec. others	Land & yield value			
ES INT1	€ ha-1	1 157	249	160	3 084	637	12 326	651	798	1 989	21 052	18 352	2 700
ES INT1conv.		1 635	782	593	3 058	637	11 275	622	799	2 018	21 417	20 489	695
ES INT1	%	5.5	1.2	0.8	14.7	3.0	58.6	3.1	3.8	9.4	100.0	output /	0.88
ES INT1conv.		7.6	3.6	2.8	14.3	3.0	52.6	2.9	3.7	9.4	100.0	input	0.96
ES INT2	€ ha-1	580	109	260	2004	209	10 928	636	645	1 833	17 205	11 846	5 359
ES INT2conv.		717	657	589	1850	198	11 135	588	630	1 877	18 240	13 512	4 729
ES INT2	%	3.4	0.6	1.5	11.6	1.2	63.5	3.7	3.8	10.7	100.0	output /	0.69
ES INT2conv.		3.9	3.6	3.2	10.1	1.1	61.0	3.2	3.5	10.3	100.0	input	0.74
ES ORG		505	0	213	2 372	457	8 897	450	546	1 304	14 744	42 184	27 440
ES INT3	€ ha-1	612	10	213	2 360	467	8 967	533	607	1 303	15 071	13 354	1 718
ES INT3conv.		850	333	532	2 020	422	7 686	488	665	1 308	14 303	9 745	4 558
ES ORG	%	3.4	0.0	1 4	16.1	3.1	60.3	3.0	3.7	8.8	100.0	output /	2.86
ES INT3		4.1	0.1	1.4	15.7	3.1	59.5	3.5	4.0	8.6	100.0	input	0.89
ES INT3conv.		5.9	2.3	3.7	14.1	2.9	53.7	3.4	4.6	9.1	100.0		0.68

Pilar de la Horadada (the ES INT1 and ES INT1 conv. systems). This is because, in this area, south of the VC, there is a higher incidence of pests because vegetables are grown much more intensively and there is a warmer climate. Conventional farming also used organic manure to a much higher level (and cost) than was the case on the Vegineco fields, where soil tests had indicated that it was unnecessary to apply more organic manure (see Sustainable Use of Resources).

The differences in hours of hand weeding between systems are shown in Figure 5.5. In Integrated systems, the number of hand weeding hours was about 10% of the total hand labour, whereas in ES ORG, it was about 22% (the third highest amount after harvesting and planting). This percentage was particularly high in the ES INT1 because there was no walking tractor available. This is the most important machine for mechanical weed control in the Spanish systems. This apart, to be competitive with conventional farming, it is also necessary to develop new machinery adapted to the structure of fields. Another factor accounting for the differences between integrated systems, was the different infestation levels of weeds in the different systems. In Benicarló, where there was a low level of weed infestation, mechanical weed control proved quite effective.

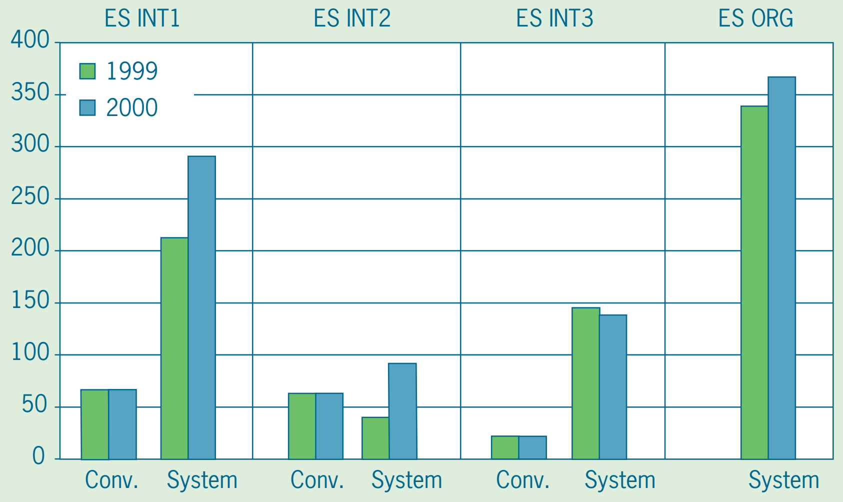

Figure 5.5 Hand weeding hours needed per system (hours ha^{-1} year^{-1})

5.3.2 Quality production

In 50% of the Vegineco systems, the estimated losses in yield were due to pests and diseases. Pests and diseases and strategies for their control are analysed in the Crop Protection Manual. When market prices are low, a small defect in the produce may mean a large loss in yield, since usually only perfect produce is harvested in these situations. Integrated produce may be at a disadvantage compared with conventional produce in these cases, as a damage threshold was usually set in the Vegineco fields. In ES ORG, the decrease in quality was mainly due to market conditions (according to conventional standards). Other reasons for decreases in production, and their importance, are shown in Table 5.3. This topic was quantified by the parameters 'quantity of produce' (QNP), 'quality of produce' (QLP) and 'nitrate content of leafy crops' (NCONT). The results for all crops in the different systems can be found in various tables in this section.

Quantity and quality

Targets for integrated systems were set according to Good Agricultural Practices (GAP) in the different areas investigated by the Vegineco project. For the organic system, the optimum yield was set at 10% below GAP.

Table 5.3 Causes of decreases in yields (as % of the total decreases)

SYSTEM		REASONS					TOTAL
		pests	diseases	climate*	market (over-production)	other cultivation causes	
ES INT1	QNP	35	10	15	25	15	100
	QLP	60	20	0	20	0	100
ES INT2	QNP	0	65	15	10	10	100
	QLP	0	100	0	0	0	100
ES INT3	QNP	35	10	25	0	30	100
	QLP	0	25	20	55	0	100
ES ORG	QNP	50	10	15	0	25	100
	QLP	0	25	30	45	0	100

* and abiotic disorders

Table 5.4 Comparison of QNP and QLP parameters between systems

	QNP	QLP								
	98	99	00	mean	target	98	99	00	mean	target
CONV.	0.80	0.80	0.80	0.80	1	0.80	0.80	0.80	0.80	1
ES INT1	0.83	0.83	0.75	0.80	1	0.74	0.75	0.94	0.86	1
ES INT2	1.04	0.77	0.64	0.82	1	0.95	1.04	0.95	0.99	1
ES INT3	0.92	1.05	1.32	1.09	1	0.78	1.05	1.01	0.96	1
ES ORG	0.94	0.92	1.38	1.08	1	0.80	1.08	1.00	0.97	1

In ES INT1, the main problem was pests: aphids in watermelon in year 2000 and caterpillars in Little Gem during the autumn season of 1998 and 1999. The cover used in watermelon did not prevent an aphids attack in year 2000 and spraying was done too late. In the autumn Little Gem crop, there were not enough opportunities to spray, but this was corrected with success in 2000. The only serious disease was TSWV virus in the pepper crop of 1998. However, new tolerant-resistant varieties may solve this problem in the short term. Bad market conditions for springtime lettuce, combined with overproduction and low prices, and a hailstorm on the celery crop of 1999 affected this system too.

In ES INT2, diseases were the main cause of the shortfall in QNP and QLP. In the tomato crop, the use of varieties tolerant to the TSWV virus did not prevent losses from other viruses. To solve this serious problem, an interesting experiment might be to substitute another crop for tomatoes in the rotation. On the other hand, several sprayings to control downy mildew in the winter-spring lettuce crop were also not effective enough, so more sprayings and other fungicides would be necessary there. Verticilium sp. and Rhizoctonia were detected in the artichoke crop, but the real problem with this crop is probably more one of non-suppressive soil conditions, which could be solved in the mid- to long term by adequate crop rotation. Other important reasons for decreases in yield were weather conditions and the excessively wide distance between plants used in crops of watermelon and green beans (25% of the total losses). A 10% of the total decrease in yield

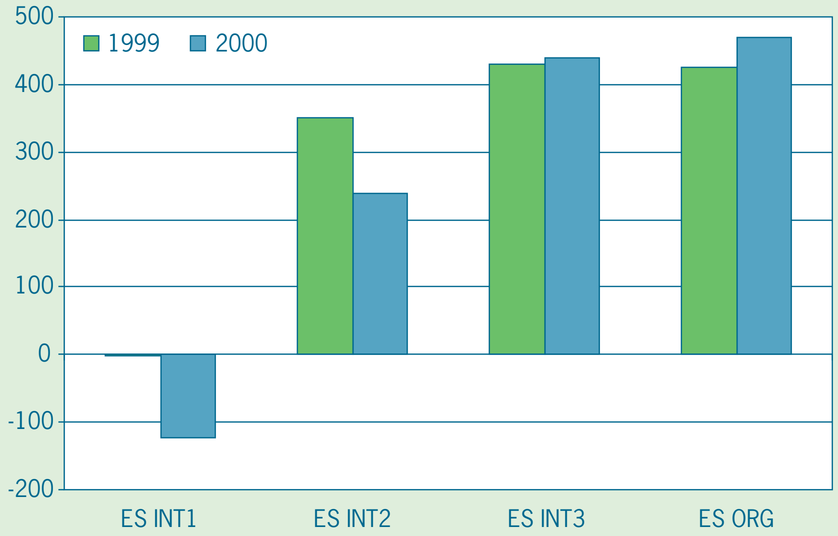

Figure 5.6 Simplified nitrogen balance (kg ha^{-1})

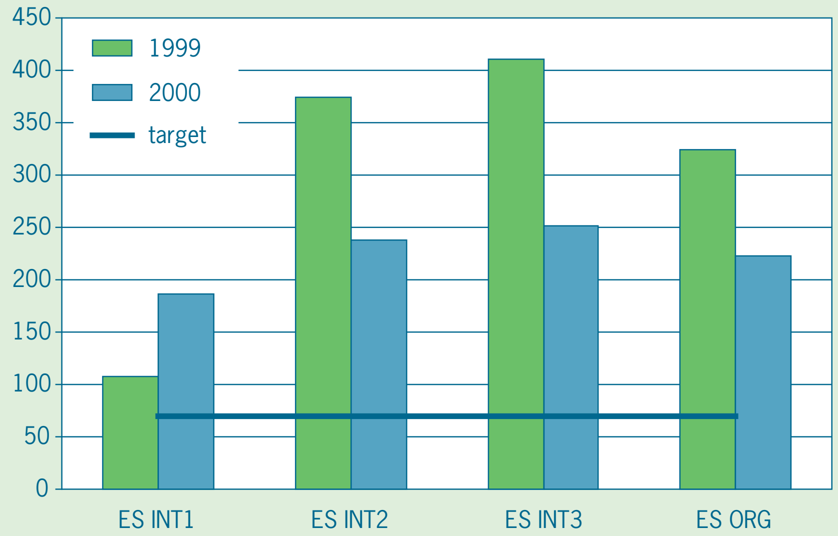

Figure 5.7 Evolution of reserves of available nitrogen (kg ha^{-1})

could be explained by market conditions and particularly by the low prices fetched by the spring lettuce crop (since it was not worth harvesting).

In ES INT3 and ES ORG, the reasons for the shortfalls in QNP and QLP were very similar since the fields were close to each other. As in ES INT1, pests were the main reason for loss in production. In ES ORG, the pests that were mainly responsible were aphids in the winter-spring lettuce crop and Diptera sp. in the onion crop. In ES INT3, the problem was Diptera in the onion crop, since it was detected too late. The disease that reduced yield quality even more was the TSWV virus in the end-of-summer lettuce crop. This was solved by removing the crop from those periods in the rotation when it is more sensitive to the disease. In the case of QLP, shortfalls had to do mainly with climate, market conditions, and crop management.

The difference in QNP between ES INT3 and ES ORG (12% lower in ES ORG, on average) was mainly due to the higher incidence of pests and diseases in the organic system.

As there are so many factors that can influence production, perhaps more appropriate would be to show a resumé of the results achieved during the project. The results achieved for QNP and QLP in all systems compared with conventional farming can be seen in Table 5.4. Note that Target 1 refers to quantity and quality yields compared to the GAP optimum in integrated and conventional systems, whereas, in ES ORG, the quantity target 1 is 10% lower than the GAP optimum, although the GAP standards apply for QLP. A further point is that although ES INT1and ES INT2 do not approach the target set for QNP, the values achieved are similar to those considered normal for a conventional farming system (80% of GAP) in general agricultural practice.

Nitrate content

The values obtained for the different crops were much lower than 2 500 ppm (EC 194/97). The highest levels of nitrate (1 127 ppm) were detected on lettuce in the winter–spring cycle, and on celery (1 097 ppm). The lowest levels of nitrate were on watermelon, tomato, onion, sweet corn and cauliflower, with values lower than 100 ppm.

5.3.3 Environment nutrients

The results under 'environment nutrients' are quantified within the parameters 'nitrogen available reserves during the leaching season' (NAR), and the 'annual balances of phosphate and potash' (PAB and KAB).

Nitrogen

The objective of the nitrogen fertilisation strategy was to provide an adequate availability of nitrogen during the the

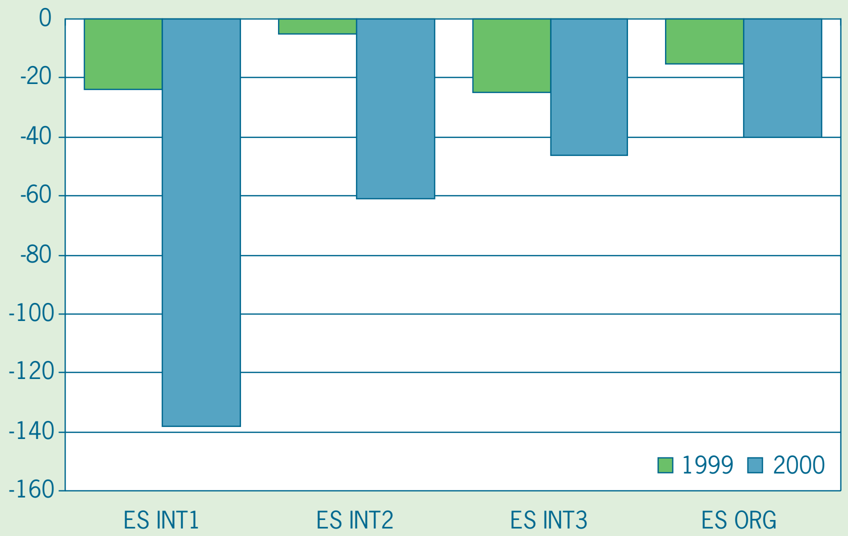

Figure 5.8 Simplified phosphate balance (kg P_2O_5 ha^{-1})

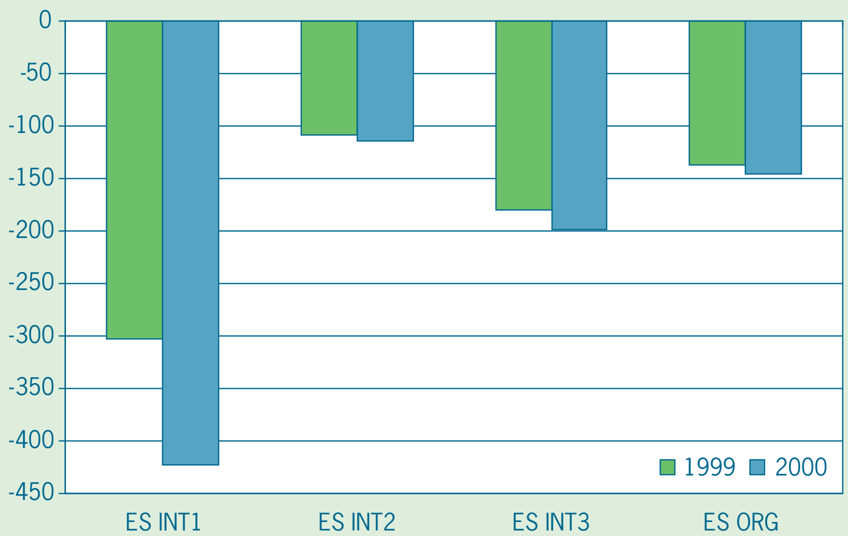

Figure 5.9 Simplified potash balance (kg K_2O ha^{-1})

vegetative season of the crops and to minimise the risk of nitrate leaching.
The nitrogen balances for the integrated and organic systems in 1999 and 2000 are shown in Figure 5.6. There were high variations between the three integrated systems. In the year 2000, the nitrogen surplus obtained was -122, 238 and 439 kg nitrogen ha^{-1} in the integrated systems, respectively. The nitrogen surplus trends in the different systems that emerge by comparing the two years show a decrease in ES INT1and ES INT2, and a stable situation in ES INT3. In the integrated systems, ES INT1 and ES INT2, the input of mineral fertiliser was estimated as being 40 - 50% lower than the rates normally used for conventional systems.

The nitrogen balance for the organic system ES ORG was similar to the balance obtained in the integrated system, ES INT3, because, in these two systems, irrigation water is the main source of nitrogen for crops.

The Nitrogen Available Reserves (NAR), which represent the risk of nitrate leaching to the groundwater, was higher in both years (1999 and 2000) than the target level of 70 kg nitrogen ha-1 (Figure 5.7). A comparison of NAR between 1999 and 2000 shows great variation among the systems, whereas in ES INT1, the values of NAR increased, while in ES INT2 and ES INT3, a decrease was found. The NAR results obtained in ES INT1 are not consistent with the total nitrogen input. The reason for these surprising results may be due to a variation in the rate of water drainage and/or organic nitrogen mineralisation in the soil.

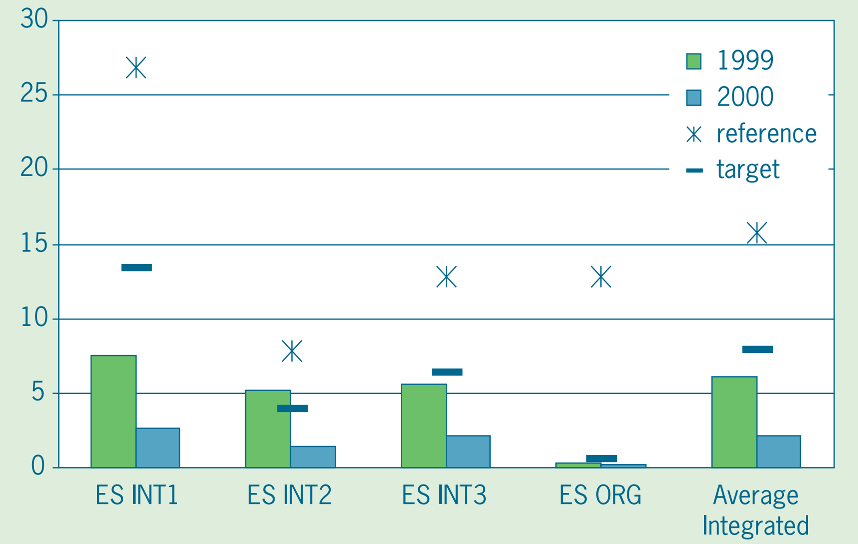

Figure 5.10 Input of active ingredients (PESTAS-Synth) in kg ha^{-1} year^{-1}

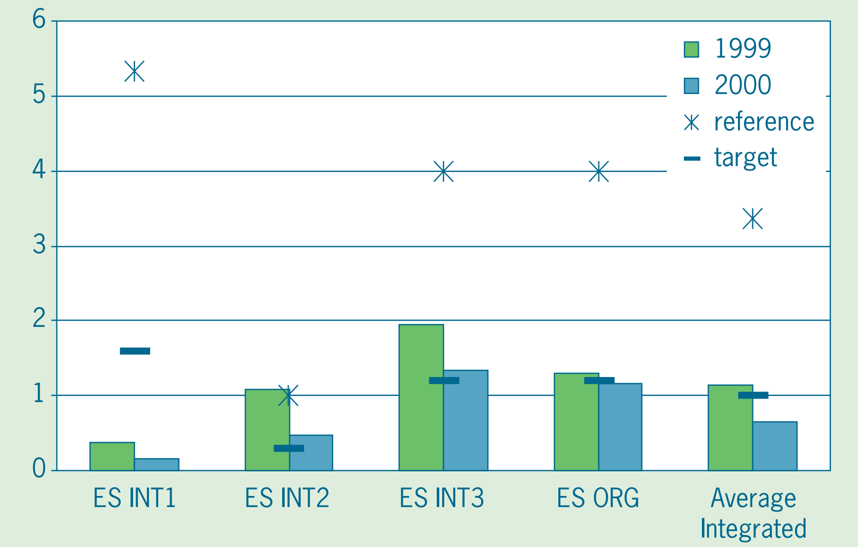

Figure 5.11 Copper input (PESTAS-Cu) per system (kg ha^{-1} year^{-1})

Phosphate and potash

The phosphate and potash fertilisation strategy was aimed at maintaining the available reserves of phosphorus and potash in soil within a desired range (agronomically sufficient and acceptable environmentally). Thus, to determine the dosages of phosphorus and potash fertilisers for each crop, the factor used to correct for nutrient off-take depends on the available reserves of phosphorus and potash in the soil. In the Spanish systems, available reserves of phosphorus and potash were higher than the desired range, hence the inputs of phosphorus and potash were lower than the off-take from crops, giving negative values of phosphorus and potash surplus in all the systems in both years (Figures 5.8 and 5.9). It is worth noting that, in 2000, the total phosphorus input was zero in all the systems, and the total potash input ranged from 0 to 11 kg K_2O ha^{-1} in the three integrated systems.
In the organic system, ES ORG, the phosphorus and potash balances were close to those of ES INT3. This is because the inputs of phosphorus and potash were similar in these two systems.

5.3.4 Environment pesticides

The parameters used to quantify this theme were ‘kg of active ingredients and copper applied per hectare' (PESTAS-Synth and PESTAS-Cu) and 'environment exposure to pesticides in soil, air and groundwater' (EEP-soil, EEP-air and EEP-groundwater). However, mineral pesticides and pesticides with concentrations measured in Ul gr^{-1}. (Bacillus sp or Beauvearia sp.) were not taken into account for the calculations. For the integrated systems, targets were set according to the figures obtained in standard conventional systems present in the areas studied (Pilar H., Benicarló and Paiporta). Even though values were very different in the three areas, it was finally decided to set a common target for the three systems, based on the average. Reductions of 70% for EEP-soil, EEP-air and PESTAS-Cu were used to establish the different targets. The target for EEP-groundwater was 0.5 ppb, in accordance with European legislation, and finally the limit for PESTAS-Synth was set 50% lower than the average applied in conventional farming. Again, as the Vegineco project only began in Spain in mid 1998, data for that year was not included.

Pesticide input (PESTAS-Synth and PESTAS-Cu)
Good results were obtained under these parameters in all integrated systems. They were always under the limit of the target or close to it. In the Vegineco project there were big reductions in pesticide input under these two parameters. Certain pesticides from the phosphorus group, very highly concentrated compared with piretroids, were mainly responsible for the high PESTAS-Synth values in year 1999. Nevertheless, in spite of the positive progress made, it should be stressed that spraying techniques and pesticide dosage must be improved. The differences between systems are partly due to the different washes used, since the pesticide dosage was usually added per litre of wash, except for herbicides where the dosage was in l ha^{-1}, so the more the wash, the more the active ingredients used. In ES INT1, 2000 l ha^{-1} of wash was normally used during the late stages of the crop; 1500 l ha^{-1} was used in ES INT3 and ES ORG, and 1000 l ha^{-1} in ES INT2.

Progress made in ES INT1 was mainly achieved by replacing the phosphorus group with piretroids + mineral oil and also because of the reduced number of sprayings on celery and Iceberg lettuce crops against Sclerotinia sp. The crops with higher PESTAS-Synth in these three years were celery, broccoli and iceberg lettuce, in that order. In ES INT2, the herbicide mainly responsible for the PESTAS-Synth in year 1999, 8 kg ha^{-1} of Ringo, was used on onion crops. Other crops associated with higher PESTAS-Synth figures in this system were artichoke, and tomato crops In ES INT3, it was artichoke, lettuce and cauliflower. In the year 2000, in the integrated systems, of the average pesticide input, 36% was herbicides, followed by 33% insecticides and 30% fungicides. In comparison, the values

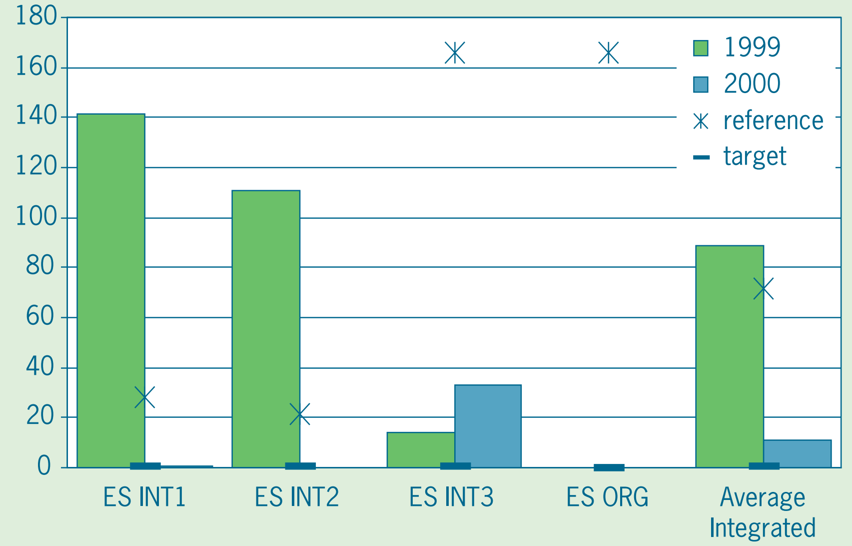

Figure 5.12 EEP-groundwater per system and per year (ppb)

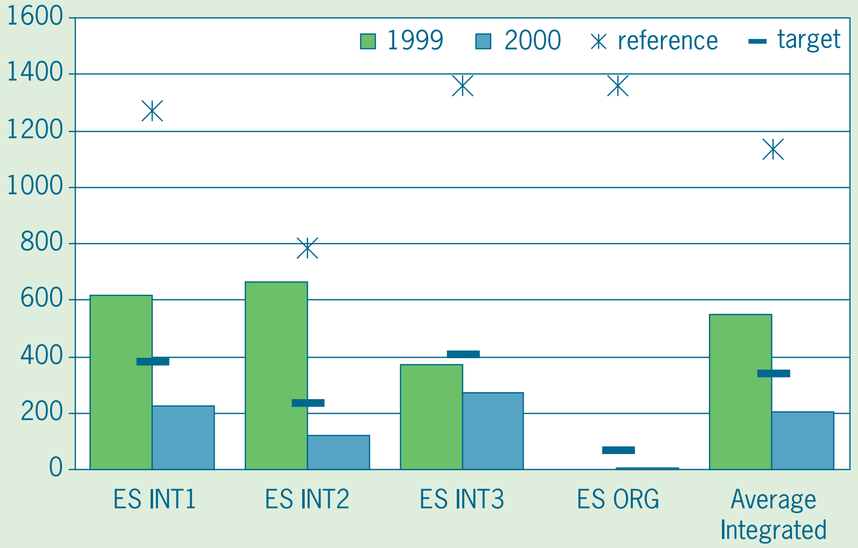

Figure 5.13 EEP-soil per system and per year (kg days ha^{-1})

obtained in the organic systems were insignificant.

Studies have been carried out recently to find ways of eliminating the use of copper as a fungicide in the organic systems. In the Vegineco integrated systems of the VC, it was decided to set a maximum quantity per hectare and per year. The target set was to reduce the amount of copper by 70% of that used in conventional farming (the standard pattern in different farming areas). Figure 5.11 shows that, in both the integrated and organic systems, this target was either always or almost always reached. The crops in which more copper was used were cauliflower, broccoli, potato, tomato, lettuce and celery crops.

There was no significant difference between ES INT3 and ES ORG.
In Spain, the use of copper as a fungicide was also reduced throughout the Vegineco project. The effects of using tolerant varieties for potato crops and taking better opportunities for spraying, mainly on cauliflower, celery and fennel crops, were clearly visible in the yearly results. The parameters PESTAS-Synth and PESTAS-Cu are both closely related to weather conditions, pests and diseases.

5.3.5 Pesticide emission

The main shortfall, mainly caused by insecticides and herbicides, was the exposure of the environment to pesticides in ground water, although this parameter was drastically reduced between 1998 to 2000. The best results, compared with the targets, were obtained in EEP-soil and EEP-air, where values were much lower than those in conventional farming. Significant reductions were achieved from the beginning of the project, but by the final year, the targets for all the parameters had been met. As expected, the values obtained in the organic system, ES ORG, were much lower than in the integrated systems.

In the year 2000, the risk of pesticide leaching (EEP-groundwater) was low in ES INT2 and ES ORG, high in the ES INT1 and very high in ES INT3. Some pesticides

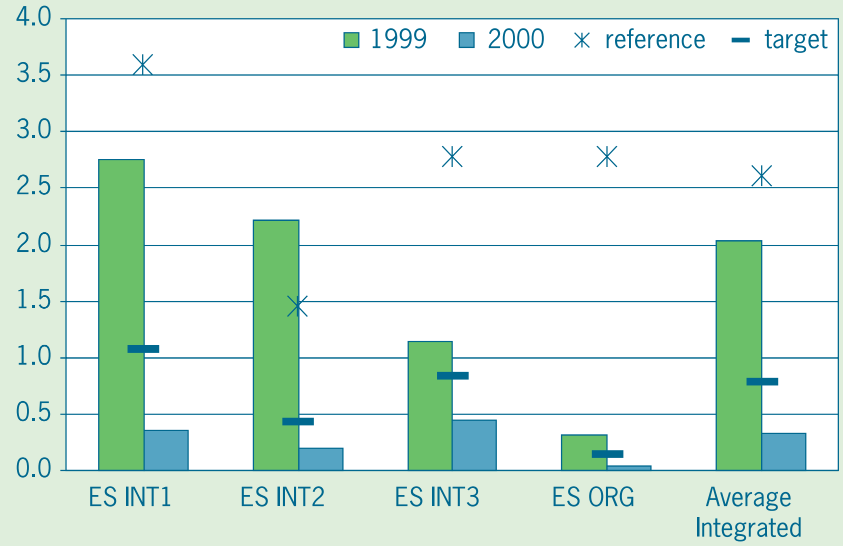

Figure 5.14 EEP-air per system and per year (kg ha⁻¹)

Table 5.5 Species used in hedgerows and natural enemies detected in them

System	Botanic species	Natural enemies detected	frequency
ES INT1	Inula viscosa	Macrolophus sp., Dicyphus sp.	High
		Aphidiidae, Coccinelidae, Chrysopidae	Low
	Nerium oleander	Orius spp.	High
		Aphidiidae, Chrysopidae	Half
	Rosmarinus sp.	Aphidiidae	Low
	Ricinus		
ES INT2	Coronilla glauca	Aphidiidae	Low
	Inula viscosa	Macrolophus sp., Dicyphus sp.	High
		Aphidiidae, Coccinelidae, Chrysopidae	Low
	Rosmarinus sp.	Aphidiidae, Orius spp.	Low
ES INT3, ES ORG	Mioporum pictum	Aphidiidae, Coccinelidae, Chrysopidae	Half
		Orius spp.	Low
	Coronilla glauca	Aphidiidae, Eulófidae	High
	D. pentaphilium	Aphidiidae, Eulófidae	High
	Medicago strassieri	Aphidiidae, Eulófidae	High

were replaced, reduced or removed from the strategies during the project (e.g. procimidone, benomyl, propachlor, and the phosphorus group of insecticides), resulting in a huge reduction in the EEP-groundwater within a year. Others were replaced, e.g. cyromazin, because of its bad efficacy and high environmental exposure. This substance was responsible for almost 80% of EEP-groundwater in ES INT3 in the year 2000. Besides cyromazin, in the integrated systems, in 2000, the pesticides that contaminated groundwater the most were m. chlorpirifos and imidacloprid. Once again the values in conventional farming were much higher than in the Veginco systems.

In the years 1998 and 1999, most of the pesticides with the highest EEP-soil were either removed or, in the different crop strategies of year 2000, restricted (e.g. some insecticides from phosphorous group, endosulfan, propaclor, pendimetalin or benomile). In this way, in 2000, this parameter was greatly reduced, nevertheless, azoxystrobin was responsible for almost 50% of EEP-soil in ES INT1 and nearly 65% in ES INT2. In ES INT3, cyromazine was the substance mainly responsible for EEP-soil, but it has since been removed from future strategies. In several crops, a substitution can be found for azoxistrobine for the control of downy mildew (e.g. metalaxyl, which has a lower DT50). In the organic system, the EEP-soil was insignificant in comparison with conventional and integrated systems.
Regarding the exposure of the environment to pesticides in air, the higher figures in 1999 were due to the group of phosphorus pesticides in ES INT1and ES INT3, whereas in ES INT2, the herbicide Ringo (chlortal + propachlor) made up almost 30% of the total EEP-air. In year 2000, this parameter was higher in ES INT3 (39% of total EEP-air) due to the use of chlorpirifos in cauliflower. In future, this pesticide can either be replaced or applied only to seedling trays.

However, as was pointed out at the beginning of this section, these parameters do not include several of the most frequently used pesticides in the different systems. These are Bacillus thuringiensis (20% of the total amount of insecticides used), azadiractin (10% of the sprayed-on insecticides), sulphur (10% of the total amount of pesticides used), potash phosphite (15% of the total amount of fungicides used) and mineral oil - the latter to improve the effect of some of the insecticides.

5.3.6 Nature and Landscape

The main function of hedgerows in the Spanish systems is as a shelter for crops from natural enemies. Secondary to this is their use in protecting crops from the wind and stopping sprayings from drifting into neighbouring fields. The size of fields and farm structure in the VC often make it difficult to set natural areas apart, as has happened in the Vegineco fields. The main problem is that natural areas, and their positioning, can make it very

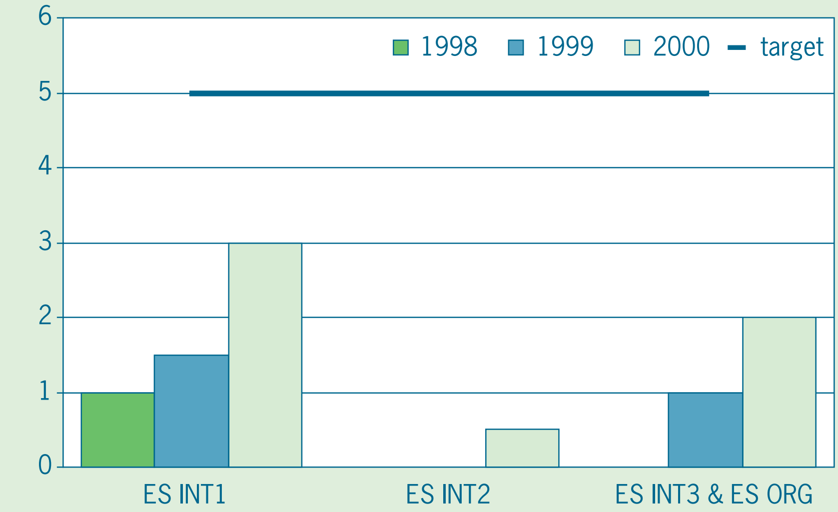

Figure 5.15 Percentage of field surface occupied by hedgerows (%)

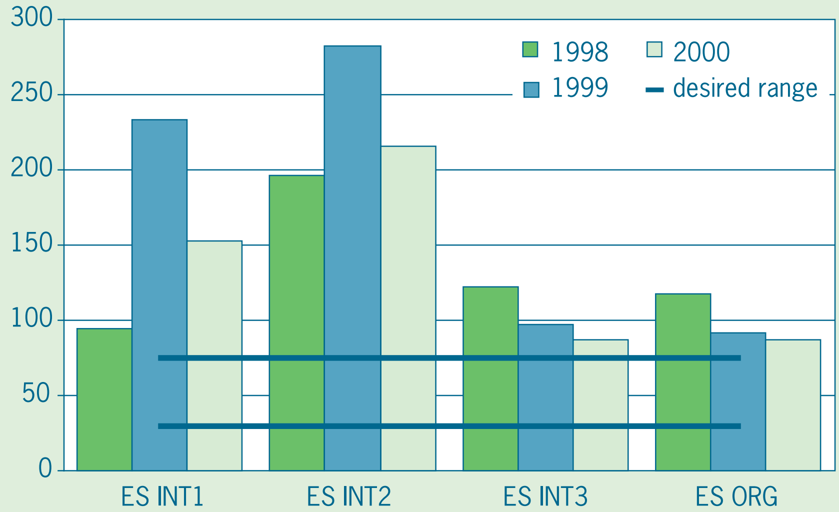

Figure 5.16 Available phosphate reserves in soil (mg P_2O_5 kg^{-1} soil)

difficult to carry out a range of normal farming tasks. Thus, within the two and a half years of the project, it was impossible to meet the target of allowing 5% of the total field surface to revert to natural areas. Apart from the species used as hedgerows, natural enemies were also found in Inula viscosa, Nerium oleander, Mioporum pictum, Doricnium sp., Medicago strassieri and Coronilla glauca.

The parameter 'ecological infrastructure' (EI) has been set to quantify the situation as well as the progress made under this theme. The evaluation was carried out at field level, since it was not possible to take action at farm level. At farm level, the ecological infrastructure could have been improved had we taken the borders into account and, above all, the abandoned fields next to those of the Vegineco project.

In ES INT2, ES INT3 and ES ORG, it was not feasible to plant hedgerows around the fields, because of their size and structure, without interferring with everyday farming tasks. Therefore, the target of 5% for EI was far from realised in these systems. In ES INT1, however, field size did allow enough space for operating machinery, so it was possible to plant hedgerows around them. Even so, the target was not met in this system either, mainly due to the fact that the project time was too short.

5.3.7 Sustainable use of resources

The parameters used to evaluate this theme in the project were 'energy input' and others parameters related to soil fertility. Energy input was developed within the framework of the Vegineco project, and it was only established at crop level for fennel, cauliflower and lettuce. The soil fertility parameters used to evaluate system performance were 'available reserves of phosphate and potash' (PAR/KAR) and the 'balance of organic matter' (OMAB).

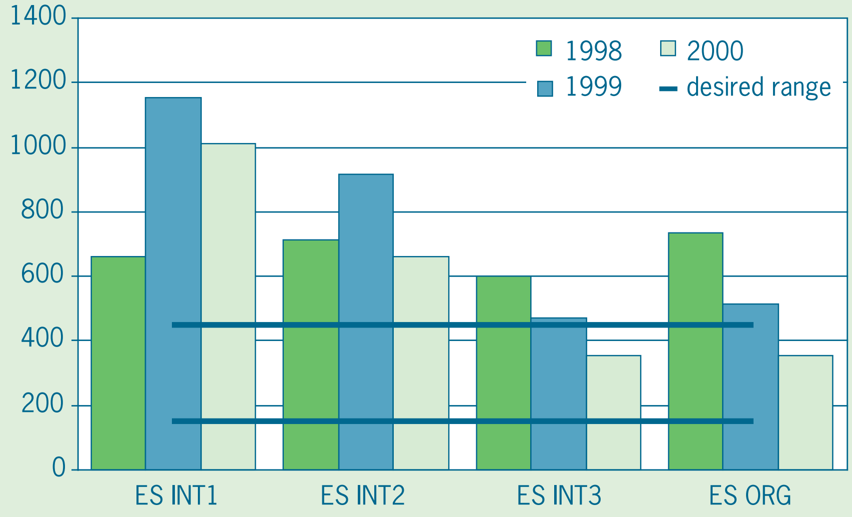

Figure 5.17 Avaiable potash reserves in soil (mg K_2O kg^{-1} soil)

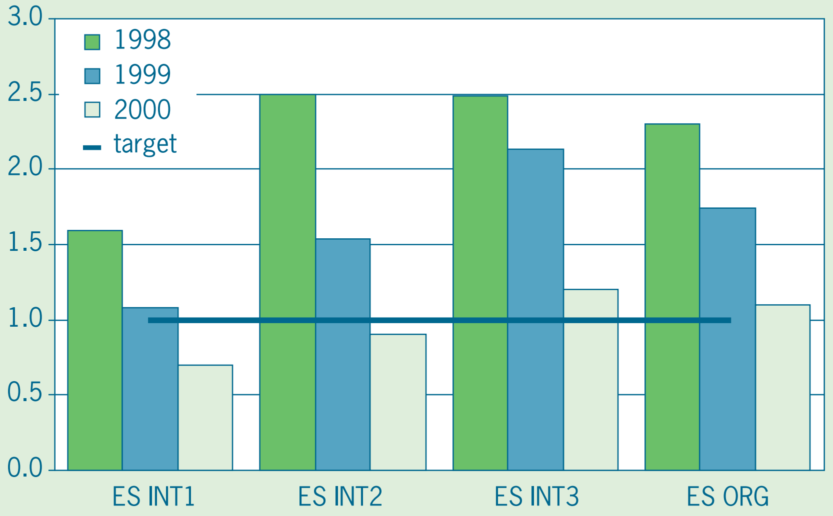

Figure 5.18 Organic matter balance

Phosphate and potash reserves

Available reserves of phosphate and potash were tested in the soil layer 0-30 cm using the sodium bicarbonate (Olsen) method for phosphate, and the ammonium acetate method for potash. The results of available reserves of soil phosphorus and potash obtained in the systems are shown in Figures 5.16 and 5.17. Several remarks can be made from this data: firstly, the values of available reserves of phosphorus and potash in all the systems are higher than the desired range; secondly, a move to reduce the levels of phosphorus and potash reserves could be seen between 1998 and 2000, with the exception of ES INT1and ES INT2, which showed a great variation from year to year.

Targets on these parameters could not be met due to a combination of factors: the figures for the Spanish systems were extremely high, nutrient changes in soil take place very slowly, and the 2.5 year period for the Vegineco project was too short to have any effect on these parameters.

Table 5.6 Energy input per crop, 1999

	Percentage over total energy input					
	Cauliflower		Fennel		Lettuce	
	ES INT	ES ORG	ES INT	ES ORG	ES INT	ES ORG
Total machinery	*28.2*	*27.8*	*19.5*	*19.0*	*28.7*	*27.0*
Direct	15.2	15.3	11.1	10.5	16.0	15.2
Indirect	13.0	12.5	8.4	8.5	12.7	11.9
Other equipment	*4.1*	*4.3*	*7.2*	*7.2*	*4.7*	*5.0*
Hand labour	*0.5*	*1.0*	*0.6*	*0.9*	*0.5*	*0.6*
Total consumables	*67.2*	*66.9*	*72.7*	*72.9*	*66.0*	*67.4*
Fertilisers	2.9	0.5	1.6	0.5	0.3	0.3
Pesticides	4.2	3.0	2.2	3.3	3.7	1.6
Plant material, seedlings	9.1	9.6	32.3	32.4	19.0	20.0
Water	51.0	53.8	36.7	36.8	43.0	45.4
Total	100.0	100.0	100.0	100.0	100.0	100.0
total energy input	47 737	45 283	49 382	49 247	53 442	50 641
energy input/piece (MJ piece^{-1} or ton^{-1})	1 821	1 594	2 062	1 975	1 188	1 407
energy input/ton (MJ ton^{-1})	1 492	1 265	2 062	1 975	1 120	1 327

Balance of organic matter
The 'organic matter balance' (OMAB), as a ratio of inputs to losses, was estimated for the different systems, and the results are shown in Figure 5.1. In all cases, the values of OMAB were close to or higher than 1 (the target value). In the two first years of the project (1998 and 1999), the OMAB figures were much higher than in 2000, during which no organic fertiliser was applied to the crops.
Remarkably, in some cases, the contribution of crop residues and green manure to the input of effective organic matter can be sufficient to balance the loss of organic matter by mineralisation.

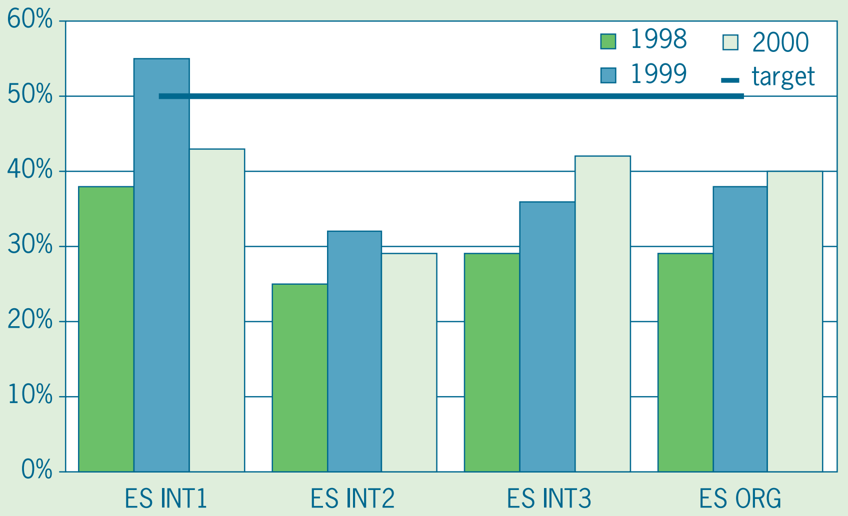

Figure 5.19 Soil Cover Index per system system (%)

5.3.8 Soil Cover Index (SCI)

This parameter was useful for evaluating the extent to which soil was protected from erosive agents. The remains of crops were kept until 20-30 days before the following crop, by either triturating them or leaving them on the surface. Then they were incorporated into the soil. The Soil Cover Index (SCI) ranged from 0.25 to 0.55. This means that between 25 and 55% of the total soil surface was covered during one year (see Figure 5.19). This parameter is related with the number of crops per year and their capacity to cover the soil and that is why, in ES INT1, ES INT3 and ES ORG, this index is higher than in ES INT2 where there was one less crop than in ES INT3 and three less than in ES INT1. The target for SCI (0.5) is probably too ambitious and can only be reached in exceptional cases.
In two cases, a number of sanitary problems arose because crop remains were permanently present: onions preceded by green beans or lettuce in ES INT3 and ES ORG, and iceberg lettuce preceded by broccoli in ES INT1. In the first case, the crop remains were fed on by Delia sp., which then seriously affected the following crop of onion; similarly, the remains of the broccoli crop sometimes increased the level of Agriotes sp. and Sclerotinia sp. in the following crop of Iceberg lettuce.

5.3.9 Energy efficiency

This parameter was calculated for lettuce, fennel and cauliflower crops. Irrigation water had the highest energy requirements (on average, 44% of the total energy used), followed by seeds and plants (20% of the total energy used, on average) and transport (15%). There are no significant differences in the total energy input between the integrated and organic systems (less than 6%). The most important values obtained in calculating energy efficiency are shown in Table 5.6.

From Table 5.6, it can be seen that the energy input was very similar for the three crops and that the most important differences occured when this energy was calculated per unit of yield. Therefore, the yield quantity is directly linked to the energy input per unit (24 ton in fennel, 48 ton in roman lettuce and 32 ton in cauliflower). The energy used on seeds and seedlings was also higher in the fennel crop since there were more plants per hectare than in the other crops. The difference between the integrated and organic cauliflower crops was caused by a lower yield in ES INT3 in 1999 and more energy needed to apply fertilizers and pesticides. For fennel, where a lower yield was obtained in the organic system, the opposite was the case. In the lettuce crop, expenses for pesticides and fertilizers were higher in the integrated system, but yields were higher than in ES ORG.

6 Results of testing and improving vegetable pilot farms in Switzerland

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6.1 Introduction

Integrated and organic farming are already well established in Switzerland. In 1999, 95.3% of the agricultural area was cultivated organically in accordance with the Swiss regulation Ökologischer Leistungsnachweis, 7.3% of which was organic farming (Agrarbericht 2000, Swiss Federal Office for Agriculture, Bern). Thus, the data for the Vegineco project could be gathered at commercial pilot farms instead of experimental farms. Seven integrated and seven organic pilot farms took part in the project (Figure 6.1). Vegetable production in Switzerland is very heterogeneous and small-structured which often makes it difficult to compare individual farms. In order to show the differences and problems in integrated and organic production of field grown vegetables, three integrated and three organic farms were selected from the 14 pilot farms and combined in pairs (see Figure 6.1). The first pair (CH INT1, CH ORG1) consisted of neighbouring farms in the Zurich canton which delivered their produce mainly to wholesale distributors (Migros, Coop), the second pair (CH INT2, CH ORG2) were direct sellers in the western part of Switzerland, and the third pair (CH INT3, CH ORG3) were farms from the Seeland region, delivering mainly to retailers or wholesalers.

6.2 Crops and rotations

The analysis concentrated on the five most important field-grown vegetables in Switzerland: head lettuce, cauliflower, carrots, leek and onions.
The two most common types of crop rotation are: a 3-4 year rotation based on the susceptibility of plant families to nematodes and soil-born diseases, and a 6-12 year rotation containing a high proportion of arable crops. Both types can be found in integrated and organic farming.

6.3 Results

6.3.1 Overview of Results

The main shortfalls can be found under the topic 'sustainable use of resources' (Figure 6.2) due to an excessive supply of compound fertilisers in the past. In integrated and organic farming, bad weather conditions and pests and diseases affected 'production quality'. However, it was only the integrated pilot farms that failed to reach the target set for 'farm continuity'. It seems that the market prices for certain integrated vegetables are insufficient to guarantee farm continuity.
The targets set for many of the Vegineco parameters cannot be fulfilled just from the effects of a cropping strategy. The levels reached are the result of the combined effects of many interacting factors.

Farm continuity
Details of the pilot farms can be found in Table 6.3. General economic data on the most important crops are summarised in Table 6.4.

In Switzerland, the Vegineco parameter 'net surplus' was replaced by the parameter 'net surplus estimation'. The definition is as follows: 'net surplus estimation' = gross revenues (= yield * price) – costs of cultivation. Its target is ≥0.

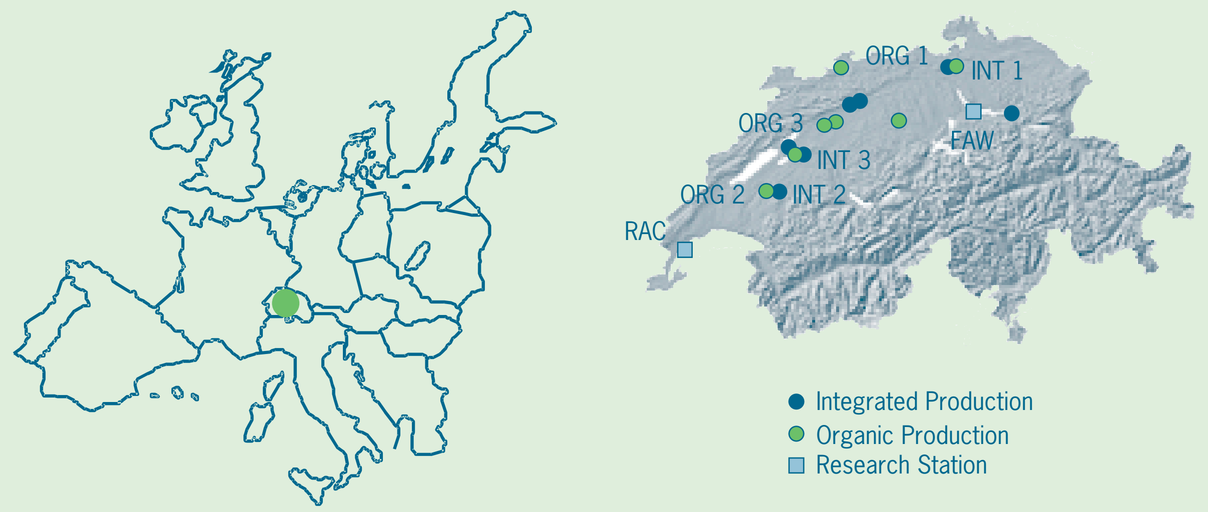

Figure 6.1 Location of the 14 pilot farms in Switzerland

At five pilot farms, the production of head lettuce led to positive values for 'net surplus estimation'; i.e. the target was exceeded. Only CH INT3 missed the target every year of the evaluation period, 1998-2000 (see Figure 6.3). This corresponds with the bad performance of CH INT3 with respect to general farm continuity (see Figure 6.2) caused by high pest and disease pressure and low prices. The values for the organic farms, however, seem to be over-emphasised, since the production costs were calculated, for direct comparison, on the basis of the available data for integrated production. Depending on the crop, the allocated costs in organic production can be higher than in integrated production (see cauliflower in Table 6.4). For most organic crops, however, detailed data were available.

6.3.2 Quality production

Quantity and quality

Due to abiotic (e.g., high precipitation or dryness) or biot-

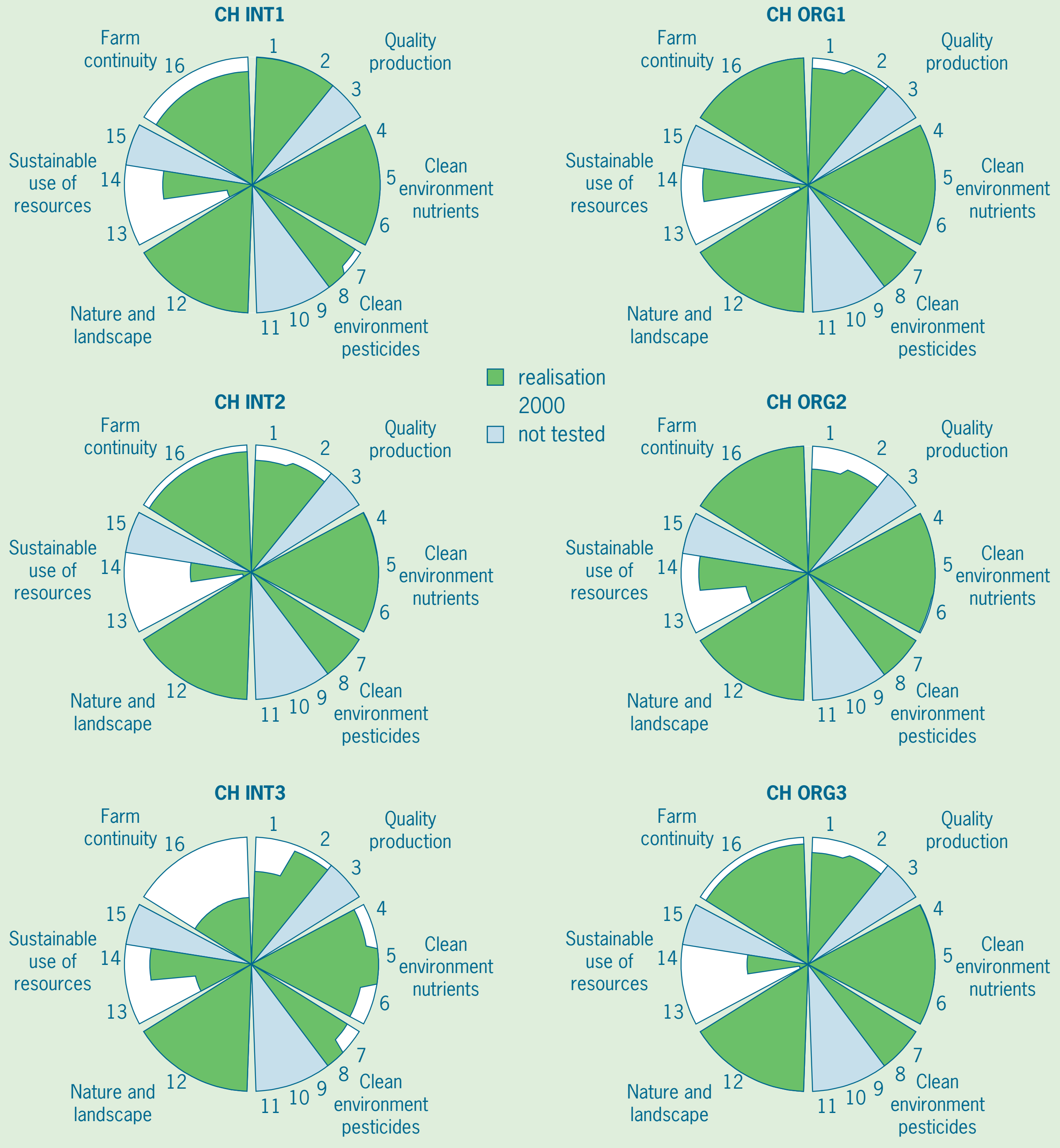

Figure 6.2 Relative realisation of the parameter targets for the Swiss pilot farms in the year 2000

ic causes (e.g. downy mildew, caterpillars), the results for yield (QNP) showed great variation over the years (see Figure 6.4). In some cases, these was a loss in total yield, while in other cases the target was even exceeded. For instance, hail in 1999, and bottom rot and bacteria in 2000, had dramatic effects on the yield of head lettuce at CH INT2 (see Figure 6.5). Thus, every farm had to be analysed individually. Nevertheless, a three-year comparison of the data gathered was insufficient to draw general conclusions about the performance of the integrated and organic production systems.

Nitrate content

Among the five selected crops, the nitrate content in Switzerland is only relevant in head lettuce, and especially in crops grown in greenhouses. For lettuce, there is a maximum tolerated value, which amounts to 3 500 ppm. As the investigations in field trials at selected pilot farms have shown, the nitrate content in field-grown head lettuce is much lower than the maximum tolerated value (see Table 6.5).

6.3.3 Environment nutrients

The results under 'environment nutrients' were quantified

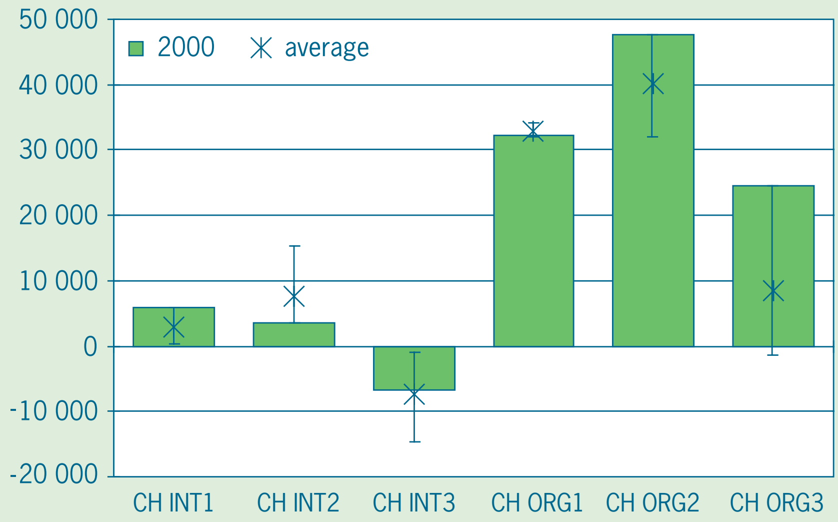

Figure 6.3 'Net surplus estimation' (€ ha $^{-1}$) for head lettuce at six pilot farms in the year 2000 (plus the variation and average in 1998-2000)

Table 6.1 Absolute target values and realisation per parameter (in 2000 and in 1998-2000)

Theme	No	Parameter	Desired results	CH INT1 2000	CH INT1 97-00	CH INT2 2000	CH INT2 97-00	CH INT3 2000	CH INT3 97-00
Quality Production	1	Quantity of produce	1.0 (≥GAP)	1.0	0.86	0.88	0.81	0.73	0.83
	2	Quality of produce	1.0 (≥GAP)	1.0	0.89	0.92	0.91	0.95	0.94
	3	N-content in produce	<3 500 ppm	-	-	-	-	-	-
Environment Nutrients	4	Estimation of P_2O_5 balance	≤1.0	1.11	0.96	1.00	0.96	1.09	1.03
	5	Estimation of K_2O balance	≤1.0	1.17	0.91	0.94	1.06	0.44	0.82
	6	Available reserves of N	<75 kg ha^{-1}	46[1]	-	33[1]	-	84[1]	-
Environment Pesticides	7	Number of treatments	GAP	0.95	0.98	1.0	0.97	0.89	0.65
	8	Copper input from pesticide	≤4 kg ha^{-1}	1.0	1.0	1.0	1.0	1.0	1.0
	9	Pesticide emission in air	-	-	-	-	-	-	-
	10	Pesticide emission in gr. water	-	-	-	-	-	-	-
	11	Pesticide emission in soil	-	-	-	-	-	-	-
Nature, landscape	12	Ecological infrastructure index	≥5%	1.0	1.0	1.0	1.0	1.0	1.0
Sustainable use of resources	13	Available reserves of P_2O_5	40<Pw-count<80	143[1]	-	116[1]	-	143[1]	-
	14	Available reserves of K_2O	120<K-count<200	244[1]	-	243[1]	-	244[1]	-
	15	Balance of organic matter	-	-	-	-	-	-	-
Farm continuity	16	Estimation of net surplus	1.0 (relative value)	0.89	0.79	0.95	0.88	0.53	0.64

[1] 1998 data

by the system parameters ‘available nitrogen reserves at the start of the leaching season’ (NAR), and the ‘estimations of the annual balances of phosphate and potash’ (PAB/KAB). Instead of the input/off-take balance of the other partners in the project, the Swiss nutrient balance estimation was calculated as an input/demand balance. The import of nutrients into the whole farm was compared with the recommended amount of nutrients (demand) for all crops cultivated at the farm.

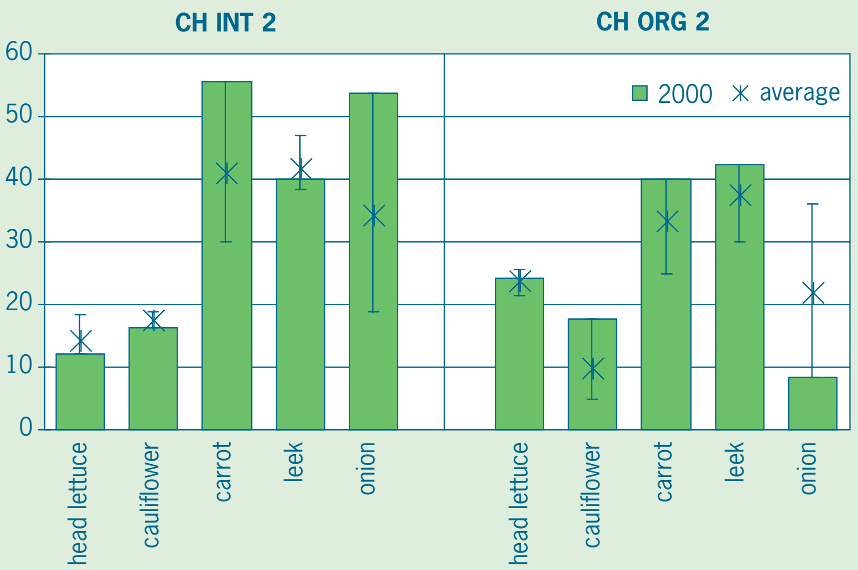

Figure 6.4 Yield of five important vegetable crops (tons ha^{-1}) at pilot farms CH INT2 and CH ORG2 in the year 2000 (plus variation and average in 1998-2000)

Nitrogen

At all the pilot farms, the input of available nitrogen corresponded with the net demands (nutrient demand - nutrients in crop residues) of the crops. Therefore, the surplus was lower than the tolerance margin of 10% (see Figure 6.6). Among the integrated and the organic farm pairs, CH INT2 and CH ORG2 had the lowest demands, since they produced small crops for direct

Table 6.2 Absolute target values and realisation per parameter (in 2000 and 1998-2000)

Theme	No	Parameter	Desired results	CH ORG1 2000	CH ORG1 97-00	CH ORG2 2000	CH ORG2 97-00	CH ORG3 2000	CH ORG3 97-00
Quality Production	1	Quantity of produce	1.0 (≥GAP)	0.85	0.81	0.82	0.74	0.92	0.87
	2	Quality of produce	1.0 (≥GAP)	0.98	0.96	0.87	0.86	0.97	0.95
	3	N-content in produce	<3 500 ppm	-	-	-	-	-	-
Environment Nutrients	4	Estimation of P_2O_5 balance	≤1.0	1.03	0.69	0.45[2]	0.45	1.33[2]	1.20
	5	Estimation of K_2O balance	≤1.0	1.30	0.70	0.46[2]	0.46	0.46[2]	0.37
	6	Available reserves of N	<75 kg ha^{-1}	54[1]	-	76[1]	-	26[1]	-
Environment Pesticides	7	Number of treatments	GAP	1.0	0.98	1.0	1.0	1.0	1.0
	8	Copper input from pesticide	≤4 kg ha^{-1}	1.0	1.0	1.0	1.0	1.0	1.0
	9	Pesticide emission in air	-	-	-	-	-	-	-
	10	Pesticide emission in gr. water	-	-	-	-	-	-	-
	11	Pesticide emission in soil	-	-	-	-	-	-	-
Nature, landscape	12	Ecological infrastructure index	≥5%	1.0	1.0	1.0	1.0	1.0	1.0
Sustainable use of resources	13	Available reserves of P_2O_5	40<Pw-count<80	197[1]	-	88[1]	-	142[1]	-
	14	Available reserves of K_2O	120<K-count<200	244[1]	-	243[1]	-	244[1]	-
	15	Balance of organic matter	-	-	-	-	-	-	-
Farm continuity	16	Estimation of net surplus	1.0 (relative value)	0.89	0.79	0.95	0.88	0.53	0.64

[1] 1998 data
[2] 1999 data

Table 6.3 *Characterisation of the six selected pilot farms in Switzerland*

Farm	Canton	Total size (ha)	Vegetable area (ha)	Trade channel
CH INT1	Zurich	26.0	19.5	wholesale distributors
CH ORG1	Zurich	24.0	19.7	wholesale distributors
CH INT2	Fribourg	5.4	1.1	direct sale
CH ORG2	Waadt	9.0	2.1	direct sale
CH INT3	Fribourg	13.5	9.2	retailers or wholesalers
CH ORG3	Bern	12.0	8.0	direct sale, retailers or wholesalers

Table 6.4 *Economic data of selected crops per ha (based on 'Daten Gemüsekulturen 2000', Landwirtschaftliche Beratungszentrale, CH-8315 Lindau), 1.0 SFR = € 0.655*

Crop	Gross revenues		Allocated costs		Gross margin		Labour input
	SFR	€	SFR	€	SFR	€	Hours
Head lettuce	36 240	23 737	13 199	8 645	23 041	15 092	797
Cauliflower CH INT	35 728	23 402	9 888	6 477	25 840	16 925	717
Cauliflower CH ORG	30 110	19 722	12 504	8 190	17 606	11 532	728
Carrots (storage)	25 225	16 522	7 772	5 091	17 453	11 432	894
Leek	61 320	40 165	17 554	11 498	43 766	28 667	1 652
Onion (storage)	22 130	14 495	6 801	4 455	15 329	10 040	512

marketing, whereas the other farms sold to retailers, wholesalers or wholesaler distributors. At the organic farms CH ORG1 and CH ORG3, especially, there has been a clear increase in the input of nitrogen during the last three years.

The 'available nitrogen reserves' (NAR) were determined on all vegetable plots of the pilot farms in autumn 1998. The NAR values within a farm showed a high variation, due to different soil types and organic-matter contents, different sampling dates and leaching intensity and different crops and fertilisation (see Figure 6.7). On average, all pilot farms achieved the target of ≤75 kg N-min ha^{-1} (0-60 cm). One exception was pilot farm CH INT3, which had a high percentage of organic soils and up to 40% of organic matter content. The NAR exceeded the target in plots with more than 10% of organic-matter content. There was also a great variation in NAR at farm level among the integrated and the organic farms. The differences between both farming systems were therefore, not very significant.

Phosphate and potash

The Swiss nutrient balance estimation was calculated as a balance between inputs and demand.

The input of phosphate should not exceed the total net demand (nutrient demand - nutrients in crop residues), allowing for a tolerance margin of 10%.

The element potash is considered as being less harmful to the environment than phosphate, so there is no official limit in Switzerland. Using nutrient imports, the integrated farms were better able to meet nutrient demand, and so to keep to the PAB guidelines (see Figures 6.8 and 6.9). On the organic farm CH ORG3, the phosphate input

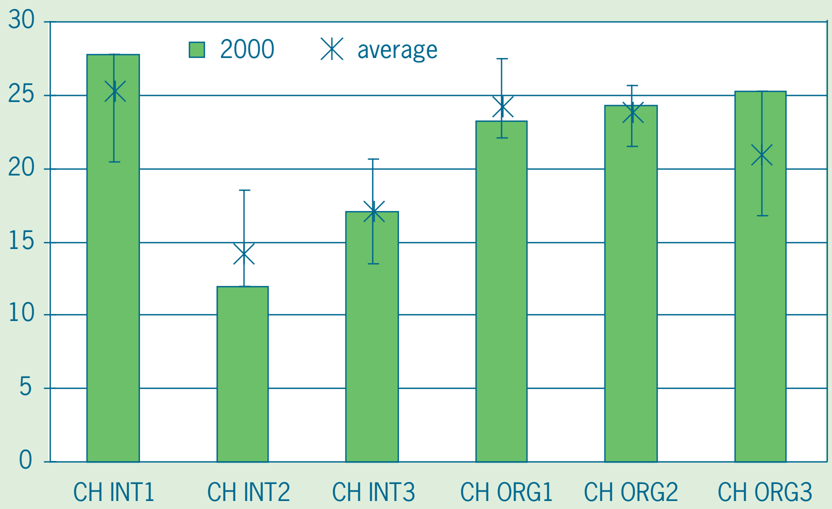

Figure 6.5 Yield of head lettuce (tons ha^{-1}) at six pilot farms in the year 2000 (plus the variation and average in 1998-2000)

Table 6.5 Nitrate content in head lettuce at Swiss pilot farms, target ≤3 500 ppm

Pilot farm	Year	Period	Nitrate content
Integrated	1998	spring	178 - 1 297 ppm
Integrated	1998	summer	766 - 1 641 ppm
Organic	1999	early spring	153 ppm

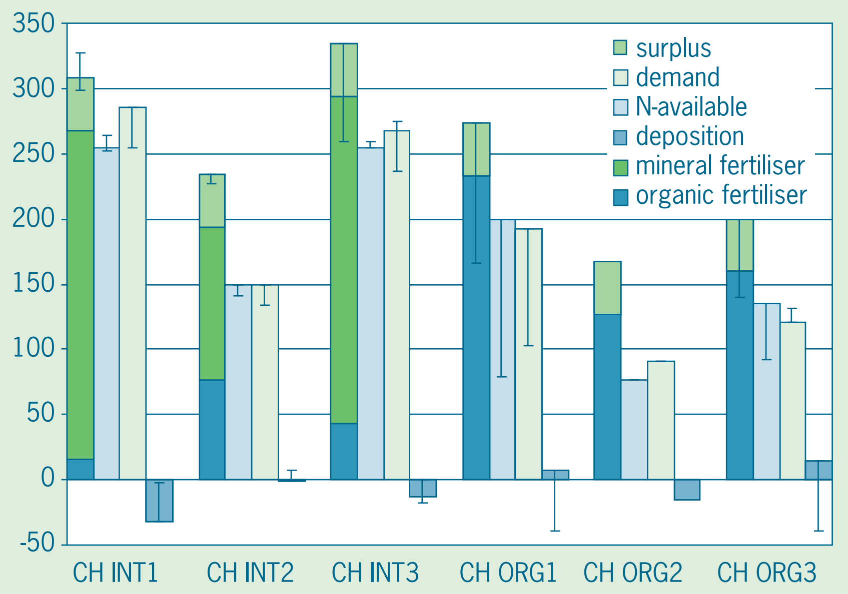

Figure 6.6 Nitrogen input, demand, and surplus at six Swiss pilot farms in 2000 (kg N ha-1), and the variation in 1998-2000 (for CH ORG2, the only data available were for 1999)

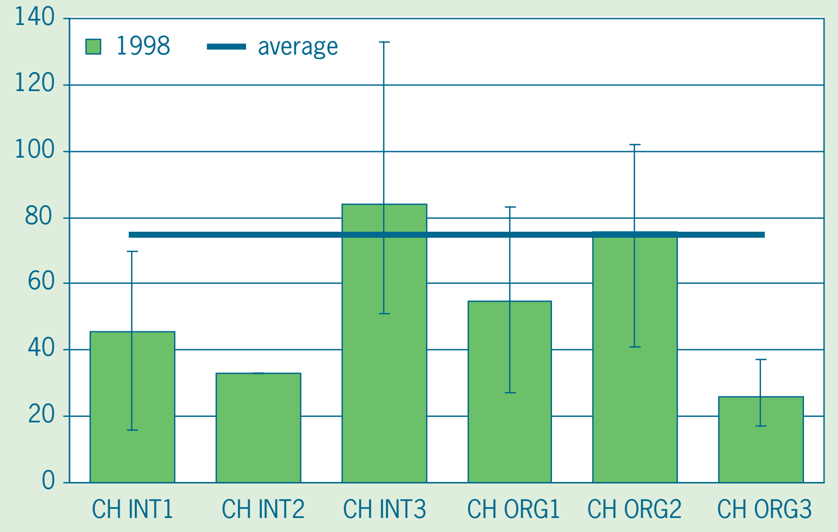

Figure 6.7 Available nitrogen reserves in autumn 1998 (kg ha-1), and the average and variation among the vegetable plots of the farms (CH INT2 has only one vegetable plot)

exceeded the tolerance margin, whereas at all the organic farms and at integrated farm, CH INT3, potash imports were too low.

6.3.4 Environment Pesticides

In contrast to the other partners, the Swiss results for the theme 'environment pesticides' are quantified as the number of pesticide treatments. They replace the parameters 'pesticide active ingredient input' (PESTAS) and 'environment exposure to pesticides' (EEP). From the Swiss perspective, it is not sufficient just to look at active ingredients. Very active compounds such as the synthetic pyrethroids are used in very small amounts of active ingredients per ha. Nevertheless, they can have very serious side effects. Since every treatment has known or unknown negative side effects, the Swiss partner characterised the pesticide input and the pesticide emission by the number of treatments. In addition, to aid comparison with the other countries, the input of active ingredients is given.

For all crops, the integrated farm in the Seeland region, CH INT3, had the highest shortfall on targets. This was because, to combat high pest and disease pressure in the region, the farmer had treated his crops more often than is normal in good Swiss agricultural practice. In particular, he applied preventative treatment to cauliflower to avoid infestations by the gall midge, which is a serious pest in the Seeland region (see Figure 6.10). Contrary to the recommendations and the management of pest resistance by insecticides, to gain a seemingly desirable result, the farmer had sprayed this crop almost exclusively with one synthetic pyrethroid, but this resulted in the lowest input of active ingredients of all the integrated farms in the year 2000 (see Figure 6.11). At farm CH INT3, which was the most problematic with respect to the use of pesticides, the opposite took place, as is indicated by the number of treatments. It is easy to draw the wrong conclusions by just looking at the input of active ingredients, as this example shows.

Bacillus thuringiensis compounds were only used at the organic farms to control caterpillars in cauliflower or leek moth in leek. Copper was applied at both the integrated and the organic farms to control the very harmful Oomycetes fungi (Phytophthora porri) in leek, downy mildew (Bremia lactucae) in lettuce and downy mildew (Peronospora destructor) in onion. At present, copper is the only available fungicide to control these fungi at organic farms. Because of higher temperatures and rainfall than, for instance, in the Netherlands, these diseases are more severe in Switzerland, and have led to high or even total loss of yields in lettuce and onion crops at organic and also at integrated pilot farms. Since the use of copper was limited to these crops and diseases, the average yearly copper input per ha and year in the selected crops in Switzerland was low (see Figure 6.12). The copper input in the single crops was 50-90% lower than the maximum allowed dose of 4 kg copper ha^{-1} and $year^{-1}$. Sulphur was only used in amounts of 0.16 to 0.32 kg ha^{-1} per year as a synergist to copper, at organic farm CH ORG3.

6.3.5 Nature and landscape

The conservation of nature and landscape has been part of the label guidelines for integrated and organic vegetable production in Switzerland since 1996. Up to 1998, a minimum of 5% of the farm area had to be allotted to ecological infrastructure. In 1999 a new legislation came into force, which required an ecological compensation area of 3.5-7% at vegetable farms (see Figure 6.13). All the pilot farms in Switzerland met their targets in this respect. In the year 2000, the size of the compensated area at the six selected pilot farms varied from 6% at integrated farm CH INT1 to 37% at organic farm CH ORG2. In the last three years, the majority of the organic pilot farms have set aside a larger ecological compensation area than the integrated pilot farms.

Apart from the size of the ecological infrastructure area, the guidelines also include other criteria, such as, for instance, a minimum size for buffer zones in addition to woody elements. In the Ecological Infrastructure Management Manual, in the chapter on Switzerland, a comparison is made of the established Swiss method and the newly introduced Dutch methodology that resulted from the Vegineco project.
Because of the high precipitation in Switzerland, it is very important to conserve soil fertility and reduce soil erosion and leaching, especially in the winter. Therefore, Swiss farms have to achieve a soil cover index in winter. This depends on the proportion of arable crops to vegetable

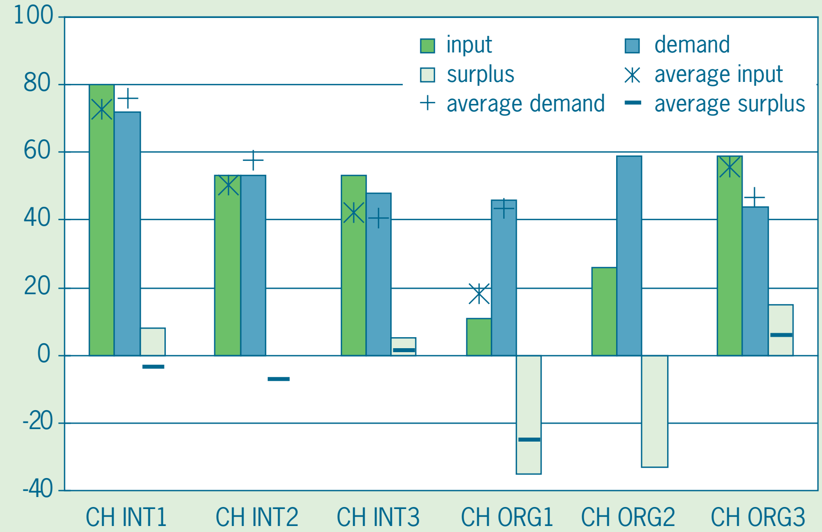

Figure 6.8 Phosphate input, demand and surplus at six Swiss pilot farms in 2000 and variation in 1998-2000 (kg P_2O_5 ha^{-1})

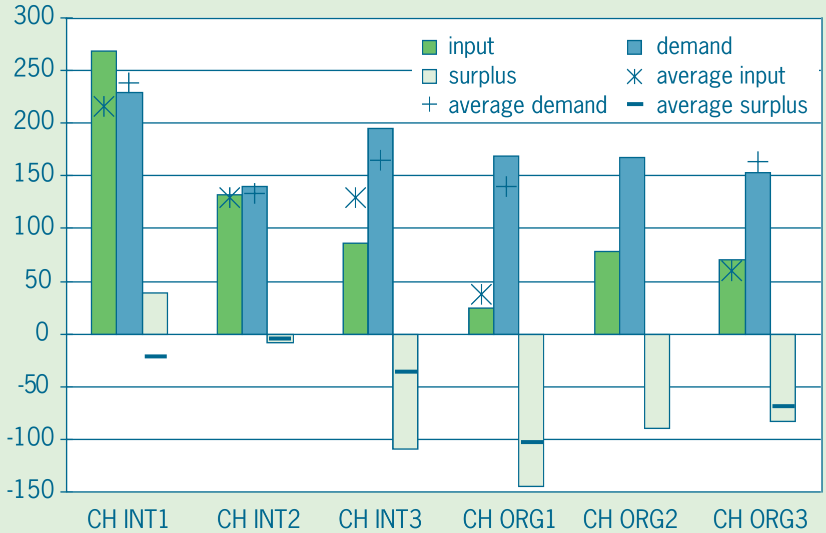

Figure 6.9 Potash input, demand and surplus at six Swiss pilot farms in 2000 and variation in 1998-2000 (kg P_2O_5 ha^{-1})

crops at the farm during that particular year, and is farm specific (see Figure 6.14). All the integrated and organic pilot farms met their soil-cover-index targets.

6.3.6 Sustainable use of Resources

The sustainable use of resources was quantified by the soil fertility parameters 'available reserves of phosphate and potash' (PAR and KAR) and 'organic matter balance' (OMAB).

Phosphate and potash reserves

Available reserves of phosphate and potash are determined every four years in Switzerland, since the response of soil fertility to fertilisation is very slow. Once in the project, in autumn 1998, soil samples were taken from all the vegetable plots of the pilot farms.

As compound fertilisers had been applied over many years already, Swiss soils were enriched with phosphate and potash. For phosphate, the desired range was exceeded, on average, at all the pilot farms (see Figure 6.15). At two organic and one integrated farm, the average potash reserves were within the target range, but they were too high at the other farms (see Figure 6.16). A large number of different soil types at a farm (e.g. on CH INT3) can partly explain a variable pattern of available reserves. Since the introduction of integrated production in Switzerland, it is necessary to take the soil nutrient reserves of a farm's last soil analysis into account when calculating yearly nutrient balances. However, to measure a reduction in PAR and KAR more time is needed than afforded by a 4-year project period.

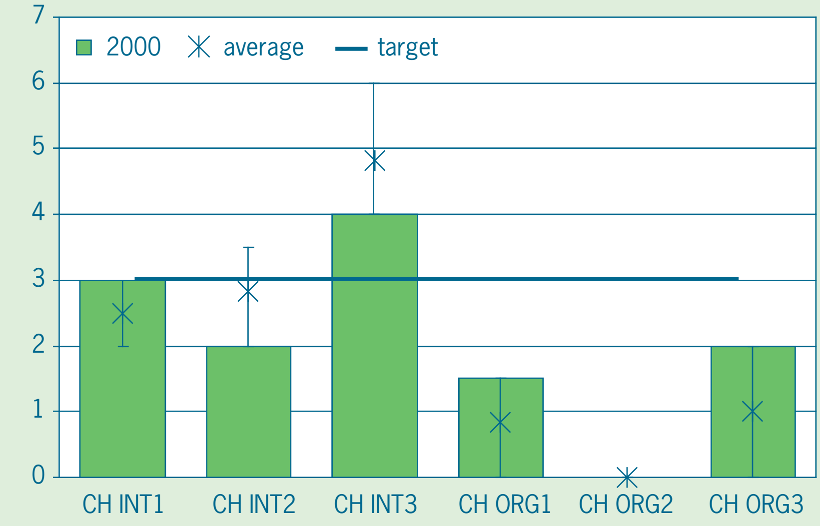

Figure 6.10 Number of treatments in cauliflower at six Swiss pilot farms (including treatments with Bacillus thuringiensis) in 2000, and the variation in 1998-2000

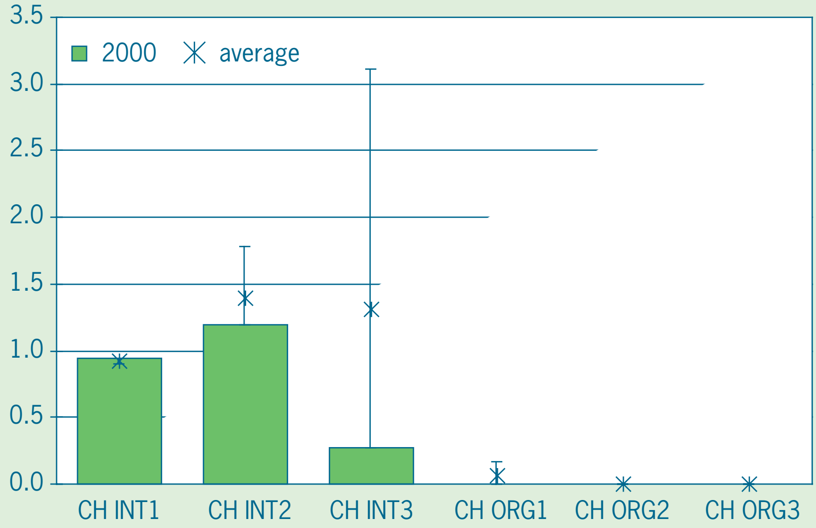

Figure 6.11 Active ingredient input in cauliflower at six Swiss pilot farms (excluding Bacillus thuringiensis compounds) in 2000, and the variation in 1998-2000 (kg ha^{-1})

Annual balance of organic matter (OMAB)

Swiss mineral soils generally have a high organic matter content (2-5%) (see Table 6.6), so further increases are normally unnecessary. On farms with a high percentage of organic soils, like CH INT3, an average organic matter content of as much as 18.5% was reached. Only fertilisers like manure, compost or commercial organic fertilisers were taken into account as organic matter input, but not crop residues. These were applied more regularly at organic farms since mineral fertilisers are not allowed there.

6.4 Conclusions

6.4.1 Farm continuity

Compared with integrated farms, the income of organic farms is equal or higher. Organic farms are often more flexible in pricing their produce, and thus can compensate for a lower quantity and quality.

Table 6.6	Organic matter content and organic matter input by fertilisers at six Swiss pilot farms			
Farm	Average organic matter content (in %) 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	not available	968	not available
CH ORG3	2.5	1 360	1 185	not available

6.4.2 Quality production

During the 3-year period of the Vegineco project in Switzerland, the average production quality of selected crops at the chosen pilot farms seems to be comparable for integrated and organic production (see Figures 6.3-6.8). In general, abiotic causes and pests, weeds and diseases more often lead to yield losses in organic than in integrated production, since the latter has more possibilities (synthetic fertilisers and pesticides) to react to those problems.

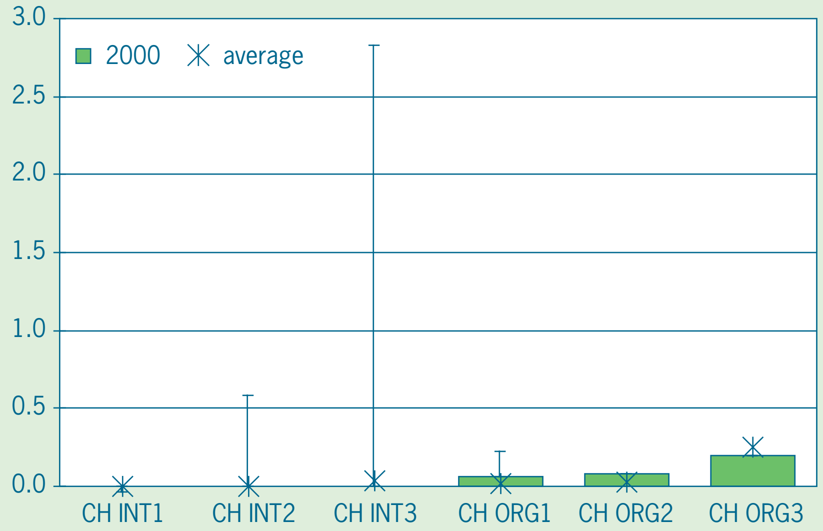

Figure 6.12 Average input of copper per ha and year on the selected crops at six Swiss pilot farms in 2000, and the variation in 1998-2000 (kg ha^{-1})

6.4.3 Nutrients

Integrated farmers use mineral fertilisers and often succeed better than organic farmers in meeting the nutrient demands of crops (especially phosphate and potash). Therefore, optimised integrated farming systems may have a less harmful impact on the environment. Nearly all the pilot farms met the target for available reserves of nitrogen, except those with organic soil. Thus, the organic matter content of the soil contributes more to available nitrogen reserve levels than the cropping system. Available reserves of phosphate and potash were above the desired range and it will take more than a 4-year project period to reduce them. The same is true for changes in organic matter content.

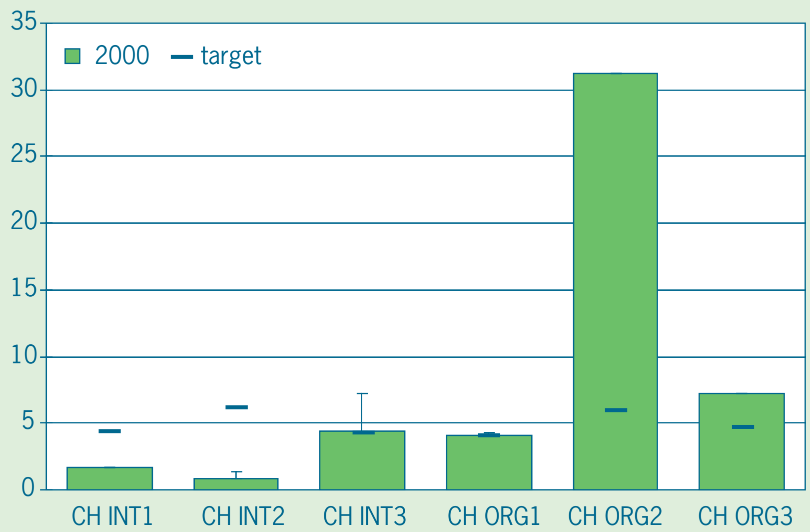

Figure 6.13 Ecological infrastructure area at six Swiss pilot farms in 2000, and the variation in 1998-2000 (% of farm area)

6.4.4 Pesticides

For a further reduction in the use of pesticides an intensified private or public extension service is

required. Nevertheless, the number of treatments that can be avoided by the supervised control of pests and diseases and manageable cropping strategies depends on the pest and disease pressure at a site and on the quality requirements of the trade channel.
At present, organic farms apply fewer treatments on most vegetable crops, compared to integrated farms. However, since the wholesale distributors started to sell organic food, the quality requirements and the crop protection strategies for organic vegetables have gradually been adjusted to integrated standards.

From the Swiss perspective, active ingredients alone are of very limited use. Very active compounds like the synthetic pyrethroids are used in very low amounts of active ingredients per ha, but, nevertheless, they can have serious side effects. Since every treatment has known or unknown negative side effects, the Swiss partner in the project preferred to express pesticide input and emission by the number of treatments. To manage pest resistance adequately, a different way of applying pesticides will have to be found.

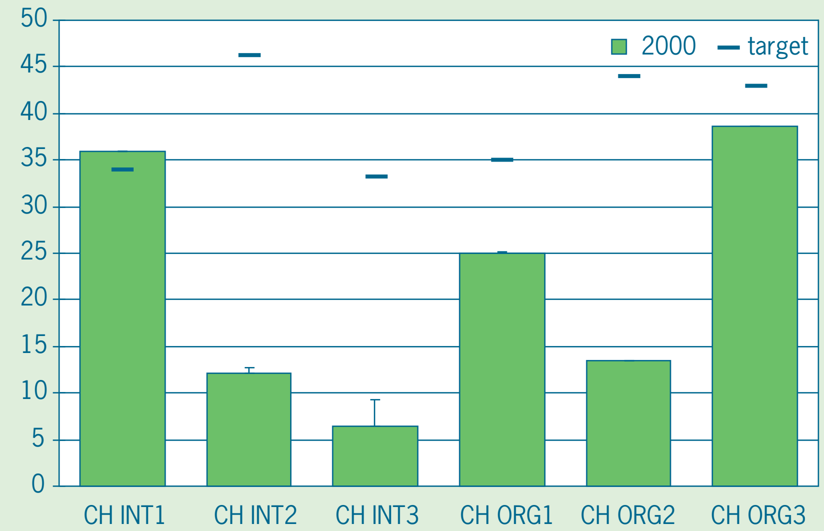

Figure 6.14 Soil cover index in winter of six Swiss pilot farms in 2000, and the variation 1998-2000 (the only available data for CH ORG2 and CH ORG3 are for 1999)

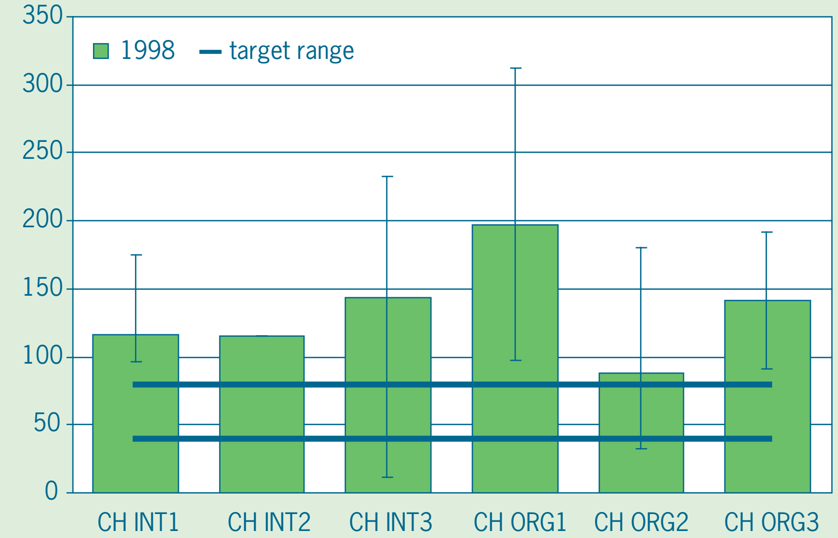

Figure 6.15 Available reserves of phosphate and its variation in fields at six Swiss pilot farms in autumn 1998 (desired range 40-80 mg kg^{-1}; NH4-ac-EDTA method, 1:10 weight extraction)

At present, copper is the only fungicide to control very harmful fungi like downy mildew in onion that is available to organic farms, so, in organic farming, immediate reductions in the use of copper do not seem feasible at the moment.

6.4.5 Ecological infrastructure

Ecological infrastructure areas, which are part of the Swiss label guidelines, are well established at integrated and organic farms in Switzerland. However, quality aspects of ecological infrastructure are still a matter of discussion and will be improved.

6.4.6 Summary

A very important contributory factor in the breakthrough of integrated and organic production in Switzerland, was the commitment of the wholesale distributors MIGROS and COOP. In recent years, the marketing of organic vegetables has led to stricter quality requirements which have gradually been adjusted to integrated standards. For this reason, integrated and organic production and the corresponding cropping strategies are becoming more similar. The extent to which the farm businss impacts on the environment depends more on where the farm is situated than on the production system used on that farm.

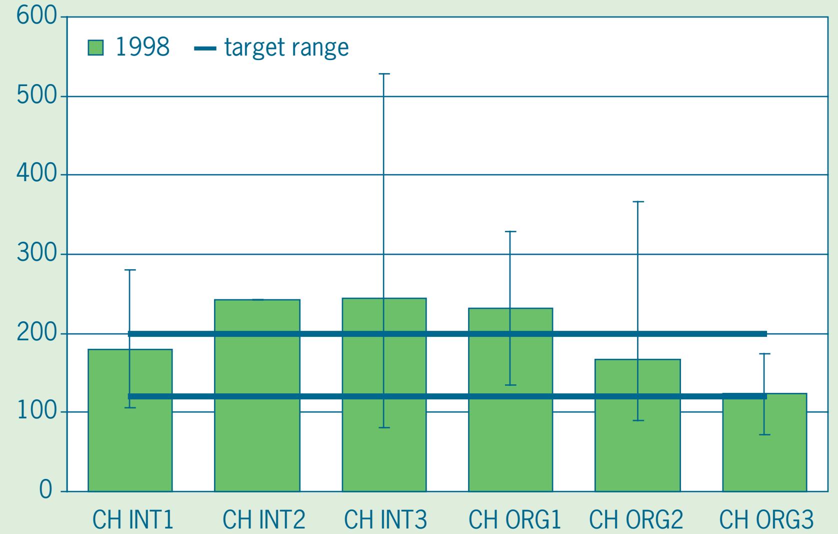

Figure 6.16 Available reserves of potash and its variation in fields at six Swiss pilot farms in autumn 1998 (desired range 120-200 mg kg^{-1}; NH4-ac-EDTA method, 1:10 weight extraction)

7 System comparison

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7.1 Introduction

This chapter compares the performance of integrated and organic vegetable farming systems within and between vegetable production regions in Europe. Unless otherwise stated, the data are for the year 2000. In some cases, these data are compared with the average data for the whole project period, and target values and/or reference data of average practice.
Research in Spain, Italy and the Netherlands was done on experimental farms, whereas, in Switzerland, it was done on integrated and organic pilot farms. The experimental farms reflect the standard farm types in the specific regions.
The comparison between countries and system types is hampered, due to different climatical and pedological conditions, different crops involved, influence of different farm management etc. For the comparison of organic and integrated systems within a country, the pairs that are best comparable are indicated with an asterix. The Spanish and the Dutch pairs are the most useful for comparing integrated and organic systems. In these cases both the organic and integrated systems were situated on the same location, had the same farm management and partly consisted of the same crops. In the Spanish situation the organic and integrated systems were even exactly the same in their crops and rotation.

7.2 Structural differences (farm structure)

Differences in farm type

There are many different farm types involved in vegetable farming in Europe. The differences are mainly brought about by cultural, climatic and economic conditions. At one end of this range of farm types are the small, intensive vegetable farms with low mechanisation, high labour input per ha, mostly with a low degree of specialisation. At the other end, there is the large, highly mechanised and highly specialised type of farm. The farms that were tested in the Vegineco project are representative of this range. However, in spite of their differences, all the farms were required to fulfill a series of sustainable production criteria. These criteria, formulated as the target values set for a series of parameters, were, in some cases, farm specific. For example, in some cases, the targets for production quality were different for organic and integrated systems. Farms were compared according to the degree in which these target values were met.

Differences between organic and integrated farming

The most important difference between organic and integrated farming is the use or rejection of mineral fertilisers and synthetic pesticides. On closer examination, however, there are numerous exceptions to this rule of thumb, e.g. the use of copper as a fungicide in organic farming, in some countries. Crop rotation is quite similar in the two systems, although rotations tend to be longer in organic farming.

Table 7.1 Integrated and organic farms used in the comparison

	System	Abbreviation	Farm size ha	Manpower number	No of crops/farm number	Rotation length years	Main vegetable crops
NL	Brussels Sprouts**	NL INT1	47	3.3	4	4	Brussels sprouts, potatoes, fennel, celeriac
	Iceberg lettuce**	NL INT2	28	3.1	4	4	iceberg lettuce, fennel, celeriac, potatoes
	Organic**	NL ORG	28	3.7	6	6	Brussels sprouts, iceberg lettuce, fennel, potatoes
I	Integrated industry	I INT1	27	1.7	6	4	tomato, melon, green beans, spinach
	Fresh market, integrated**	I INT2	4	2.3	6	4	lettuce, strawberry, melon, celery
	Fresh market, organic**	I ORG	4	2.7	5	4	lettuce, strawberry, melon, fennel
ES	Pilar de Horada	ES INT1	4	4.1	8	4	pepper, celery, little gem, watermelon
	Benicarlo	ES INT2	4	2.9	7	4	artichoke, lettuce, tomato, cauliflower
	Paiporta, Integrated**	ES INT3	4	3.0	7	4	watermelon, fennel, artichoke, onion
	Paiporta, Organic**	ES ORG	4	3.0	7	4	watermelon, fennel, artichoke, onion
CH	CH INT1	CH INT1	20	-	25-30	4	divers
	CH INT2**	CH INT2	1	-	25-30	4	divers
	CH INT3	CH INT3	9	-	25-30	4	divers
	CH ORG1	CH ORG1	20	-	30-40	4	divers
	CH ORG2**	CH ORG2	2	-	30-40	4	divers
	CH ORG3	CH ORG3	8	-	50-60	6 – 8	divers

** = the integrated and organic systems marked with double asterix are compared within a region

To compare the performance of integrated systems with organic farming, comparable farms within a region were selected as far as possible (see Table 7.1). The organic and integrated systems in Spain were not only located in the same area, at Paiporta, but they also had the same crops and rotation. For the Netherlands, the two integrated farms and the organic farm had the same location, and the crops farmed were mostly the same, but the length of rotations was different. In Italy, the crops grown on I ORG and I INT2 were mostly the same, but they were located in different places and their rotation system differed. The integrated and organic farms were the same farm types in Switzerland, most of their crops were similar, but they were located in different places.

7.3 Overview of Results

In Figure 7.1 the overall view of both systems is given as a pie chart. We will focus on the different parameters in the following sections. Production quantities fell short of the targets in both types of system, but the shortfalls were more pronounced in the integrated systems than in the organic ones. However, nitrate content was low in the products from both system types.

Most of the organic systems failed to reach the clean environment nutrient targets. This was due to the intensity of the systems and the exclusive use of organic fertilisers containing fixed ratios of nutrients. Because of these fixed ratios, it is very difficult to completely balance fertilisation to the needs of the crops. However, organic systems scored better than the integrated ones regarding to clean environment pesticides, mainly because synthetic pesticides are either used very sparingly or not at all. The only poor results, in organic systems, were in the use of copper. In the integrated system, the use of a few pesticides with a high potential for leaching into the groundwater resulted in very high levels for the parameter EEP-groundwater. The target for nature and landscape could not be reached in Italy and Spain, due to the small scale of the vegetable farms.

Due to high fertiliser use in the past, the nutrients in the soil of both systems are over abundant. This is a common picture in vegetable farming. However, the balance of organic matter was not good enough in half of the cases The organic systems performed a more positive organic matter balance, mainly caused by the greater use of organic fertilisers. In the integrated systems, there was no reason to use organic fertilisers, because of the high levels of nutrients in the soil.

The most striking difference between the organic and integrated systems lays in their capacity to meet the target set for farm continuity. In most cases, the integrated systems failed to reach this target, whereas the organic systems scored much better.

7.3.1 Farm continuity

The figures obtained by comparing farm continuity (see 'revenues per 100 costs', Figure 7.2) are difficult to compare because they are based on different crops, sites and prices in different countries. Despite this, it is obvious, that:

- For most tested integrated systems, as well as for the conventional farms used as reference, costs exceed income.
- For all organic systems, income exceeds costs.

The favourable revenue/cost ratio for organic systems in Spain and Switzerland was due to the high prices gained for organic vegetables sold directly at the farm gate. In the other countries too, the good financial results were

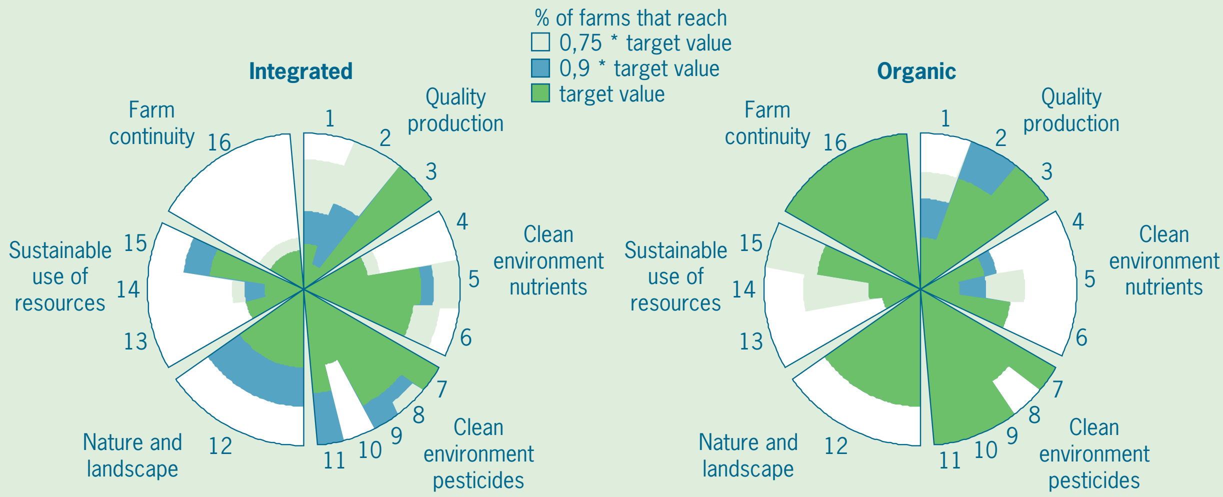

Figure 7.1 Comparison between integrated and organic systems, percentage of farms that reach 75%, 90% and 100% of the target value

due to high market prices. The higher prices paid for this produce compensated for lower yields and the extra number of hours needed for hand labour.

The numbers of hours needed for hand weeding, as demonstrated by the Spanish and Dutch systems, were two to four times higher in the organic system and thus made up a substantial proportion of the total costs. To reduce the time needed for hand weeding in farms with large fields significantly, mechanical weed control needs to be investigated. Experiments in large fields, in the Netherlands, showed that less than 10 hours ha^{-1} were needed in the integrated system and 40 hours ha^{-1} in the organic system, representing 5 - 15% of the total labour input. In Spain about 150 hours ha^{-1} were needed in the integrated system and about 350 hours ha^{-1} in the organic system, i.e. 10 - 22% of the total labour input.

In all integrated systems in the project, the costs of fertilisers and pesticides were considerably reduced compared with average farm practice. However, in vegetable farming, this cost category was a very small part of the total costs. In the test systems it was only between 3% and 7% of the total costs, and so had little effect on the farm's cost/income balance.

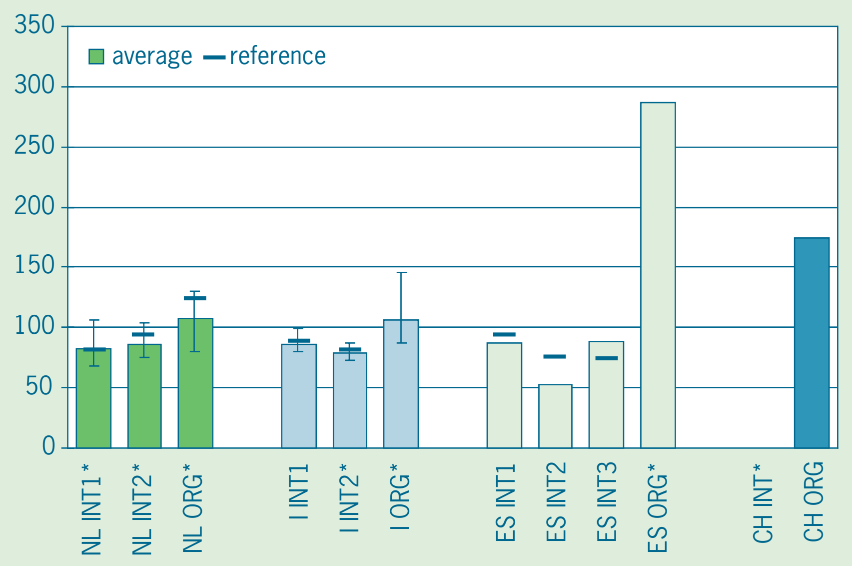

Figure 7.2 Income per 100 costs per farm (€ ha^{-1})

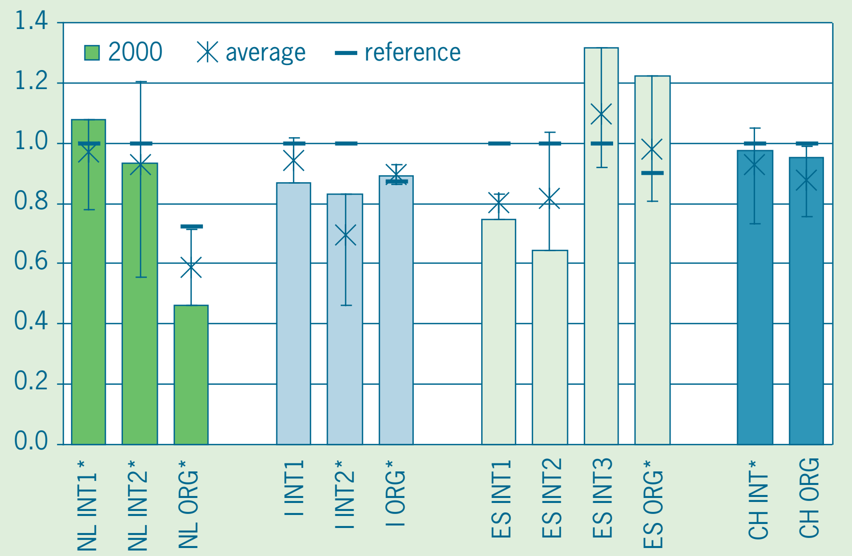

Figure 7.3 Integrated and organic yields on test system levels and regional good yields relative to integrated target yields

7.3.2 Production quality

The production quality levels achieved in the test systems were compared with accepted levels of good production quality for regional standard (conventional) farming. Production quality in the organic systems was also compared with this regional standard for conventional farming. Depending on the crop, the average achievement in standard practice is normally 80 to 100% of this regional good production standard. In most cases, average yields from the test systems (see Figure 7.3) was between 80 - 100% of the regional good production standard, which is comparable to the average result on conventional farms. Remarkable were the good results achieved by three of the four organic systems in the project, where the quality of produce equaled that of the regional good quality standard. The only organic systems to show significantly lower yields relative to this standard were the Dutch, where the quality was only 70% of the regional standard.

Depending on the crop, yields varied widely. For example, due to uncontrollable circumstances, the whole of lettuce crop was lost. Of course, both organic and integrated farms are subject to pests and diseases and to weather problems. In integrated production, however, the farmer has more possibilities to react to threats from pests and diseases. The differences in yields between integrated and organic systems are also strongly dependent upon the crop. Pests and diseases cause most of the losses in organic grown crops. A comparison of fennel, potato and lettuce yields in the Netherlands and Spain (Figure 7.4) it shows that fennel is an 'easy' crop, because there is no difference in yield between the organic and integrated systems. However, if yields per country are compared, important differences emerge (20 tons in the Netherlands and 30 tons in Spain), probably because of different growing conditions (light, temperature, rainfall, etc.). Potato and lettuce are clearly more difficult crops. In the organic system, substantially lower yields — up to 50% lower than integrated — were obtained. For lettuce, this was caused by aphids in the Netherlands and Spain and downy mildew in the Netherlands. In the Dutch potato crop this was caused by late blight due to humid conditions and, in the organic system, it was partly due to rejecting the use of 'bio' pesticides, such as copper.

7.3.3 Sustainable use of resources

In this theme, one can distinguish between on-farm resources, e.g. as soil or biodiversity, and off-farm resources such as energy and water. A methodology for the quantification of farm input of (fossil) energy was developed during the project, but it has not been used as a steering parameter yet. The efficient use of water has neither been quantified nor used as a steering parameter, but should definitely be considered in future, as it plays such an important role, especially in the Mediterranean countries.

Comparisons under this theme will only deal with soil as an on-farm resource, taking into account the reserves of phosphate, potash and organic matter in the soil. Changes in these soil parameters are very slow and can hardly be established within a 4-year period. Therefore priority was given to creating strategies to move reserves in the desired direction.

For phosphate and potash, an agronomically sufficient and environmentally desired range was defined of (available) reserves in the soil. Figure 7.5 shows the relative deviation of actual soil reserves from this desired range. Levels above this range mean that soil nutrients have to be decreased because they are detrimental to the environment. This occurs very often with phosphate in fields used to produce vegetables and is also the case for a number of the tested systems (see Figure 7.5). A long-term reduction in these excess soil reserves is easily manageable where only mineral fertilisers are used, but in organic systems or in systems where the organic-matter content in the soil is too low, the need to apply organic fertilisers makes a

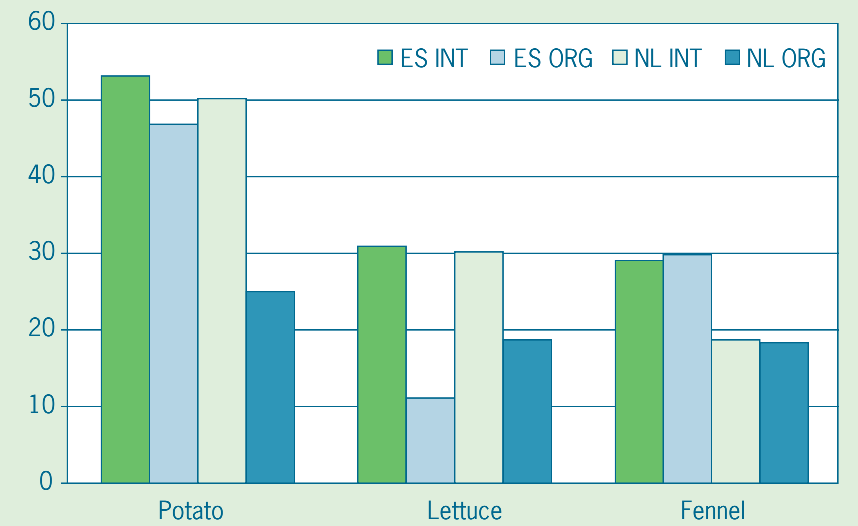

Figure 7.4 Average yields of potato, lettuce and fennel in the Netherlands in the INT 1 and 2 systems, and in the Spanish INT3 and ORG systems (tons ha-1)

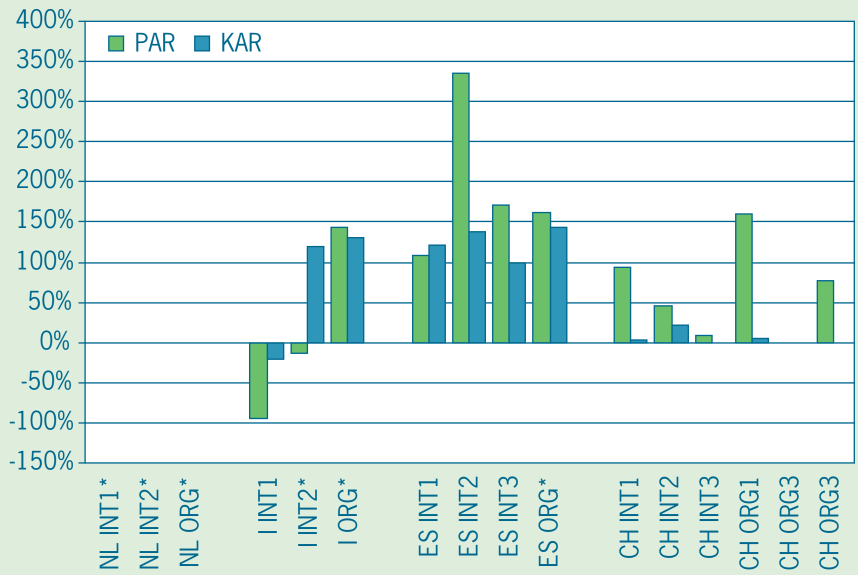

Figure 7.5 Phosphate and potash reserves, the relative deviation of the desired range per system

long-term reduction of excess reserves more difficult to achieve. The effects of fertilisation strategies regarding surpluses of phosphate and potash can be found under the heading 'environment nutrients'.

Not enough information has been gathered so far to establish the optimum range for organic matter content. The Italian I INT2 seemed to need more input of organic matter in order to improve the soil structure. The strategies applied for the input of organic matter focused on at least maintaining existing levels of organic matter content. The desired level of input was based on a respiration rate of soil organic matter of 2-3% per year. Except for the Italian fresh market systems (I INT2 and I ORG), all other systems showed sufficient input of effective organic matter. In I INT2 and I ORG, the extra input of effective organic matter required conflicted with the need to reduce phosphate (in I ORG) and potash (in I INT2 and I ORG) inputs.

7.3.4 Clean environment nutrients

Risks from nitrate leaching

For the Netherlands, Italy and Spain, the available reserves of nitrogen in autumn (NAR) are at least in a reasonably good balance with the nitrate concentration in the upper layer of the groundwater. Although NAR is influenced by controllable factors such as the fertilisation strategy, it is also partly influenced by certain factors that are partly or entirely uncontrollable in the long term, such as the rate of mineralisation, precipitation surplus, nitrogen deposition, nitrogen in irrigation water, and crop choice. For these reasons, the efforts to lower the NAR in the Italian and Spanish systems was only partially successful. In this cases regional- and farm-specific measures can only improve this situation in the long term.

Nitrogen surplus, which is one of the factors causing leaching, did not exceed a level of 125 kg ha^{-1} (excluding deposition) in any of the Dutch, Italian or Swiss systems. In practice, in the Dutch and Italian systems, this meant an average reduction in the nitrogen level of 60 to 80 kg ha^{-1}. In the Spanish systems, the nitrogen surplus in the year 2000 varied from –120 kg ha^{-1} because of a high rate of mineralisation to +470 kg ha^{-1} because of the high concentration of nitrates in irrigation water.

The target value for available reserves of nitrogen in autumn (NAR) was set at 70 kg nitrogen ha^{-1} (layer 0-100 cm). In Spain and Italy, the available reserves of nitrogen were much higher than the target value in both the integrated and organic systems. In Spain and Italy, the available nitrogen reserves in integrated or organic systems varied greatly. In most cases, the extremely high levels of NAR in these systems were reduced during the project. In Switzerland and the Netherlands, the variation between different systems and years was much smaller, presumably due to lower rates of mineralisation and lower nitrogen surpluses. In spite of the decrease in nitrogen input in the Spanish systems during recent years, the level for nitrogen in autumn was too high in the year 2000, as shown in Figure 7.6. Further improvements are needed in nitrogen fertiliser management to reduce the risk of leaching, particularly in view of the high nitrate content in irrigation water. In Italy, in the organic system, high nitrogen values were caused mainly by the mineralisation of ploughed in crop residues, or, in the integrated system, by a high input of fertiliser (in the celery crop). The situation could be improved by including additional catch crops in the rotation.

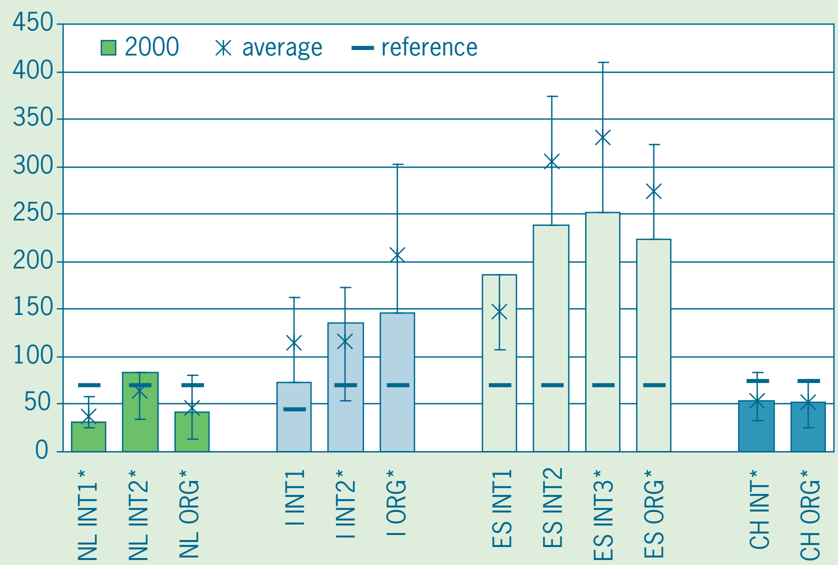

Figure 7.6 Available nitrogen reserves in autumn (data from 2000, average and variation in years; for Switzerland, data from 1998 and variation over farms) (kg ha^{-1})

Phosphate and potash balance

Phosphate and potash balances depend very much on the level of available reserves in the soil. In the Spanish and Italian fresh market system, as these reserves were very high, only small additional amounts would be needed (see the section on 'sustaining resources').

The phosphorous balance is shown in Figure 7.7. In Italy and the Netherlands, there is some phosphate surplus, particularly in the organic systems. This is caused by applying organic fertilisers with high concentrations of phosphate. In Italy, the phosphate surplus in I INT2 and I ORG was drastically reduced during the project by reducing the input of mineral fertilisers and by choosing different organic fertilisers. In the Netherlands, a 20 kg ha^{-1} surplus is tolerated to compensate for unavoidable losses. Taking the project period as a whole, the average surplus almost equaled the tolerated loss in both systems. On the other hand, the results in organic systems in Spain and Switzerland were negative, indicating that the output was higher than the input. These systems profited from reserves accumulated from previous years. This is a desirable situation, because these soils are too high in phosphate compared with the environmentally and agronomically desirable levels. Where the balance was negative, the potential risk of phosphate emission to the groundwater could be reduced. In the 'reference' situation — the situation found on the average farm — input was mostly much higher than output.

In both types of system, except for the Netherlands, available reserves of potash in the soil were very high, so there will be no need to refill the potash reserves in the near future (see Figure 7.8). In the Netherlands, the reserves are within the target range, and, in the integrated systems, the 4-year average surplus is close to zero. The positive surplus in the organic system was caused by an unbalanced composition of nutrients in manure and the priority that was given to obtaining a sustainable phosphate balance.

7.3.5 Clean environment pesticides

The adverse effects of using pesticides can be quantified in several ways. None of these approaches gives a complete picture, because there is still much to be learnt about what happens to pesticides when they are released into the environment. In the Vegineco project, two approaches were adopted to minimise the adverse effects of pesticides: (1) lowering the total input of active ingredients and (2) lowering the risks of emissions (EEP, see section 2.3.) to environmental compartments by carefully selecting the pesticides used. When additional criteria were available e.g. toxicity for humans, selectivity or potential damage to non-target biota, these aspects were also occasionally taken into account.

Figures 7.9 to 7.12 give an overview of the input of active ingredients and the risks of pesticide emission in the tested organic and integrated systems. Pesticides can be divided into synthetic pesticides, copper, sulphur

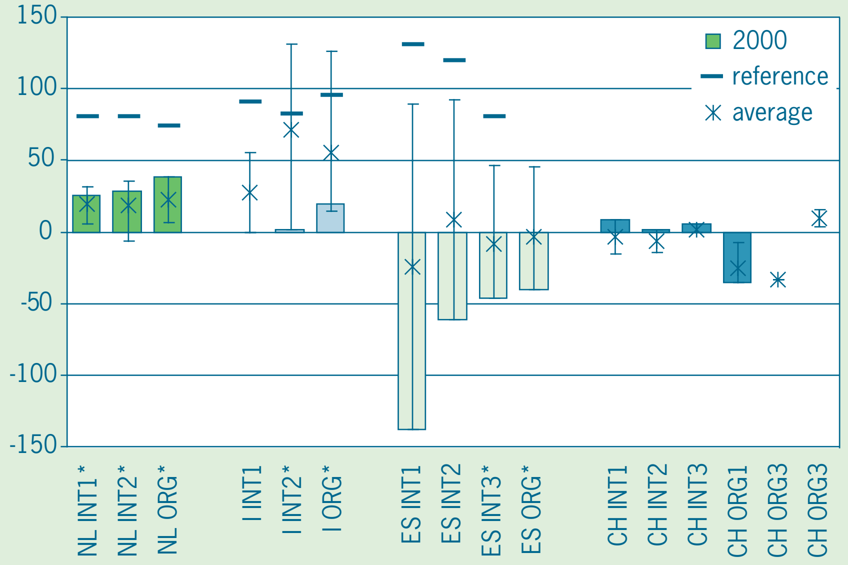

Figure 7.7 Phosphate surplus (kg ha^{-1}) for organic and integrated systems, compared with the average phosphate balance in practice

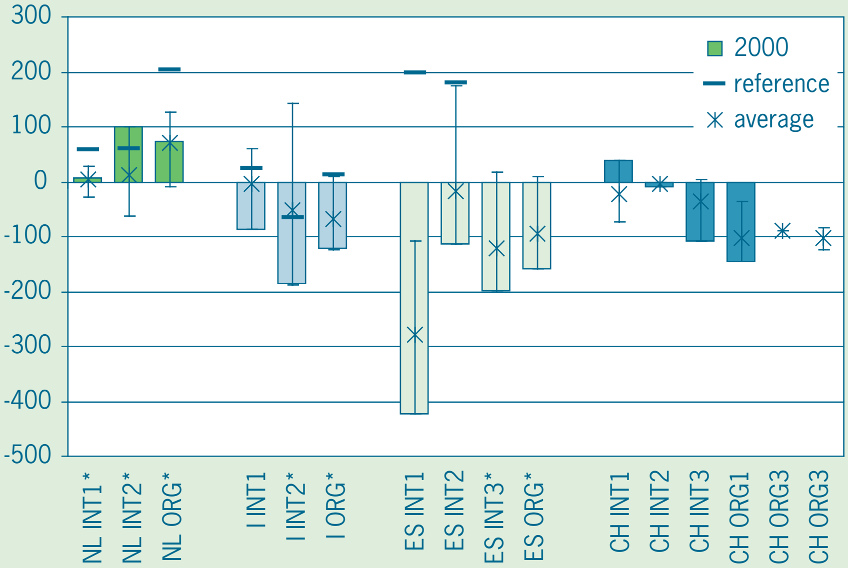

Figure 7.8 Potash surplus (kg ha^{-1}) for organic and integrated systems, compared with the average potash balance in practice

and other pesticides (mainly Bacillus thuringiensis, Bt.). Where Switzerland is included in the figures, the data are averages for five croptypes grown on three pilot farms and not averages per farm. The synthetic pesticides used in all integrated systems contain about 1.5 to 4 kg active ingredients ha-1 (see Figure 7.10.). Due to the intensity of land use, the integrated system in Spain had the highest input of pesticides at the start of the project. This was reduced drastically during the course of the project, by replacing organophosphates with synthetic pyrethroids.

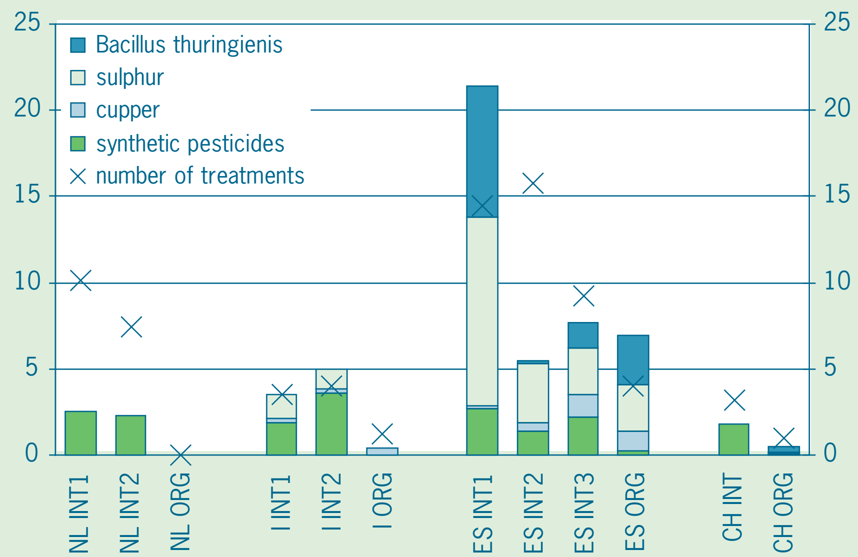

Figure 7.9 Pesticide use in integrated and organic systems (kg a.i./ha and number of treatments ha-1) (sum of all types of application)

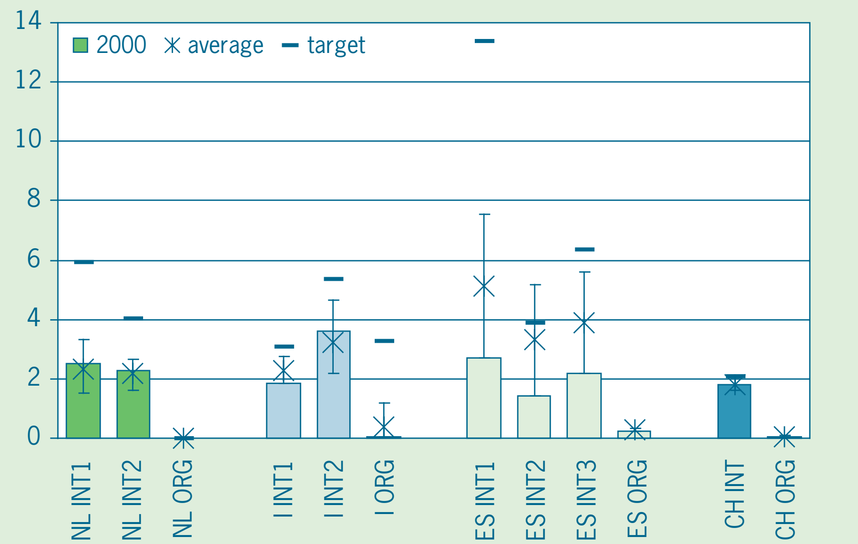

Figure 7.10 Input of synthetic pesticides (kg ha-1) in the tested systems compared with the target of reducing conventional levels by 50%

Synthetic pesticides can be replaced by other classes of pesticides such as sulphur compounds. These were used intensively in Spain, in the integrated and organic systems, and also in the integrated system in Italy. These alternatives tend to be less effective, however, so the input is usually quite high. On the other hand, they are usually less risky for the environment. Application of copper is another possible alternative, as was done in Switzerland, Spain and Italy. Copper was used in organic farms to control harmful fungi in onion or lettuce, such as downy mildew. The input of copper compounds increases the risk of them accumulating in the soil if the input is higher than around 1 kg ha-1 (which is the estimated off-take by produce). For organic farming, the planned revision in EU legislation will restrict or forbid the use of copper.

In the organic system in the Netherlands no pesticides were used at all, assuming that all pesticide agents would have a negative effect either on the environment or on human health. In the Swiss situation, pesticide input is not presented in kg active ingredients ha-1. Since every treatment has known or unknown negative side effects, the Swiss partner preferred to express pesticide input (and the pesticide emission) by the number of treatments.

A comparison was made between the average input in comparable systems in practice, and the actual (reduced) input of active ingredients achieved in the tested systems (see Figure 7.11). The data for the averages in practice were based on available input data per crop and on the crop protection strategies currently used in practice. Figure 7.11 shows that a huge reduction has been achieved compared with the pesticide input in average practice. By reducing inputs by between 55-85%, all systems achieved the reduction target of 50%. The reduction in input of pesticides was achieved by:

- focusing on prevention in all systems,
- using mechanical weed control instead of herbicides,
- using damage thresholds,

guided control, weather forecast systems and other techniques to reduce the number of treatments,
- by optimising the timing of the treatment, and in some cases using improved spraying techniques to reduce the dosage per application.

Figure 7.11 shows that emission risks (EEP) in the systems were also substantially reduced. As no legal or scientific norms were available, the targets set for EEP-air and -soil were 70% of the general levels resulting from average farming practice. For all systems, the results for EEP-air and EEP-soil either met the target, or came close to it. In 2000, the actual figures over all systems ranged from 0.20 - 0.66 kg ha^{-1} for EEP-air, and from 60 - 270 kg days ha^{-1} for EEP-soil. An example is shown in Figure 7.12 of the effect on EEP-air of reducing input and pesticide selection in I INT 2.

The EU guideline of 0.5 ppb was used as the target for EEP-groundwater. Pesticide selection proved an important factor in meeting this parameter. Nevertheless, all the systems except the Spanish ES INT3 and the Italian I INT1 met this target, or came close to meeting it. These systems failed initially because there were no effective or economic alternatives for one or two pesticides used in these systems.

7.3.6 Nature and Landscape

A methodology was developed during the project to quantify and evaluate nature and landscape values, but it has not yet been used to improve these values. A description can be found in this report under 'new approaches', and in a method manual on the development of on-farm nature, published as a result of this project. The percentage of farm surface which should function as ecological infrastructure was established for all systems. In Switzerland, all farms achieved the target of 5%, but, in Spain, especially on small farms and some of the experimental farms operating on a semi practical scale this target was not reached.

7.4 Discussion and conclusions

Basis for the conclusions are the data presented in the previous paragraphs and the data in the country chapters. In some cases they are complemented with experiences in the project and expert knowledge both of which cannot be abstracted from the hard data. The conclusions on the comparison between organic and integrated systems, are mainly based on the comparable pairs of Spain and the Netherlands. These systems were situated at the same location and had an equal or comparable set up. Keeping in mind the flaws of the comparison between different systems, the next general picture arises:

Economic performance

- For all integrated systems producing for the EU market, costs are higher than the revenues.

When looking at the farms from a purely economic point of view, none of the integrated systems (as well as conventional farms) could survive. In practice these type of farms survive because the entrepreneurs accept a low hour rate, partly live from the interest of their capital or can hire cheap labour. EU-market (or world market) prices are actually to low to guarantee a economical sound farming system. The Swiss situation is an exception because integrated farms are rewarded for their public services and at the same time the prices at the Swiss home market tend to be higher than the EU market prices.

- The organic farms showed a better economic performance as the integrated systems in all countries.

This better economic performance of the organic systems was established in spite of slightly (Spain) or considerably (Netherlands) lower yields and a higher labour input for handweeding (Spain, Netherlands).
The good economic results were realised by the high market prices realised for the products. In some cases

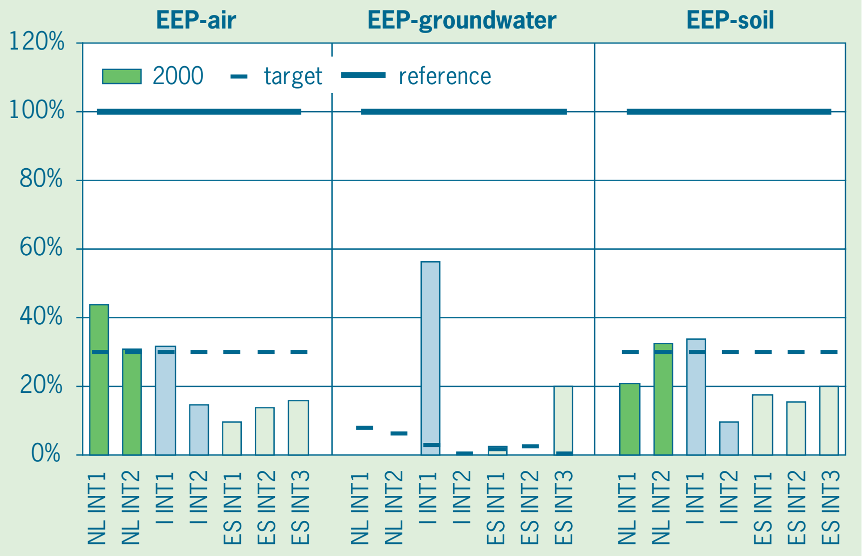

Figure 7.11 Percentage reduction of emission parameters compared with emission in conventional practice and Vegineco targets (year 2000 results)

prices three times higher than the integrated products were realised. These high prices were possible because of specific marketing channels (in some cases direct sales from farm to consumer) and a high market demand for organic products. With the further expansion of organic production, including sales by supermarkets, it may be expected that product prices will decrease to a level that will be about 25% to 50% higher than conventional produce.

Production

- The integrated farms reach a level of quality production which is comparable to, or slightly lower than conventional farms.

- Depending on crop and production conditions, organic yields ranged from comparable with, to much lower than integrated yields.

Hard data to found the first conclusion were not available. The conclusion is based on the expert knowledge of the involved researchers and farm managers. Reduction of yield and quality was in most cases caused by pests and diseases. Of course, both organic and integrated farms are subject to pests and diseases and to weather problems. In integrated production, however, the farmer has more possibilities to react to threats from pests and diseases. Considering an expected decrease of the market price for organic produce, solutions have to be found to improve the low yields of some crops.

Clean environment nutrients

- In some systems and in specific crops the nitrate mineral reserves gave risks of a high level of nitrate leaching.
- The nitrate leaching risks in the organic and integrated systems were at the same level.

Nitrate leaching risks as quantified in nitrogen mineral reserves in autumn, depend only partly on the fertilisation strategy. Crop choice, soil conditions and weather conditions also play major roles. Long term effects of the fertilisation strategy could not be established. In the organic systems a gradual increase of the organic nitrogen reserves in the soil was caused by the use of organic fertilisers. This could in the long term result in a higher mineralisation rate and a higher risk of nitrogen leaching. The use of a crop cover (including catch crops) all year around can be a helpful instrument to reduce these risks.

In spite of their efforts and a substantial reduction, NAR remained too high in the Spanish and Italian systems. This was possibly partly due to high organic nitrogen reserves and/or a high mineralisation rate of the organic matter in the soil. Also in the Dutch and Swiss systems high levels occurred for specific crops. Especially leaf vegetables (lettuce, leek, spinach etc.) cultivated in autumn resulted in a high NAR.

- Both in the organic and integrated systems there was no environmentally unwanted (further) accumulation of potash and phosphate in the soil.

Phosphate- and Potash-balances cannot be judged without knowledge of the level of the soil-reserves of these nutrients. An environmental unwanted (high) level of soil nutrient reserves means that a zero or negative surplus is wanted. For the integrated systems this situation was quite easy to realise. For the

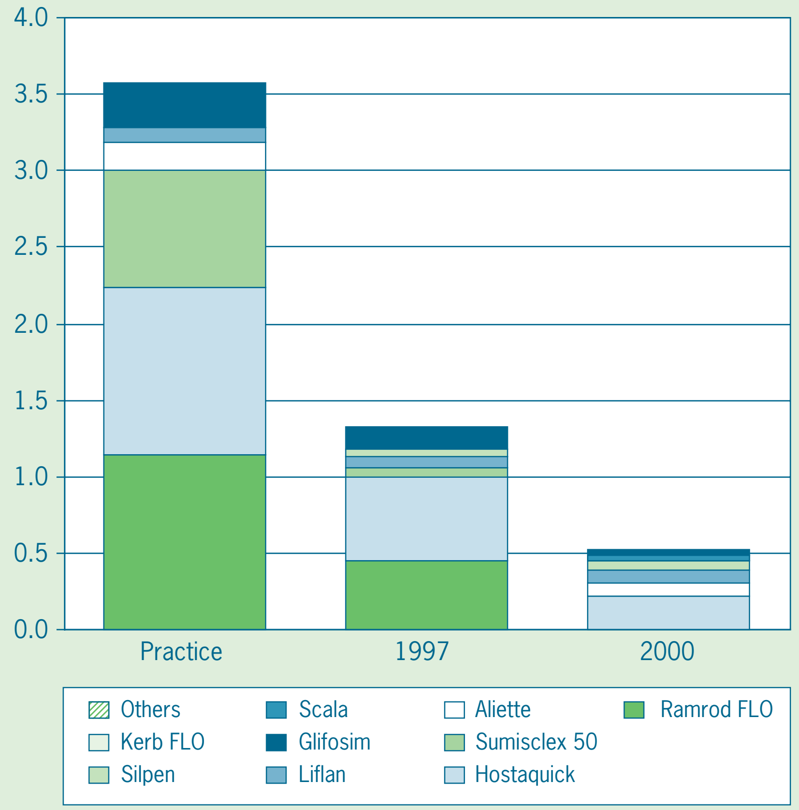

Figure 7.12 Example of the reduction in EEP-air in the Italian I INT2 system (kg ha^{-1}). The figure depicts the emission from different pesticides used in average practice, at the starting year of the project, and in the final year.

organic systems a big effort was made to minimise the potash and phosphate input. In some cases specific types of manure had to be selected. It is questionable whether in the farmers-practice this selection of the right type of manure will be feasible (availability and costs). The realised phosphate and potassium surplus in the organic systems was slightly higher (or less negative) than in the comparable integrated systems.

Clean environment pesticides

- Compared to conventional farming, large reductions of pesticide input and emission risks were realised with no or minor negative effects on quality production.

The combination of integrated crop protection using all available knowledge to reduce the necessity of pesticide inputs with a careful pesticide selection proofed to be successful. For the Swiss situation no reference data were available but the reduction in these pilot farms were not so drastic because integrated farming practices are already standard farming practice. Reduction of the pesticide leaching risk to the level of the drinking water directive of 0.5 ppb was in some case not realised. The exceeding of the norm was due to one or two herbicides for which there was no feasible alternative. The use of this type of pesticides will probably not be admitted in the future. The use of the EEP instrument for selection of pesticides will possible (and hopefully) be less effective after completion of the EU harmonisation on pesticide admittance. However this EU harmonisation in some cases seems to work contra productive. Especially in situations were there are no alternatives left for control, practice tends to use illegal applications which can give rise to even bigger emission problems.

- In the organic systems use and emission of pesticides is (much) lower than in integrated systems.

A logical conclusion, as synthetic pesticides are not allowed in organic farming. However toxic compounds are allowed to be used in organic farming. Because of their sometimes low efficacy these toxic compounds are often used in high quantities. Moreover toxins used in organic farming are not necessarily safer than synthetic pesticides. This is a point of attention for the guidelines and legislation on organic farming.

8 Discussion, conclusions and recommendations

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8.1 General

The project proofed to offer, as intended, the synthesis framework to integrate all available knowledge. The process of designing the systems and methods in the light of a comprehensive set of targets inevitably leads to a clear overview of the gaps in knowledge. The process of running the system and testing the result showed clearly the shortfall in relation to the methods involved. As such, it showed that for every region rather big improvements in the farm overall performance were possible. The intense interaction between partners contributed greatly to sharpen the discussion, to improve the quality of the design, the testing and the methods applied in the systems. The project proofed of great value as focal point in the concerned regions for research into more environmental friendly production systems.

8.2 Methodology

The prototyping methodology of designing, testing, improving and disseminating new "farming systems" (Vereijken, 1994 and 1995) was used in the VEGINECO project. It can be characterised as a synthetic research/development effort starting off with a profile of demands (objectives) in agronomic, environmental and economic terms for a more sustainable, future-oriented farming and ending with tested, ready for use prototypes, to be disseminated on a large scale. The general concept of the methodology proofed to be useful. However the methodology was mainly developed for arable farming systems. When going into details, adjustments needed to be made to make the methodology fit for outdoor vegetable farming systems.
As a whole, great progress was made in the application and further development of the methodology of prototyping new farming systems. During the project improvements were made on several points. The major improvements and important points of attention are:

- The analysis of the shortcomings of the present farming systems is the basis for the formulation of the system targets. The analysis has to be thorough motivated with facts and figures. Practice shows that especially for vegetable farming, hard data on several topics are often missing, so apart of the analysis based on expert knowledge.
- Specific adjustments and improvements have been made in the set of multifunctional parameters. Some parameters had to be newly defined (like quantity and quality parameters and energy efficiency) others seem to be inadequate or only descriptive (like soil cover index). Also all the target levels have to be set, together with a full motivation of these target levels. Are the target levels derived from legislation (EU, national, number legislation etc) based on scientific research (references) etc.? There is not always enough scientific evidence available to set real objective targets. As much as possible targets are based on scientific evidence or otherwise legislation or expert knowledge (such as targets for quantity and quality of produce). Nevertheless working with subjective elements is inevitable in this type of research and setting targets has shown to be very helpful in improvement of farming systems.
- The design of the Multifunctional Crop Rotation is a basic choice that strongly influences the characteristics and the testing results. Therefore the choice of crops and the order of the crops in the rotation have to be very well motivated. Especially in vegetable farming systems were there is a large variety of crops to chose from the options are numerous. Information on interaction between crops is often missing or only available as expert knowledge.
- Strong focus has to be put on the analysis of the shortfall between realisation and target. Next to a sharply focussed evaluation method there are other barriers to overcome. Psychological, cultural, social or financial barriers also play an important role in improving a prototype. Every researcher and farm manager is more or less handicapped in vision by his or her environment. This aspect became very clear in the cooperation of applied research from different European countries in the Vegineco project. Also the right balance between being innovative and acceptance by the farmers has to be found. On-farm discussions between partners have proven to be a great help to overcome these barriers.

Development of new parameters
Next to the fine-tuning of the already existing parameters, new parameters have been developed and tested within the project. Energy Input has been developed as parameter than can describe energy input in crops or farms and is ready to be used as an additional tool for choosing the most optimal farming technique.
Environment Exposure of Pesticides is newly developed by the Netherlands and tested with the results from the project. It proved to be an extra tool for making an optimal pesticide choice and reducing the risk of pesticides being spread in the a-biotic environment.
The set of parameters that has been developed for the evaluation of on-farm nature is a potentially very valuable tool for testing and targeted improvement of on farm nature values. The need for such a tool is growing, especially where there is a high demand for multifunctional use of the rural area.
Still lacking in an instrument to quantify Water Use Efficiency. Water is a limited source in especially the

Mediterranean countries, but also more and more in countries like the Netherlands.

Testing and improving

The basis for improvement is a clear analysis of the reason for the shortfall. Strong focus should be gained then on those topics and methods that cause the shortfall, asthe way to improve from year to year. The methodology of testing and improving needs further improvement. The causes of the shortfall are not always clear from the analysis and the proposed changes in the farming methods are not always clearly a consequence of the shortfall in the parameters.

Another aspect of experimental settings is the difficulty to determine whether methods are acceptable and manageable for the farmers. The Swiss pilot farm project offered good opportunities in this respect. For the experimental systems it is essential to communicate the developed methods with extension and practical farmers to check whether methods are acceptable and manageable in the farmers practice.

8.3 Reducing the gap between vision, prototype and practice

Two types of comparison were made in this project. The performance of all farms was compared with a quantified vision of an all-round sustainable (target) farm and, if possible, with the average performance of standard practice in the region. However, neither of these comparisons is ideal. The definition of an all-round sustainable farm is based on current legislation, scientific views and expert knowledge. It is logically time bound and partly subjective. Defining average practice performance is hampered by a lack of data on average practice. Moreover, the test systems only represent a small part of the range of possible farm types and farming conditions in vegetable farming. Nevertheless, despite these flaws, the study gives a general view of current shortfalls in vegetable farming, and of the possible progress that could be made in current farming if it was better informed.

Towards all-round sustainable vegetable farming systems

The production process was improved to bring it closer to meeting clean environment objectives, sustainable use of resources and varied nature and attractive landscape. Compared to average practice, both organic and integrated production systems drastically reduced emission risks to the environment from pesticides and nutrients. Where performance was below desired levels, it was in the areas of (potential) excesses of phosphate and potash in the organic systems, of risks from nitrate leaching in both system types and of risks from pesticide emission in the integrated systems.

To improve the performance of the tested systems, to bring them nearer to desired levels, technical innovations are needed.

Further improvements in sustainability could be brought about by the development of resistant varieties, improved techniques and mechanisation, better information on the epidemiology of pests and diseases and a broad spectrum of pesticides that are safe in that they minimise the emission of harmful substances into the environment. For the disciplinary aspect of these innovations there are probably enough skilled scientists available. However what is missing to include these techniques into a total system approach, are general agronomists. ‘Agronomy is dead’ is a statement that is probably valid for most European countries. For the development of more sustainable farming systems there is an urgent need for these general agronomists.

Another set back for vegetable crops is the large variety of crops resulting in a relatively low economic importance for each individual crop. This makes the development of resistant varieties and safe and low emitting pesticides to be used in vegetables less interesting for the multinationals.

Recommendations

- to stimulate a shift of emphasis in plantbreeding from yield towards variety resistance,
- to stimulate the development of (small scale) mechanisation for especially mechanical weedcontrol in vegetable farming,
- to develop organic fertilisers with a hig N/P and N/K ratio,
- development of techniques to reduce the level of mineral nitrogen in the soil before periods with a precipitation surplus,
- to develop novel (non chemical) weed, pest and disease control techniques, thresholds and guidance systems for vegetable crops,
- to stimulate the development and admittance of safe and low emitting pesticides to be used in vegetable crops,
- to develop improved spraying techniques (large and small scale) with a minimum emission and a maximum efficacy,
- to develop guidance systems to choose the optimal combination of timing (weather condition) and pesticide choice,
- to stimulate schooling for general agronomy and system approach at the university level as well at the higher technical education level.

Towards improvements in practice

The improvements in the integrated and organic systems were brought about by knowledge gained from experimental systems or by intensive cooperation with farmers. In the experimental systems, the underlying methods and techniques were tested mainly for their effectivity and economic feasibility. Aspects such as manageability and acceptability could only be partly tested. The next step

that is needed is to test, develop and introduce these methods and techniques on practising farms.
To operate sustainable integrated and organic farming, farmers will require more information and a somewhat different level of knowledge. Process integrated solutions will have to replace end-of-pipe solutions, and this will involve another way of thinking. The introduction of integrated farming techniques in practice will necessitate a lot of knowledge transfer and exchange between scientists applied research, extension, farmers and beyond. As the Vegineco project has showed additional international exchange of knowledge on practical integrated strategies and schooling of applied research and extension can strongly contribute towards the shift to more sustainable production methods.
The effect of knowledge transfer and change of attitude however is limited only to those integrated farming methods that bring about reduced costs, extra profits or limited extra costs and efforts. Probably the biggest bottleneck in applying integrated farming methods, is the current economic situation of farmers.
The key factor for the success of integrated farming systems is to reduce the shortfalls in economic performance. Farmers are reluctant to change to this farming type because of the investments in knowledge and machinery required, coupled with a situation in which their income is already very low and where the risks of losses in vegetable production yields are high. Moreover in vegetable crops, the costs of input of pesticides and minerals are relatively low compared to the crop value. Inputs of pesticides and minerals are often considered a cheap insurance for the valuable crops.
To promote integrated farming, cost reductions, increase in yields, higher market prices, tax benefits or a basic reward for 'services in the public interest' are possible options that could be used. In general, the first two options will lead to specialisation and scale enlargement, solutions that could conflict with other objectives, such as clean environment and nature and landscape improvements. However, the more specialised, large-scale, test systems — NL INT1 and NL INT2 and I INT1 — did not perform substantially better than the small-scale systems. Options such as higher market prices, tax benefits or basic payments are outside the scope of this type of research, but they could make an important contribution to sustainable vegetable production. In this respect are most farmers reluctant to live on subsidies and are most of the time in favour of a higher product price.

Recommendations

- to school applied research and extension in the system approach and process integrated and sustainable methods and strategies,
- to ensure international exchange of knowledge and experience on sustainable farming and system approach,
- to implement and test the developed strategies on a number of practical farms under a variety of conditions and to make them manageable and acceptable for farmers,
- to translate the developed integrated techniques to practical and simple tools to be used in practice,
- to ensure transfer of knowledge and implementation of more sustainable techniques, farming strategies and methods,
- financial boost of using sustainable farming methods.

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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

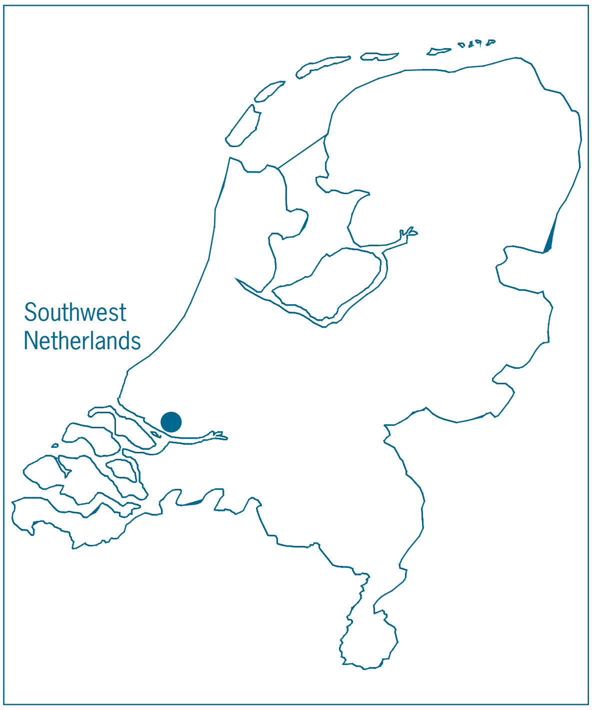
Soil characteristics	Integrated	Organic
main soil type	marine clay	marine clay
clay (%)	33	33
organic matter (%)	2.4	2.2
pH (KCl)	7.5	7.2

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

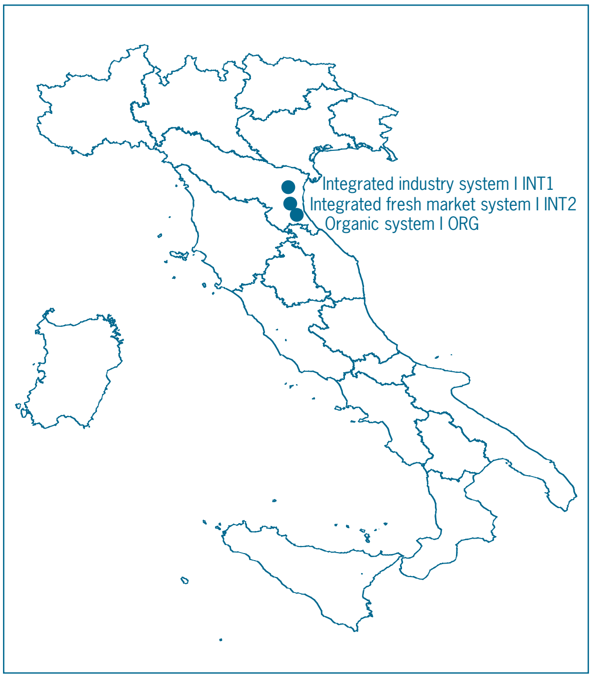
Regional context

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

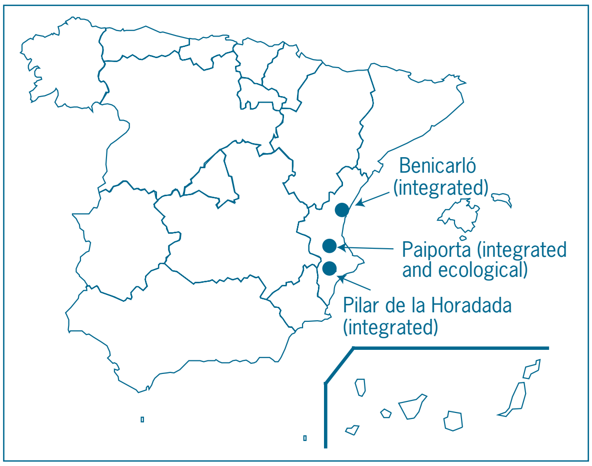
Integrated industry system (I INT1)	Integrated fresh market system (I INT2)	Organic fresh market system (I ORG)
1. spinach tomato	1. lettuce spr./sum./aut. catch crop	1. green beans fennel
2. wheat green beans	2. green beans	2. melon
3. sugar beet catch crop	3. strawberry celery + catch crop	3. catch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

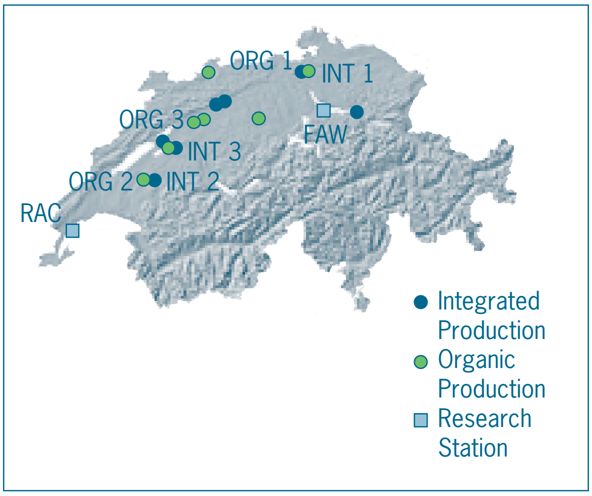
Three integrated and three organic pilot farms were tested:
INT1/ORG1: wholesale distributors, Zurich
INT2/ORG2: direct sale, French-Swiss
INT3/ORG3: retailers / wholesalers, Seeland

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

Research programme

A selection of strategies, based on an inquiry and analysis of the main problems, were tested on the pilot farms to improve the cropping systems:

1. Nutrient management:
   soil cultivation strategies, leguminous intercrops, mineral soil nitrogen and nitrate in plant sap guided nitrogen supply, application of a nitrogen management model, different sources of nitrogen fertiliser
2. Pest and disease control:
   choice of resistant varieties, mixed crops of different resistant or different coloured varieties, ridge planting, preconditioned for earlier development, soil cover with intercrops, silver foil or PP mulch, flowerbeds strips along crops, monitoring pests and diseases, crop cover, biological control strategies, application of threshold concepts
3. Weed control
   seedbed preparation in darkness, false seedbed technique, ridge planting, soil cover with cover crops or intercrops, mechanical control with weeder or roll harrow, (band) flaming, period threshold concept.

Farm level assessments

In each pilot farm, a field that represents a prototype farming system is selected. The prototype field was representative for the entire farm with respect to crop choice and site characteristics. The parameter values were determined on these prototype fields, either for each crop or for the subsequently grown crops on the field. Some parameters are not tested on all farms, and not all parameters were calculated on farm level.
Target values for the prototype fields were discussed and set together with the farm manager individually for each pilot farm. Recommendations and support from the project is focused on these prototype fields. Results from the prototype fields was extrapolated to the whole farm and compared to the reality of the farm assessed by a selection of the parameters.
On selected farms, experiments were performed to develop specific aspects of farming systems (weed management, disease and pest control, nutrient management). These experimental plots serve as pilot sites for the prototype farming systems. As much as possible, the parameters were used to assess the progress in the experiments.

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 *(out-dated)* costs for inputs and outputs and the original *(out-dated)* 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.

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