VEGINECO
EU. FAIR PROGRAM

Manual on prototyping methodology and multifunctional crop rotation

VEGINECO Project Report No. 2

The Netherlands   Italy   Spain   Switzerland

Manual on prototyping methodology and multifunctional crop rotation

VEGINECO Project Report No. 2

J.J. de Haan & A. Garcia Diaz (eds.)

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

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

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

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

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

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

Table of contents

Introduction

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

1.1 Vegetable production in Europe: shortcomings and new farming systems

Although vegetables cannot be said to be a key issue within European Union market policy or political discussion, they are, nevertheless, a major constituent of the daily diet of hundreds of millions of European citizens. Consequently, it is very important to ensure the availability of a wide variety of relatively cheap, high-quality, fresh vegetables on a daily basis.
The farms throughout Europe producing field-grown vegetables are relatively small, and are mostly concentrated in certain regions (for practical market-oriented reasons). These farms are characterised by very intensive land use (all-year-round soil utilisation) and high (external) labour requirements per hectare. Thus, there is almost no 'space' to incorporate nature and landscape elements. 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 agrochemical-based) methods have to be reconsidered, redesigned, and replaced by new multi-objective methods that are able to meet these new objectives. In redesigning these methods, the key issues of farming are involved, such as crop rotation, crop protection and nutrient management. In addition, new strategies for nature and landscape development are urgently required. All these different aspects need to be integrated in safe, efficient, acceptable and manageable strategies. At the farm level, this can only be done within the context of a farming system.
At present, there are two major visions with respect to integral approaches towards agriculture: integrated and organic farming systems (I/OFS). Integrated production is slowly growing in importance, and integrated labels have been introduced in a number of European regions and countries. The development of these labels is still in progress, but, too often, it is only based on single factor research. A consistent research base on comprehensive farming systems, and on the potential and possibilities for integrated production, is mostly lacking. Switzerland is possibly the only exception. Here, as early as the end of the eighties, large-scale pilot projects were carried out, which resulted in detailed production guidelines.
For organic production, national labels have long been available and have recently been harmonised with the European directive on organic farming (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 ecological farming systems for outdoor vegetable farming systems. The overall objective of this project was:

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

This EU project focused on research into farming systems to develop, test, evaluate and compare prototypes of integrated and ecological vegetable farming systems in four important vegetable-producing regions in Europe, selected to represent different socio/economic, soil and climatic conditions. These regions were: the clay region in the 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.), Switserland
F.A.W. performed 'on-farm research' at 14 private pilot farms scattered over the country – seven integrated farms and seven organic farms. By monitoring the practices and results at these selected farms, a clear picture emerged of their differences. This made it possible to target specific elements in need of further development and to introduce improvements in these areas into farm practice.

VEGINECO publications

This VEGINECO 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. In addition to these methodological manuals, other publications include workshop proceedings and a final report on the VEGINECO project. The workshop proceedings focus on project results in general and their implications for policy and certification. The final project report concentrates on the results of the prototyping methodology, in terms of application and development, and how well the tested systems performed. A complete overview of the publications can be found in the VEGINECO publication list.
This report consists of two parts. The first part describes the prototyping methodology and how it was used in the VEGINECO project (Chapters 2 - 5). The second part describes the methodology for developing crop rotation strategies with examples of its application under different conditions in Europe (Chapter 6 - 11).

Part 1. Prototyping Methodology

2 Methodology for prototyping Integrated and Organic Farming Systems

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

2.1 Innovation and prototyping

Innovation in agriculture is a continuous process of creating or utilising opportunities, counteracting threats and solving problems. At present, a complex of problems is destabilising agriculture and threatening the sustainability. However, at the same time, there are opportunities available to revitalise agriculture by looking for connections with the urban population. This is accomplished by offering scarce products and functions as agro-tourism, recreational facilities and diversified landscape. Therefore, innovation in agriculture is now synonymous to finding integral and coherent solutions while integrating different objectives and functions.

Innovation is encouraged with:
1. the total complex of policy regulatory packages,
2. technological developments,
3. market developments,
4. more social action at the basic farming community level.

Policy packages offer an excellent opportunity to create incentives for change and to facilitate this change. Technological developments are necessary to make innovation possible. These technological solutions can be divided in three levels: 1) system innovations, 2) process-integrated solutions and 3) end of pipe solutions. It is obvious that end of pipe solutions are often improvised solutions that alleviate the negative effect of farming. Sustainable farming systems have to be based on system innovation and process-integrated solutions. Novel systems are based on strategic overall concepts that constitute and enhance system innovation. Novel systems are also based on integrated, technology-based agro-ecological principles; agronomy; and biological, physical and chemical methods. In essence, these novel systems are low input – high output systems that will have to be more sustainable in ecological, agronomical, economical and social terms.

Socially based solutions refer to farming communities with common objectives and plans that operate as a group when communicating with the "stakeholders" in the region. This community forming and communication process can be stimulated and facilitated by social scientists and extensionists (Butler Flora, 1998; Pretty, 1998).

Innovation is always a process made up of design, testing and improvement (see Figure 2.1) based on multiple objectives. Innovation is, however, not always a rational process resulting from or guided by institutions. The innovation process can be stimulated by all the above-mentioned approaches. In many projects all over the world, this is attempted in a top-down approach. As initial step, this might be appropriate. However, when insufficient attention is given to interaction with the target group and their learning process, innovation is destined to fail. On the other hand, when successful, the initial linear innovation model (top-down) evolves into a circular, continuous innovation model, supported by the group itself. The prerequisite is, that from the start, the viewpoint of the farmer is taken into account, in addition to the viewpoints of other stakeholders. Prototyping is a method that structures the process of continuous innovation towards more sustainable farming systems from a technological perspective. Prototyping of farming systems allows theoretical design to be applied in practice in different systems. Therefore, the four steps as described in Figure 2.1, apply as well to innovation as to

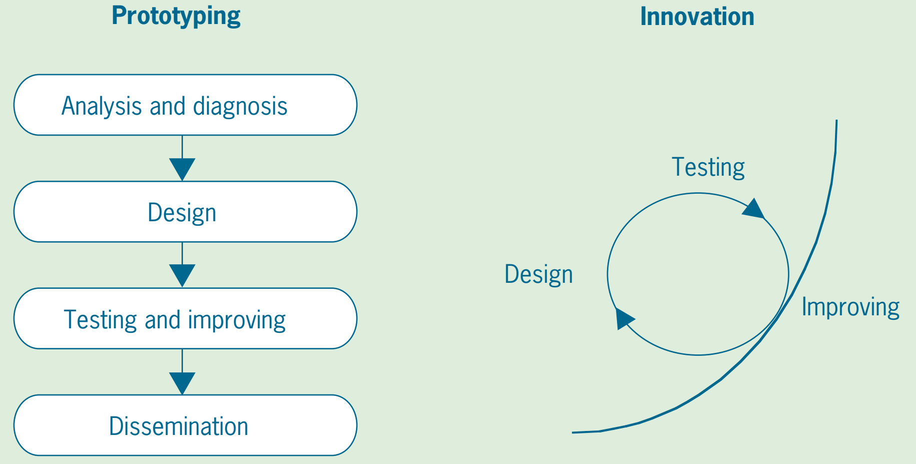


Figure 2.1 Innovation as a dynamic continuous process of design, testing and improvement. Prototyping is a four-step process

prototyping. These steps are elaborated in more detail in the following sections.

2.2 Analysis and diagnosis

The process of prototyping starts with an extensive regionally based analysis and diagnosis phase. In addition to examining the past and the current status, future trends have to be identified as well. By identifying trends and progressive views, a window of opportunities opens.

Figure 2.2 presents a possible framework of the analysis. The central point in the analysis is the farm. First, it is important to get a good view of the farming practice by studying sectoral statistics, farm structure and the agro-ecological problems. Also structural changes are identified. Social demands have to be examined, economically and politically as well as socially. Finally, the ecological and environmental impact of current farming systems needs to be studied. The three phases are described in more detail below.

Farming practices

1. *Sectoral statistics:*
   A statistical analysis has to be made of all possible factors concerning the sector under study.
   The factors include: the total surface area, the crops, the area per crop, the trade value per crop, the involved trade channels, the import/export flows of products and commodities. With this analysis, a picture the sector's importance and the chosen crops can be established. When possible, this analysis has to be out for different regions or for the region where the project is located, in perspective to national data.
2. *Farm structure:*
   The farms are analysed as production units in order to define a comprehensive typology of the chosen farms in terms of size, geographical location, scale and type of crops grown.
3. *Agro-ecological, state-of-the-art:*
   An analysis of the following factors: current farming practices (methods and strategies); threats; problems and sustainability of production in terms of quality production and the underlying maintenance of soil fertility (especially biological and physical soil fertility); crop protection (long term control options of (soil-born) pests and diseases); and other agronomical aspects.
4. *Trends in structural changes:*
   The developments during the past decade have to be analysed in terms of farm size, specialisation, mechanisation, demand and availability of labour, and market developments to put the present situation into perspective. For example, some general trends in the EU are a decreasing number of farms, decreasing employment in agriculture and increasing specialisation.

Social demands

5. *Socio-economic situation:*
   Economic conditions in farming and developments in markets are analysed. Factors examined included: farmers' incomes, production costs such as labour and land, product prices and competition in national and international markets. Also, options to enhance farmers' incomes are studied. An inventory is made of possibilities to increase efficiency (specialisation and scale enlargement), to add value to products with post-harvest processes (sorting, packing) or to focus on special products or niche markets.
6. *Current socio-political conditions:*
   An analysis is carried out of all legislation, rules, policies and subsidies that influence the way farmers work on different levels (EU, national, regional and local level).
7. *Multi-functionality:*
   The demands on and expectations of agriculture are gathered from stakeholders in the region, including the urban population. Opportunities are derived from these demands and expectations.

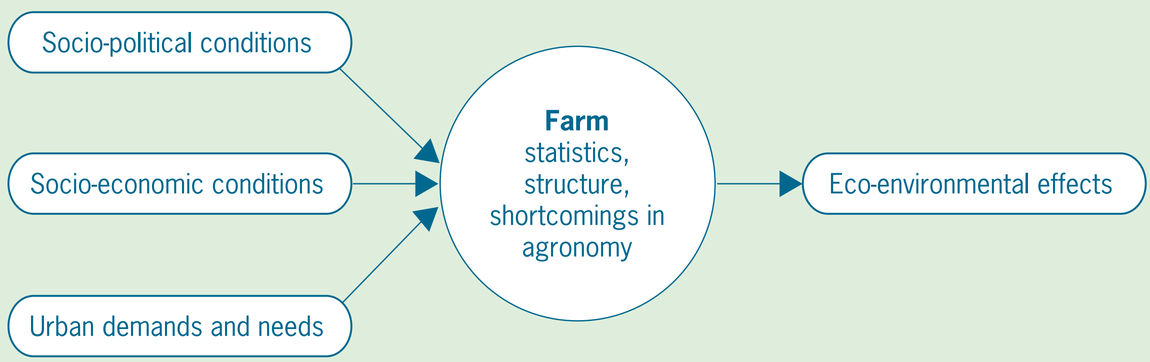


Figure 2.2 The farm in the context of agriculture and society

Ecological and environmental effects

8. *Ecological/environmental impact:*
   Effects of farming on the quality of ecology (biodiversity, nature, landscape) and environment (contamination of soil, air and water) have to be identified and documented in relation to farming practices.

Based on this analysis, a clear view can be described of a sector's structure and importance in the region, the typology of the farms and the relative importance of different crops and their marketing needs. In addition, the shortcomings in agronomy, farming, ecology and environment, and the degree of anticipation of socio-political changes can be identified. This includes the economic position of farms and their development in general. Future perspectives are made clear. The outcome of this process forms the basis for the second step in the prototyping: the design phase.
In Chapter 3, the results of the analysis and diagnosis carried out in VEGINECO study are summarised. The following items are described in detail: farm economic and structural aspects, farm types, policy, legislation on an EU and national or regional level, certification guidelines and environmental problems.

2.3 Design

In the design phase, the prototype is developed. Before this can be done, the objectives of the prototype must be clear and the parameters need to be developed to evaluate the prototype. Therefore, the design phase consists of several steps:

- Defining objectives from an innovation vision.
- Quantifying objectives with a set of parameters, covering the objectives totally and setting ambitious and relevant target values for these parameters.
- (Re)designing farming practices to be able to reach the target values.
- Implementing general strategies in a theoretical prototype, drawing up specific farming and cropping programmes, and designing the agro-ecological layout.

2.3.1 Objectives and themes

To formulate objectives, it is important to have a clear innovation vision. This vision has to be based on the results of the analysis and diagnosis. The vision contains a search direction for the position of farming in the total field of multifunctional agriculture, the type of farms and cropping activities and the position in market, society and environment. Then, the current situation can be described in terms of shortfall to the vision. When the causes of the shortfall are known, priorities can be set for development of new systems and objectives can be defined.
Based on this innovation vision, objectives can be established. In the prototyping methodology, there is a standardised well-defined set of main objectives and subobjectives (between brackets) (Vereijken, 1992):

- food supply (sustainability, stability, accessibility, quality and quantity),
- employment (farm, region, national),
- basic income/profit (farm, region, national),
- abiotic environment (water, soil, air),
- nature/landscape (flora, fauna and landscape),
- health/well-being (farm animals, rural or urban population).

Table 2.1 Description of the themes

Quality production	The objective is to produce a sufficient volume and quality. A secondary objective is the production of healthy and safe products.
Clean environment	The objective is to prevent and minimise the emission of environmental damaging inputs. Emission and damage of nutrients and pesticides are the most important aspects.
Nature and landscape	The main objective is to strengthen and protect the current ecological value of farms, integrated in an ecological infrastructure, embedded in the regional landscape to enhance the environment for humans, flora and fauna. Other functions can be implied as well, for example care for different groups of people on a farm and water storage.
Sustainable management of resources	The main objectives are maintenance and/or improvement of production means (soil and water) and minimisation of the use of production means with a lasting stock (energy, water and phosphates). Maintaining or improving the soil means maintaining or improving soil fertility (biologically, physically and chemically) without causing environmental damage and organic matter management.
Farm continuity	Safeguarding farm continuity by improving farm economics, use of labour and management, especially with respect to crop rotation, fertilisation, labour organisation and integral quality chain care. The main objective is to manage a farm with profitable result.

These rather abstract objectives can be converted to directional themes that cover all aspects of farming. The themes used in the VEGINECO project are: quality production, clean environment, multifunctionality, sustainable use of resources and farm continuity (Table 2.1). Another possible theme is well being/health, which is mainly important in animal production systems. These themes are significant for all progressive systems. There can be a difference in the degree in which priority is given to different themes and sub-aspects and the targets.

When the innovation vision is clear and the objectives are set, a choice has to be made on the type of farms to be used in the project. Also, the type of system to be defined has to be chosen: integrated, organic or both type of systems, pure vegetable farms or a combination with arable crops. For example in the Netherlands, the trend is to include vegetable crops in arable rotations. Therefore, this type of farm was chosen to work on, with integrated as well as an organic systems.

2.3.2 Quantification of themes: parameters and target values

Next in the design phase, the requirements of the system have to be identified. A target picture for the medium-long and long term has to be developed for the type of systems chosen. Within each theme, a set of parameters needs to be chosen which represents the state of a theme in a clear and understandable way. Parameters need to be chosen that are objective-oriented (in contrast to means-oriented) and easy to define. In addition, the parameter must be able to be influenced by one or more farming practices. Parameters are not only descriptive, but they must be controllable as well. To evaluate a prototype of a farming system, only a limited set of parameters can be used, for practical and strategic reasons. In the prototyping methodology, only parameters should be chosen whose status is taken seriously in the improvement process. “Empty shells” should be eliminated. From the objectives and the vision can arise that the development of new parameters is necessary.

Every parameter needs a target value to give ambition and focus to the development of the system. The difference between a parameter’s actual value and the target value indicates the deficit in the parameter.

Target values can be elaborated from different sources:

- policies and legislation on regional national and global level,
- system specific values,
- scientific state-of-the-art technology.

If all of the parameters have target values, the target picture is quantified and the results of management are verifiable to the target picture. Sometimes, more research is

Table 2.2 Overview of the common set of multi-objective parameters

Theme	Parameters	Abbreviation
Quality production	1. Quantity of produce	QNP
	2. Quality of produce	QLP
	3. Nitrate content of produce	NCONT
Clean environment nutrients	4. Nitrogen (mineral) Available Reserves	NAR
	5. Phosphate Annual Balance	PAB
	6. Potash Annual Balance	KAB
Clean environment pesticides	Pesticides input active ingredients	
	7. Synthetic	PESTAS-Synth
	8. Copper	PESTAS-Cu
	Environment Exposure to Pesticides	
	9. Air	EEP-air
	10. Groundwater	EEP-groundwater
	11. Soil	EEP-soil
Nature and landscape	12. Ecological Infrastructure	EI
Sustainable use of resources	13. Phosphate Available Reserves	PAR
	14. Potash Available Reserves	KAR
	15. Organic Matter Annual Balance	OMAB
	• Energy Input	ENIN
Farm continuity	16. Net Surplus	NS
	• Hours hand weeding	HHW

needed to establish a target value. Then, estimations can be used in first instance.
A target picture can be more or less ambitious. The farm type in its regional context determines this picture. The picture can often be deduced from the innovation vision and the overall objectives set. Overall, the target picture can be set on different levels:

- minimum requirements from policy and legislation or economic laws,
- technical feasibility,
- the ideal picture for the middle-long or long term.

It can be considered to define target values at all three levels. Then the distance of the actual realisation with the different target pictures can be made.
Target values can also be a result of negotiations between stakeholders in the development of these new systems. The nature and justification of a target value therefore might vary considerably between parameters. Target values are necessary as they play a crucial role in the process of testing and improving.
The parameters used in the VEGINECO project are listed in Table 2.2. The definition, justification for the choice of parameters and target values are discussed in Chapter 4. More comprehensive definitions of the parameters are given in Annex 2.

2.3.3 Methods

In the next step, a suitable set of farming methods has to be designed that enables the targeted results to be reached as quantified in the parameters. The conventional, one-sided, production-oriented methods have to be evaluated, redesigned. New methods have to be developed to be able to meet all of the objectives. Methods are defined as coherent strategies for the major aspects of farming, consisting of packages of several techniques (Figure 2.4). All of the traditional areas of farming are involved starting with crop rotation, followed by nutrient management, crop protection and soil tillage. Farming is not possible when the principles of these methods are not applied.

As in every system, the system is a result of interacting processes (Figure 2.3). Processes have internal effects, influencing the system itself, and external effects. A set of coherent strategies has to be redesigned to create the right method, which optimises internal effects (interaction) and minimises external effects. In each strategy, the right techniques should be chosen from the toolbox with techniques to reach the target values of the parameters. For instance, the general crop protection strategy is stepwise from prevention, need of control to control. To operate this strategy, different techniques are available for each step. A suitable technique in prevention is cultivar choice, decision support systems can be used to establish the need of control and application techniques can help during control. The techniques should be chosen with the aim to reach target values.

It may be clear that this redesign cannot be done on an ad hoc basis or a case-by-case approach. It has to be done in the context of farming with the full awareness of the interaction with the other farming methods. Every single technique has to have the character of a process-integrated solution contributing to the system innovation. To elaborate on the methods in the context of new farming systems, the following steps have to be taken:

1. inventory of all available knowledge,
2. analysis of negative external effects, specifically focused on the interactions within the system context and on the (re)interpretation of the validity of these conclusions as these are often biased by the one-sided focus on physical yields,
3. consultation with specialists to extract the available expert knowledge in the light of the systems objectives,
4. adapting and integrating knowledge in the farming method strategies and the underlying toolbox of available techniques.

The elaboration of methods follows a natural sequence: it starts with the elaboration of a multi-functional crop rotation, followed by the design of methods for nutrient management, soil tillage, crop protection and nature conservation on the farm. Optimisation of the farm structure concludes this.

Below, an overview is given of the methods that are in operation; definitions that are more extensive are given in Annex 3. Most of these methods were defined previously in the EU concerted action (Vereijken, 1994; 1995; 1996; 1998). The specific manuals on the farming methods (see VEGINECO publication list) will go into a considerate amount of detail on each of these methods.

Multifunctional Crop Rotation (MCR)

MCR is the major method to preserve soil fertility in biological, physical and chemical terms and to sustain quality production with a minimum of inputs (pesticides, manual and machine labour, fertiliser and support energy). A well-balanced “team” of crops is lined up to reach these objectives.

Integrated and Ecological Nutrient Management (I/ENM)

I/ENM gives directions to supply nutrients to crops in such amounts and forms and at such time to achieve optimal quality production, minimise nutrient losses to the environment and maintain agronomically desired and ecologically acceptable nutrient and organic matter reserves in the soil. Maximum use is made of the nutrients within the rotation and application techniques.

Integrated and Ecological Crop Protection (I/ECP)

I/ECP supports MCR and Ecological Infrastructure Management (EIM) in achieving optimal quality production by selectively controlling residual harmful species with

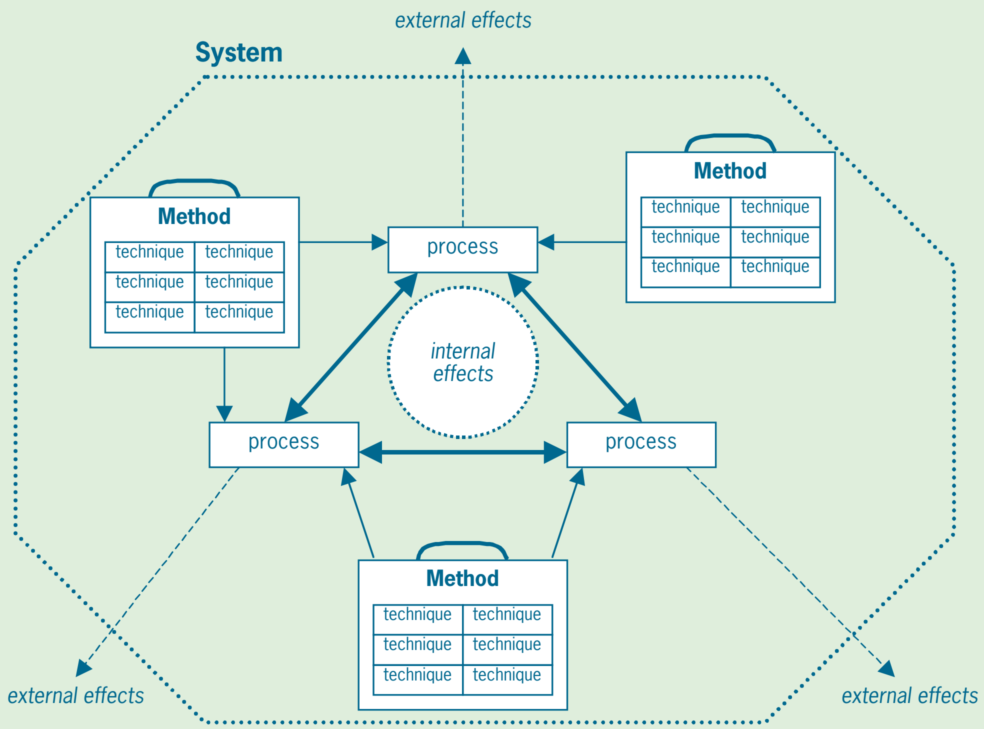


Figure 2.3 Schematic overview of the influence of methods on interacting processes and their effects

minimal exposure of the environment to pesticides. Need of control is reduced by giving maximum emphasis to prevention (resistant varieties, cultural measures such as adapted sowing date and row spacing), a correct interpretation of the need of control. Careful pesticide selection and application technique can lower risks of emission.

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

Minimum Soil Cultivation (MSC)
MSC is a method additional to all other methods to sustain quality production by preparing seedbeds, controlling weeds, incorporating crop residues and restoring physical soil fertility reduced by compaction from machines, notably at harvest. However, 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 predators and landscape/nature values; and to maintain an appropriate organic matter annual balance too.

Farm Structure Optimisation (FSO)
FSO determines the minimum amounts of land, labour and capital goods needed to achieve the required net surplus (all revenues - total costs, including labour), which should be larger than zero. A region specific tested prototype that can meet the quantified objectives has to have also farm economic perspective. FSO elaborates insight in the needed farm structure to render an agronomically and ecologically optimised system economically optimal too. A method “new” style is a coherent multi-objective strategy that is safe, flexible and utilises a diversified set of techniques, dependent on the specific conditions on the farm and during the growing season. Each method will affect the status of several parameters in different themes. The influence of the method on a parameter can be different. In Figure 2.4, the relation between the methods and the themes (and underlying parameters) is visualised.

2.3.4 Theoretical prototype and cropping programmes

As a last phase in the design process, methods have to be put together in a theoretical prototype. A design has to be made for the prototype in the actual place where it will be tested and cropping programs have to be set up.

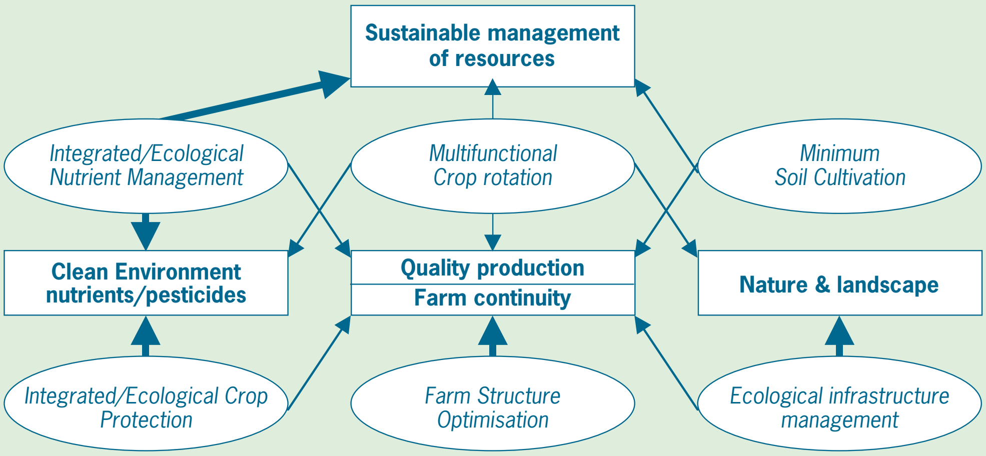


Figure 2.4 Relationship between methods and themes (parameters) used in the VEGINECO project. Thick arrows indicate a strong relationship between the methods and the themes (the parameter value in a theme is mainly influenced by the method). Thin arrows indicate a weaker relationship between the method and the theme (the parameter value in a theme is partly influenced by the method, however other methods are important as well).

In a theoretical prototype, parameters and methods are linked to each other as basis for a correct evaluation. This final step is necessary to check the links between methods and parameters and functions as basic framework for interpretation of the results. Before the prototype is put into practice, a theoretical ex-ante evaluation of the prototype can be made. Values of the parameters can be calculated or estimated on the basis of expert knowledge and standard figures. These estimated values are compared with target values. If the values are far below the target values in some parameters, it may be necessary to redesign the system. Lack of knowledge can also be identified, which can be included more disciplinary research programs.

The basis for a successful test phase is the design of the farming system in time and space. This concerns not only the design of a multifunctional crop rotation and the other methods, but the agro-ecological identity of the farm as well.

"A farming system is an agro-ecological unity that consists of a set of continuous interactions, and rotating of crops and possibly livestock, together with their accompanying (beneficial or harmful) flora and fauna" (Vereijken, 1994).

An optimal, agro-ecological layout contributes to the biological soil fertility by controlling harmful species with crop rotation and encouraging beneficial species. Additional criteria can be formulated with regard to the layout such as: field adjacency, field size, field length and width, adjacency of subsequent crop rotation blocks and the ecological infrastructure. This ensures that crop rotation contributes optimally to the prevention of pests and diseases (Vereijken, 1994). In this framework, subsequent fertilisation, soil cultivation, crop protection and the management of the ecological infrastructure are also optimal. The agro-ecological layout is discussed in more detail in the design of the MCR (Chapter 6.3.4).

The last part of the theoretical exercise ends with a detailed operational plan, the cropping programmes. Before the first growing season, exact and detailed cropping programmes are set up in which the tasks are described that have to be done, at which time and the expected inputs to be used. Running the system is then a matter of operating these cropping programmes. Adjustments to the cropping programs in practice might be necessary depending on actual crop, weather and soil conditions.

2.4 Testing and improving

2.4.1 Pilot farms or experimental farms

When the design of the prototype is completed, it is ready to be put into practice. Prototypes can be tested and improved on experimental farms or with groups of pilot farms. The advantage of testing on experimental farms is the experimental freedom. The design of the system can be carried out without compromises. The level of detail can be very high which provides opportunities for a thorough analysis of the shortfall. Especially when the systems seem to be very experimental, a first development phase on experimental farms is necessary. On these farms, a full implementation, testing, and improvement of the prototype is possible.
The advantages of pilot farms are the interaction with the farm management and the possibility to have "replicates" with respect to soil, farm, and management conditions.

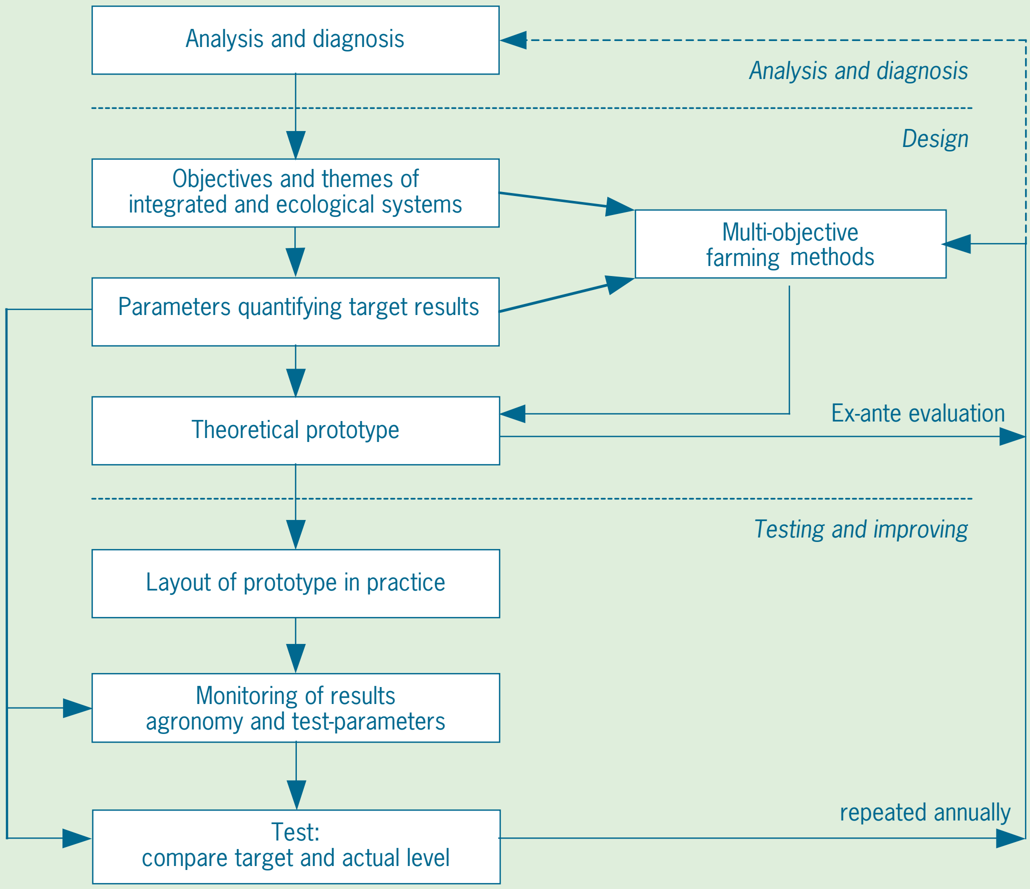


Figure 2.5 Schematic overview of prototyping procedure

When working with farmers, interaction and communication is essential. However, in order to guarantee sufficient innovation and implementation of the prototype, farmers will have to commit themselves to a contract that commits to a fundamental and well-planned "conversion" of their present system.
If testing and improving is done on an experimental farm, it has to be repeated again as dissemination on small scale with a group of farmers. A more detailed analysis of the problems and challenges encountered in this interactive method of working can be found in Wijnands, 1992 and Wijnands et al. 1998.

2.4.2 Annual implementation and monitoring of the prototype

In order to develop the prototypes in practice, each year the complete prototype on the farms needs to be run according to the cropping programmes with specific weather, field and other conditions. This task is usually time-consuming and involves a great deal of fieldwork and input costs. A high level of strategic and agronomic expertise is needed from the research group and the farm manager with the team. It is recommended to appoint a researcher as the responsible co-ordinator for this task, who will work with the farm manager as a team on implementing the plans.

All agronomic data is recorded including: all inputs and outputs, all operations, machinery and equipment utilised, all data of operations and labour. This experimental agronomic database forms the basis for all relevant evaluations. Sets of all test parameters are assessed according to the standardised formats, aggregated where necessary and compared with the target results.

2.4.3 Testing and improving of the prototype

Testing implies that the shortfall between the parameters' target values and actual results are analysed. The method that causes the shortfall has to be identified. Within this method, the responsible strategies and techniques need to be improved. The agronomic database and the qualitative observations during the growing season are indispensable for the analysis of the shortfall (Figure 2.5).

In this phase, detailed knowledge is generated about the different methods and underlying production techniques; their compatibility with other farming methods; their effectiveness in relation to the objectives; and the (potential) conflicts with other methods and objectives. This information is directly used to improve the prototype. It increases the general knowledge of input-output relationships and enables to exchange production techniques in model studies when different balances of objectives are to be reached (Rossing et al 1995).

Testing on farm level also implies testing of the degree of usefulness and manageability of the newly developed methods. On pilot farms, attention also has to be paid to how well the farm manager accepts the new methods (Vereijken, 1995).

The prototype will be improved by enhancing the set of methods in a precise manner. This means looking at how to make the currently utilised farming methods more safe, efficient, acceptable and manageable and, at the same, reach the desired results. The prototypes will continue to be improved from year to year. Any adjustment in the cropping programmes must be considered carefully in order to avoid new conflicts between the objectives and needs.

The testing and improving continues until the objectives as initially defined for each of the relevant parameters are reached. Agro-ecological objectives are tested under field conditions. Economic objectives can be studied and optimised with model studies, involving different scales of farms. These studies can be done during and after the testing and improving of the agronomic parameters. In these studies, the needed farm structure can be made explicit to fulfil the agronomic and ecological objectives. This is a very important point of view for policymakers. The required time to reach the objectives is dependent on the objectives, the specific character of the parameters (variability and response-time), the specific situation of the prototype and the extent to which production methods are already developed.

2.5 Dissemination

The potential of new prototypes can only be evaluated in practice. Management is the key factor for the success and feasibility of these new approaches. When the prototype shows stable results, such as when parameter values are stable and have reached (almost) all target values, dissemination is the next step. Dissemination can be take place on a small scale or on a large scale. During small-scale dissemination, a small group of pilot farms is guided closely. During large-scale dissemination, larger groups of farmers are supported more extensively.

Dissemination on a small scale

A first test on a small number of pilot farms of the prototype(s) developed on experimental farms is an indispensable step before introducing new prototypes on a large scale in practice. The first phase of dissemination should involve a group of well-motivated practical farmers with various soil, farm and management conditions. For each farm, a specific variation of the general prototype has to be set up. The two major objectives of this phase are 1) to evaluate the effectiveness and feasibility (manageability and acceptability) of the prototype and 2) to gain the necessary knowledge to implement the prototype safely and successfully on a large scale under a wide range of circumstances.

Very close co-operation between the researchers, extensionists and farmers is a pre-requisite for the dissemination of the results in the next phase: the dissemination on a large scale.

Dissemination on a large scale

The aim of dissemination on a large scale is to introduce as efficiently and effectively as possible the prototype tested on a small scale. This can only be successful if the expertise is available to adapt the general prototype into farm-specific variations. It is important that the agricultural community's (extension, education and farming industries) motivation for and the familiarity with the new prototype should be sufficient. These conditions can only be fulfilled if during the preceding stage, sufficient attention was given to the transfer of this expertise. It is recommended to approach this phase as a coherent project with a clear infrastructure as this ensures clear objectives and good transfer of expertise.

Obstacles in the dissemination process

How the dissemination of new prototypes must be organised is highly dependent on the motivation for, the knowledge of and the experience with the new prototypes of the individual farmers and the farming community as a whole. Motivation has to be gained from an increasing awareness of the agronomic, environmental, ecological and economical problems that agriculture is currently facing. Different points of view on these topics are expressed in society and the public discussion in agricultural magazines is rather confusing. Awareness of the necessity for changes leads to a change in attitude. When alternatives with sufficient potential are available too, a change in behaviour is possible.

The alternatives in this case are the new prototypes. Increasing knowledge about the new systems and building up individual experience follows naturally when the positive motivation is apparent. Support from the sector is inevitable for a successful implementation of future-oriented systems because the "social carrying capacity" has to originate there. Moreover, sector (farmers or product-oriented) organisations often play an important role in financing these types of projects. A complicating factor is that these types of systems often base their objectives on the same perspective that policy visions are based on. Thereby, they acquire a political and negative dimension in the view of the sector.

3 Analysis of the shortcomings in current vegetable production

J.J. de Haan
Applied Plant Research (PPO), Lelystad, The Netherlands
V. Tisseli
Centre for Plant Production Research (CRPV), Cesena, Italy
A. Garcia Diaz
Institute for Agricultural Research (IVIA), Valencia, Spain
C. Hippe
Swiss Federal Research Station for Fruit Growing, Viticulture and Horticulture (FAW), Wädenswil, Switzerland

3.1 Introduction

In this chapter, the analysis and diagnosis as carried out in the VEGINECO project are summarised to present the problems and the environment in which the farming systems were designed. In Chapter 2.2, a framework was presented for the analysis and diagnosis. This framework is used to present the results. However, not all of the points were treated at this point. In each method manual, a short analysis and diagnosis is presented related to the method. As it can be seen in this chapter, there is overlap between the subjects treated in relation to their place in the framework.

From the analysis and diagnosis as carried out in the VEGINECO project, some general developments are summarised:

1. Changes in farming practices:
   - scale enlargement,
   - specialisation to a few crops,
   - better mechanisation for weed control, planting and harvesting,
   - inclusion of vegetables by larger arable farms,
   - a decrease in the number of small specialised farms.
2. Changes forced by social demands:
   - rise in control systems for quality production chains,
   - more integrated production labels and increasing importance of organic production,
   - attention to other functions in the rural areas and farming.
3. Changes in eco-environmental effects:
   - innovative environmental compatible farming methods.

The speed of development in the different practices is different for different countries, however, the general picture remains the same over all of Europe. As the length of the project was limited, it was not possible to finish the analysis and diagnosis before designing and testing the farming systems. Therefore, some important conclusions about the analysis and diagnosis were not accounted for in the design of the farming systems. In the following paragraphs, these main points will be examined in more detail.

3.2 Farming practice

3.2.1 Farm structure

Farm structure is specific for each region. A statistical analysis was made several factors including: the total surface area, the chosen crops, the area per crop, the trade value per crop, the involved channels for trade and the import/export flows for vegetables in the country and, when possible, in the region in which the partners are working.

Figure 3.1 shows the area for field-grown vegetables in every region and the number of farms involved. Figure 3.2 focuses on the 10 major crops per region. The field-grown vegetables account for only a small surface area (between 1-4%) of the total agricultural land in the regions. The surface area of field-grown vegetables is about 3-4 hectare on average per farm. The surface area per farm is larger in the Netherlands than in other countries. The crops grown in vegetable farming are diverse. The surface area of the largest crop is in all cases less than 20% of the total cultivated area in the region. Especially in Italy and Switzerland, there are no typical crops.

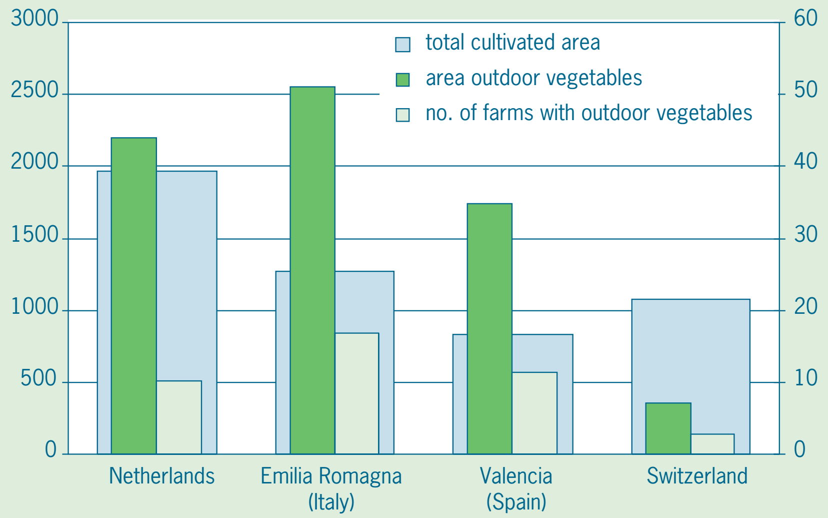


Figure 3.1 Total agricultural cultivated area (left axis in 1 000 hectare), area for field-grown vegetable (right axis in 1 000 hectare) and number of farms with field-grown vegetable (right axis, x 1 000).

Southwest region in the Netherlands

The Southwest region, the area in which the experimental farm is located, is relatively important with more than 7 000 hectare of field-grown vegetable (3.7% of the total farmland area compared to an average of 2.2 hectare per country). In the Netherlands, onions, processed peas and potatoes are considered to be arable crops and as such, they are not taken in to account in Figure 3.2.

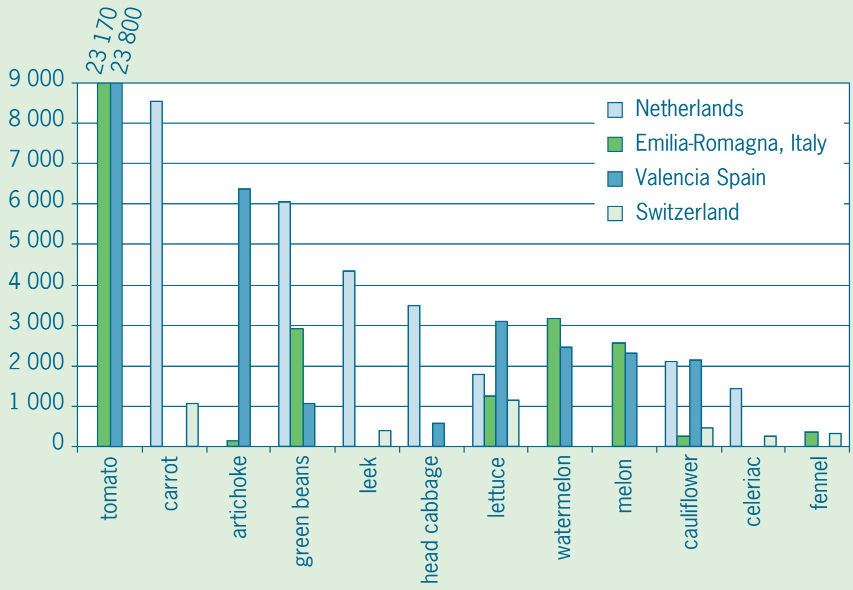


Figure 3.2 The major crops per partner in terms of area (ha)

Italy (Emilia-Romagna)

In Italy, more than 15 million hectares are cultivated, of which 3.7% is used for field-grown vegetables. Vegetable production in Italy stays almost unchanged in importance with 15% of the total agricultural market value. Vegetable production areas are located in Southern Italy as well as in Emilia-Romagna and Veneto (north-eastern Italy). From the beginning of the 90's, there has been a great increase in integrated and organic production. Mechanisation is spreading in industrial vegetable crops such as onion and potato, partly because of labour shortage. This has caused a decrease in production costs and in some areas, an increase of leased land.

In Emilia-Rmagna, the surface area of field-grown vegetables is about 51 000 hectares. Some of the crops in Figure 3.2 have a small surface area in Emilia-Romagna (cauliflower, fennel). Nevertheless, these crops are very interesting for small farms that are typical of the Cesena area in Emilia-Romagna.

Spain (Valencian community)

In Spain, the farming area for field-grown vegetables is about 539 000 hectares (2.9% of the total cultivated surface area). In the Valencian community, the surface area for field-grown vegetables is 34 600 hectares. The average size of the vegetable farms is about 13.6 hectares in Spain, and 4.5 in Valencia. The surface area with integrated vegetable cropping in Valencia is still small, but these farming systems are well accepted among the farmers. A rapid increase is expected in the coming years, mainly due to the pressure from the market. Organic farming was introduced in Spain in the eighties; at present, the surface area for this production system is about 152 000 hectare, of which 1 044 hectare are used for producing vegetables. The surface area and production of organic vegetables shows a progressive increase. Nevertheless, some of its characteristics such as a higher labour costs represent a serious limitation to expanding organic farming.

Switzerland

The cantons of Zurich and Bern are very important for producing vegetable in fields in Switzerland. Zurich is very important in greenhouse vegetable production as well. Other Cantons such as Tessin or Genf are important in greenhouse vegetable production, but less important in field production. Carrot, lettuce and onion are the most important vegetables based on total area. Corn is very popular in Switzerland, which is indicated by its monetary value (domestic and import) more than by its surface area. Over the last 20 years, the total number of vegetable farms and the total manpower has decreased greatly by about 40%. The average farm size in the same period has more than doubled, while the number of workers per farm has increased only by about 15%.

3.2.2 Major farm types with field-grown vegetable

In general, there are three types of farms:

1. Specialised field-grown vegetable farms that are small in size (less than ten hectare) and have a large number of crops (labour intensive), fresh market-oriented, family run and very intensive in terms of land use, labour use and use of inputs (fertilisers and pesticides). A small group of these farms is specialised in one or two crops and has a high level of mechanisation (for example, Brussels sprouts in the Netherlands and tomatoes in the Valencia region).
2. Arable farms in the Netherlands, Italy and Switzerland and citrus and fruit tree farms in Valencia with vegetables fields and low labour costs: relatively large farms (10 to 50 hectare) with well mechanised vegetable crops.
3. Remaining farms: farms that combine greenhouse and field-grown vegetables (Switzerland, Valencia and the Netherlands) or combine labour intensive, fresh market crops with arable farming (Emilia-Romagna and Netherlands).

Below, the specific situation for the countries and regions of the partners is explained:

Southwest region in the Netherlands

There are three types of farms producing vegetables in the Southwest of the Netherlands. These types differ from the types described above.

1. *Specialised vegetable farms*
   These farms specialise in growing mainly one fresh market vegetable crop (Brussels sprouts, iceberg lettuce or cauliflower). This vegetable crop generates their main income. Crop rotations are short. The farms are highly mechanised, are relatively large (less than ten hectare) and often lease extra land from arable farms. Most of the production is sold at auctions. However, the production is sold more and more to individual clients.
2. *Arable farms with vegetable fields*
   The farms main source of income is from arable crops (potatoes, sugar beets and cereals). Depending on the size, these can be divided into three subtypes:
   - Small arable farms (smaller than 30 hectare). A surplus of labour on these farms is used to cultivate fresh market vegetable crops (Brussels sprouts, celeriac and carrot).
   - Middle size arable farms (30 to 50 hectare) that often lease land to specialised vegetable farms (iceberg lettuce, Brussels sprouts).
   - Large arable farms (larger than 50 hectare) that concentrate mainly on arable crops, but sometimes cultivate industrial crops (peas, phaseolus beans) on a contract basis or lease some land to cultivate highly mechanised, labour extensive crops such as chicory roots.
3. *Combination of greenhouse and field-grown vegetable fields*
   These farms are usually quite small (smaller than five hectare). The crops grown are mostly labour intensive (parsley, celery, endive and several types of lettuce). These farms grow a variety of vegetable crops (less than five crops) and have a low level of mechanisation. The number of this type of vegetable farms is decreasing rapidly through urbanisation, specialisation and scale enlargement.

Emilia-Romagna (Italy)

In Emilia-Romagna, there are three types of vegetable farms:

1. *Specialised vegetable farms for fresh market (specialised farms)*
   Specialised farms are located mainly in the districts of Bologna, Forlì and Rimini (Central and South-eastern part of the region). These family farms are small (2.5 to three hectare), specialised in four to five profitable, labour intensive crops. Levels of mechanisation are very low. Products are sold through co-operatives that directly supply to supermarket chains, to the wholesale market or directly to private traders. More than 80% of the incomes depends on vegetable production.
2. *Farms growing vegetables for industrial and arable crops (commercial farms)*
   Commercial farms are usually situated in the districts of Modena, Parma, Piacenza and Ravenna (Western and North-eastern parts of the region). The average surface area is 15 to 20 hectare. Levels of mechanisation are high. Products are sold directly on contract basis for industrial processing. More than two-third of the income comes from vegetable crops.
3. *Farms growing vegetables for fresh market and arable crops (mixed farms)*
   Mixed farms are usually situated in the districts of Ferrara and Modena (Northern part of the region). The average surface area is eight to ten hectare. The main crops are melon, watermelon, onions and green beans (fresh market). The income is medium-high and labour input is lower compared to farms growing more intensive crops such as lettuce, celery, strawberries. Co-operatives or private traders sell the products. More than 50% of revenues comes from vegetable crops.

Valencian community (Spain)

In the Valencian community, there are three types of field-grown vegetable farms:

1. *Specialised farms*
   This group is divided into two subgroups:
   a. A small group of specialised farms growing one vegetable crop for fresh market, mainly tomatoes. These farms are highly mechanised and their surface area is relatively large. Privately owned companies/farms usually trade their own production.
   b. A large group with low acreage (less than ten hectare), few crops (less than five) and with a low level of mechanisation. The crops are labour intensive.
2. *Citrus and fruit tree farms with vegetable crops*
   These farms' main source of income comes from growing citrus and fruit trees. This type of farms has a wide range of surface area. Only a small number of vegetable crops are grown with low labour needs.
3. *Combination greenhouse and field-grown vegetable*
   Small farms with a combination of greenhouse and field-grown vegetables (less than five hectare). A few labour intensive crops are grown. The mechanisation level is low.

Switzerland

The local markets in Switzerland are traditional, which means the Swiss farms grow a very large number of crops and are in a different position than the farms in the other partner countries. In Switzerland, vegetable farms with both protected and field-grown vegetables are widespread. Specialisation in greenhouse production is an exception (Tessin and Genf). On the other hand, the two large trade chains Migros and Coop, prefer large specialised farms. These farms are able to guarantee large quantities with standardised quality of production.

- *Vegetable farming in "Seeland" (Canton Bern, Freiburg, Neuenburg)*
  The main vegetable production area in Switzerland is the "Seeland" area, which is located between three lakes (Bielersee, Neuenburgersee, Murtensee) at an average altitude of about 450 meter above sea level. The region "Grosses Moos" is a part of Seeland with about 600 vegetable farms producing 25% of the vegetables in Switzerland (Hormes, 1996). The very intensive production is mainly destined for fresh market, only a small part goes to industrial processing. Small family farms produce a broad diversity of different crops. Specialisation is not very advanced. Nevertheless, some farmers have started to reduce their assortment.
  An interesting characteristic of Seeland is the importance of vegetable trading companies that sell directly to supermarket chains.
- *Vegetable farming in Zürich*
  In the Zürich area, vegetable farms are not as concentrated as in Seeland. This is why crop rotations with arable crops are much more widespread and consequently, the pressure from some pests and diseases is lower. There is production for the canning industry, and rationalisation and specialisation is more advanced as well. There are some large farms (> 50 ha). Often, production goes to supermarket chains (Migros, Coop) or directly to consumers.

Severe and rapid changes must be expected in Swiss vegetable farming in the coming years. Specialisation (fewer crops) will continue as well as mechanisation and average farm size will increase (fewer farms). Structural changes in vegetable farming were first seen in the price of field-grown vegetables in 1996. The prices were sometimes 50% lower than in the previous year (Hurni, 1996; 1997). Depending on certain conditions such as direct selling or cheap family labour, a higher diversity of crops and smaller farm areas will still be possible.

3.2.3 Economic analysis

An analysis was made of the developments in the last decade in order to put the present situation into perspective. This analysis examined farm size, specialisation, mechanisation, market developments, and labour demand and availability. In all countries, some general trends can be seen:

- The number of farms is dramatically decreasing, partially due to lower average income.
- Agricultural employment is greatly reduced, partially due to high labour costs.
- Farms are specialising more and more in order to reduce costs with better mechanisation.
- Arable farms are gradually integrating the better mechanised vegetables in their crop rotation.
- Prices are under pressure, especially when there is open competition in the international markets (Netherlands and Italy).
- Leasing land is expensive (Netherlands and Spain).

Farmers are looking for possibilities to reduce the costs, on one hand, by increasing efficiency (specialisation and scale enlargement). On the other hand, they try to add value to their produce with post harvest processes (sorting, packing), focusing on special products or finding new niches in the market.

Netherlands

In the Netherlands, the average income is € 30 000 per person. The average income for a farmer with field-grown vegetables is € 16 000 (excluding interest on private capital). The Dutch vegetable growers are trying to increase their income by reducing costs, improving production per hectare or improving the added value of their produce. Product prices are world market prices and as such the individual grower has little influence on the price. The consumers demand produce with a very high "cosmetic quality". Vegetable production in the Netherlands is a free market economic occupation and there are no subsidies. However, farmers that change from traditional to organic farming are subsidised during a transitional period.

As most of vegetable production is exported, the production is sold against world market prices. Prices are constantly under pressure. Farmers have to work efficiently and keep their production costs as low as possible. The major costs are labour and land and to a smaller extent trade (auction). Costs for fertilisation and crop protection are very low compared to the major costs. In order to reduce the labour costs, farmers try to improve their mechanisation and labour organisation. This causes specialisation on one or two vegetable crops.

Land is a limited resource and therefore land is relatively expensive in the Netherlands. Improvement in yield makes these costs relatively lower. In addition, the land in the arable farming regions is less expensive than the land in the traditional areas for cultivation of intensive vegetables, which are often located close to the cities. For efficient use of land, labour and mechanisation, vegetable farming needs to have larger acreages. This makes vegetable farming more and more suitable for arable farms.

For these reasons, there is movement to specialisation, higher mechanisation and scale enlargement. For example, improved mechanisation allows arable farms to include vegetable crops in their rotation, which improves their profitability or makes use of their surplus of labour. Specialising in a limited number of crops leads to very intensive cultivation of crops such as Brussels sprouts and iceberg lettuce in the Southwest. In order to expand the rotation, these crops will be grown more on leased or exchanged arable land. These developments allow more vegetable crops to be cultivated on arable farms, either privately or as land leased to specialised vegetable farms.

The organic farmers' incomes are equal to or slightly better than the income of traditional farmers, which increases the attractiveness of organic farming.

Italy
In Italy, vegetable farms can be divided into two groups by level of income: unspecialised farms with an average income of € 8 110, and the specialised farms with an average income of € 19 560. In 1994 in Italy, the income for every agricultural worker was about € 11 900 on average. In Emilia-Romagna, it was € 15 140 in 1994. From 1980 to 1994, the Italian average income increased by 2.5%, while in Emilia-Romagna, there was a decrease of 23.1% (at constant prices). The net profit for each worker was about € 800 in 1995. The dependent worker in agriculture receives a gross income that is equal to 62.5% of workers in other categories (data: INEA/National Institute Agricultural Economics, 1994).

In Italy, 1 574 000 men work in agriculture, 575 000 men are employees and 999 000 are self-employed. In 1994 in Italy, the average financial contribution to agricultural production was about 13.2% of the total income in Italy, while in Emilia-Romagna it was about 8.6%.
The main costs are mechanisation and labour. In fresh market vegetable production, the main costs are labour (55-70%), technical means (20-25%) and mechanisation (15-20%). In the vegetable production for industry, the main costs are technical means (55-60%), mechanisation (35-40%) and the remainder for labour. Tomatoes are an exception as labour costs account for only about 2.5% of the total. Generally, incomes for farms producing vegetables for industrial processing are guaranteed with contracts. Supply and demand of fresh market vegetables are changing and this causes dramatic fluctuations in market trends and farmers' incomes.

Farms must reduce production costs and must improve food quality. To reduce the labour needs, it is necessary to increase levels of mechanisation. The main problem is that farm are too small for large investments and suitable use of machinery.

The main changes that will have to be made by the farms are:
- increased use of mechanisation,
- specialising in a group of crops that assures suitable crop rotation,
- increasing the surface areas of farms through land lease and exchange.

Spain
Vegetable production in Spain is very important in the agricultural sector, making up of 23% of the total agricultural production. Vegetable production is concentrated in the Mediterranean regions: Valencia, Murcia, Andalucía and Cataluña. In the Valencia region, vegetable production makes up about 12% of the total agricultural production and 16% of the exported agricultural production.

On a regional level, the vegetable sector shows a general trend of a decrease in both surface area and production. The following are the main reasons:
- vegetable growers' low incomes,
- high labour costs,
- changing land used to grow vegetables to other crops with lower of labour needs such as citrus or fruit trees,
- high demand for land to used for urban and industrial activities.

Costs for labour and land are the highest production costs, each being about 40% of the total costs. To increase income in vegetable farming, a high level of mechanisation is imperative. However, increasing mechanisation is difficult to implement in many cases because of the small size of the farms. Fertilisation and crop protection costs are very low. These low costs frequently cause fertilisers and pesticides to be overused to lower production risks. However, in at the same time, environmental and ecological risks are increased and food quality is threatened.

The low level of mechanisation is the main problem in organic farming. The weeding must be done manually and this adds to labour costs. In addition, the lack of adequate outlets for sales can be a limitation for this type of production.

Many vegetable farmers are part-time farmers; most of their income comes from other activities. About 57% of the farms use only family members as sources of labour.

3.3 Social demands

3.3.1 Policy and legislation
An analysis was carried out on all of the policies and legislation that influence farming methods. In general terms, this analysis revealed that farmers must deal with the following topics:
- Pesticides and fertilisers: legislation to reduce the input and emissions (Netherlands and Spain government policy), legislation to counteract the undesired negative side effects (Italy) and restrictions built in the production guidelines for "integrated" production (all partners).
- Conversion to organic farming is encouraged with funding policies (all partners).
- Funding is coupled to restrictions in the production methods and the management of farms (Switzerland).
- Subsidies are given to co-operatives to employ technicians for transfer of expertise concerning integrated farming practices (Spain).
- Switzerland is gradually becoming more open to competition by gradually lowering import taxes.

European Union
In the EU, specific regulations have been set up for organic production (EC 91/2092, and revised in EC 01/426), with regulations on input use (seeds and plants, fertilisers and pesticides). For integrated production, no regulations at the EU level exist.

To protect environmental and ecological quality, direct regulations have been set up for the quality of surface water and drinking water (EC 98/83, EC 91/676 and EC 75/440). In these directives, maximum levels for pesticides and nutrients have been set. Also, additional measures were set to reach the objectives as codes for Good Agricultural Practice within the nitrate directive (EC 91/676). To ensure food quality, EC 90/642, EC 86/362 and EC 97/194 regulate the maximum residue levels of pesticides and nitrate in food products. In the EU, Uniform principles have been set for the admission of pesticides. Requirements for quality and application of pesticides are being harmonised.

The EU is making more and more policies on rural development (EC 99/1257). To protect the environment, agri-environmental procedures have been set up, which provide funding for commitment to Good Agricultural Practices. Also, member states must link funding for farmers partially to meeting environmental requirements (cross compliance).

There are two other important directives for agriculture that help to protect natural resources and landscape. These are the directive for protecting wild birds, and the directive for habitats that establishes a network of protected areas throughout the EU.

Netherlands
In the Netherlands, policies have been set up in response to the environmental damage caused by agronomic activities and there is national legislation to minimise the environmental effects of agriculture:

- Legislation concerning the input of nutrients to reduce the volatilisation of ammonia and the pollution of surface water and shallow groundwater with nutrients.
  - MINAS: requiring registration of nutrient use and maximum surplus for nitrogen and phosphate at a farm level. There is a penalty if the allowed surplus is exceeded.
  - Restrictions on the method of application and the time of application of manure in the winter period on sandy soils (September until January). Restrictions on working after the manure have been applied.
- Legislation for the reduction of pesticide pollution.
  - MJPG legislation (until 2000) to reduce the volume of pesticide use. Average targets were set for the field-grown vegetable sector. There were no penalties for individual farmers.
  - Chemical policy: pesticides are examined for emission and toxicity for the environment; the most environmentally damaging applications are forbidden.
  - Legislation for decreasing drift of pesticides to surface water by requiring cropping free zones, prohibiting spraying in strong winds, regular examination of spraying equipment, spraying licences and special equipment for spraying edges of fields bordering a waterway.
  - New policy (“Zicht op gezonde teelt”) aimed at integrated production for certified farms to improve environmental quality, labour conditions and food safety.
- Policy to stimulate organic farming (entering the organic market) includes:
  - the aim to make organic farming up to ten percent of all farming in 2010,
  - provision of funding for changing from traditional farming to organic farming,
  - improving the chain of organic food production,
  - provision of funding to stimulate research and expansion in organic farming.

Italy
In Italy, for the past 20 years, several regions started the “guided control of pest and disease”. Up to now, there has been no specific legislation to limit the use of pesticides or nutrients in Italian agriculture. Nevertheless, within the “financial law of 2001”, there is a specific regulation (art.123, rule 388/2000) that fixes taxes (2% of the sale price) on the most dangerous pesticides. The law requires to use the money from this tax for the development of sustainable agriculture.

Spain
In Spain, in addition to the EU and state policies, legislation is different per region. At the state level, the promotion of integrated production started in 1983 through the creation of the ATRIAs (Associations for the Application of Integrated Protection). They are regulated by regulations set up by the Ministry of Agriculture on 26 July 1983 and 17 November 1989 (BOE 22-XI-89). The salaries for specialised technicians in integrated production are partly subsided by this regulation. In Valencia, these subsidies are complemented with the ADVs (Asociaciones de Defensa de los Vegetales) with regulations from the Agriculture Regional Council of 19 April and 23 May 1990 (DOGV 15/5/90 and 18/6/90). Legislation in different regions has recently regulated integrated production for specific field-grown vegetables:

- Murcia: celery, lettuce, melon, broccoli, cauliflower and tomato (1998),
- Navarra: broccoli, white asparagus and cauliflower (1998),
- Andalusia: strawberry (1996),
- Catalonia: tomato (1996).

In the Valencian community, legislation for integrated production of citrus and grapes (1997 and 1999) was set up. Also, a Code for Good Agricultural Practices was published in April 2000, with the main objective of avoiding the pollution of groundwater through reduction of nitrogen input.

Switzerland

In Switzerland, three main policies with economical consequences for vegetable farming have been formed within the past years:
On 1 July 1995, there was an important change concerning vegetable importation. Previously, a system existed with three phases of import restriction for each crop depending on the amount of domestic production (phase 1- free import, phase 2 - limited import, phase 3 - no import). After 1 July 1995, vegetables may be imported throughout the entire year because of the Gatt-treaty. During the main growing season, there is a certain amount of import with small duty taxes; the remaining part was charged a higher rate. Nevertheless, this duty tax is now reduced every year (Bourgeois et al., 1995). One consequence is an increasing number of companies importing vegetables (120 in 1992, 450 in 1998; Hurni, 1998). This puts pressure on prices (international competition).

Due to the changes in Swiss agricultural policy in recent years, prices for arable crops are decreasing and arable farmers began to produce field-grown vegetables (Hurni, 1996). This means more domestic competition, unlimited quantities of field-grown vegetable and reduced price security.

There are quite severe legal restrictions in Swiss vegetable production, such as protection of groundwater and complicated permits for buildings and greenhouses. Moreover, costs will continue to increase in the future because of required quality assurance systems (Qualitätssicherungssysteme) and a new nutrient law (Lebensmittelgesetzgebung) (Hurni, 1997).

3.3.2 Certified production

The market's demand for a controlled production chain of vegetables is growing. In addition, legislation has been and is continually being developed to reduce the negative effects of agronomic production on the environment. This creates the need for integrated and organic production labels. There is an increasing need for farmers to have some type of controlled production in order to be able to sell their products.

Governments stimulate the development of organic farming by funding the conversion (in all countries). The large retailers are also stimulating organic production by including this produce in their stock (in Switzerland and the Netherlands). The development of integrated production labels started in the early nineties in Italy and the Netherlands. This was stimulated by either the auctions or co-operatives (Netherlands and Spain) and other groups in society (Netherlands) or the government (Italy). In Switzerland, this development has existed for a longer time and has lead to the present situation that almost all vegetable growers produce under an integrated production label. They are not stimulated by the corresponding subsidies from the government. Subsidies acquired by production processes that are more or less the same as the guidelines for IP production.
Improving controlled quality and reduction of hazards can be achieved by developing the chain of quality control. It will also lead to increasing costs for the farmers.

"Integrated" labels

There are several labels for integrated production (IP) in EU countries, promoted either by the government or by supermarket chains. These labels usually have protocols for specific vegetables that include compulsory regulations at the farm and crop level, and recommended regulations. It is often required to record data concerning different farming practices.
Nevertheless, there are not specific protocols for all field-grown vegetables in every EU-country. Furthermore, the requirements change very much depending on the labels because there is no international standard for integrated production.

The new EUREP-GAP protocol concerning Good Agricultural Practises is the first attempt to establish one IP-label for all of Europe. This protocol and its label may become a standard in the near future. The protocol, set by a leading group of retailers in Europe, has been set up for the global production of horticultural products, which means the requirements are very general in many cases and different interpretations will probably develop.

Independent bodies for certification must determine which conditions must be met and monitored in the integrated production processes. Monitoring can be carried out by the staff in supermarket chains, the owners of the label, or even the government, as in the case of Italy. Certified products are usually similarly priced to conventionally produced vegetables, but it is assumed that they are sold more easily.

Netherlands

In the Netherlands, up until 1997, there was one "integrated" label for field-grown vegetables, named MBT. In 1998, the MBT label was combined with a more "strict" new label, named AMK. The AMK label already existed for arable crops. Both labels had the same basic requirements, but the AMK label had rules or levels that were more difficult to meet. The guidelines for MBT changed quite drastically in 1998 in order to make upgrading from MBT to AMK and downgrading vice versa possible.

These labels have compulsory regulations at the farm and crop levels, and recommended regulations at farm level and crop level that growers can earn points with.

A specific number of points is needed in order to fulfil the label requirements.

The compulsory rules cover:
- Registration of the purchase of, storage of and use of pesticides and nutrients.
- A restrictive list of pesticides that can be used.
- Phosphate fertilisation dependent on soil fertility and based on balanced fertilisation.
- A maximum surplus of nitrogen per crop or per farm.

The regulations for AMK are additional to (new) national legislation for pesticide and nutrient use. Monitoring and certification will be carried out by an organisation appointed by "Stichting Milieukeur". The prices for MBT products are at the same level as the prices for standard products.

Italy
No collective label that identifies the integrated productions in Italy is available, but commercial labels exist, which are managed by supermarkets and/or farmer associations of fruits and field-grown vegetables. Emilia-Romagna has been one of the firsts regions that provided Regional Integrated Production Guidelines inspired by the IOBC directives[1]. These guidelines, applied since 1992, are for the major part of field-grown vegetables for the fresh market and industry, and monitor the entire production process. In 1996, Emilia-Romagna set up a QC label ("Qualità Controllata"= quality control) for vegetable production. To be able to use the label, the Regional Integrated Production Guidelines must be followed.

In Emilia-Romagna, integrated production represents about 20% of the total vegetable production. This was made possible due to the regional government that promoted the drawing up of specific "Integrated Production Guidelines". The increasing demand for quality foods produced in a healthy environment was expressed by consumers (and as a result by agro-industries and supermarket chains). This encouraged farmers to adopt integrated guidelines guaranteed by an official label. Generally, prices of integrated products are lower than of conventional products, but the sale of the produce is easier, even if market conditions are poor.

Spain
In Spain, there are different public regional labels as well as some private labels. The situation is different in each region. The Murcia region has integrated production labels for certain crops (see policy and legislation). The regional labels for vegetables in Andalusia are mainly intended for greenhouse crops. In the Valencian community, the IP guidelines are intended for citrus and grapes, although guidelines for vegetables and fruits are expected in the nearby future. The 2nd degree co-operative, Anecoop, in Valencia has drawn up guidelines for tomato, pepper, watermelon and cucumber crops, both for field-grown and greenhouse crops (label Naturane). In general, the Spanish consumers usually do not demand integrated produce because they generally not familiar with this concept. Therefore, most of integrated production is produced for the export market.

Switzerland
Most vegetable farms in Switzerland have integrated production (8 348 ha in 1996) and only a very small remainder uses conventional methods. The two supermarket chains, Migros and Coop, offer products of both labels in their assortment. Migros has its own integrated production guidelines (MigrosSano) checked by its staff whereas Coop only sells already labelled products (IP SGU).

Organic labels
Most labels for organic production in EU are based on regulation EC 91/2092. The regulation treats several topics in a comprehensive way and, therefore, the regulation can be interpreted in different ways, reflecting the national guidelines.
All operators, who, as part of a business activity, produce vegetables from organic production, are subject to a special inspection scheme established by the member states. The creation of an EU-logo for organic products in March 2000 has reinforced protection against fraud. The prices of these organic products are, in the case of Italy, around 20% higher than conventional produced products. In Spain, it is very common that prices of organic products are 100% higher than conventional produced products. Nevertheless, the trend in the Northern Europe is to set the "organic prices" equal to the conventional prices, (which is already done in some supermarkets as a marketing strategy).

Netherlands
In the Netherlands, there are two labels for organic production named the EKO label for biological production and the DEMETER label for biological-dynamic production. Both regulations are based on regulation EC 91/2092. The most important guideline is ban of chemical pesticides and fertilisers.
Monitoring is carried out by SKAL, which is the inspection organisation for organic production methods. The inspection consists of an annual inspection of the registration records, production process and means of production. In addition to this annual inspection, there are random checks of organic farms.
Certified production in the Netherlands is still small, but is growing quite quickly. Table 3.1 gives an idea of the amount of the certified production in 1995.

Italy
In Italy, there is no national label for biological or biodynamic production. Organic production guidelines do not exist and the farmers operate according to the regulation EC 91/2092. The label monitoring is done by private

[1] *IOBC = International Organisation for Biological Control*

Table 3.1 Number of farms and surface area of certified production in field-grown vegetables (1999, MBT figures 1995)

Subject	number of farms		surface area (ha)	
total field-grown vegetables	8 695		48 195	
organic production of field-grown vegetables (EKO)	261	(3%)	1 897	(4%)
"integrated" production of field-grown vegetables (MBT)	1 655	(16%)	10 307	(23%)

organisations authorised by the Regional Government. At this time, about ten private organisations make periodic, administrative inspections of the farmers' registration of cultivation activities.

Spain
In Spain, every region regulates the organic farming with different regional committees (CAEs). The Committee of Organic Agriculture in the Valencian community was established in 1994. It is financed with public and private money, and it is in charge of registering, monitoring and certifying the organic production in this region. In the Valencian community, the surface area of organic farming in 2000 was 18 890 hectare in total with 204 hectare planted with vegetable crops.

In addition, some farmers also use other labels such as "ECOCERT" for biological products or "DEMETER" for biological-dynamic production. The organic products are sold for higher prices than those from conventional systems. Most of the organic production (90%) goes abroad.

Switzerland
In Switzerland, the two supermarket chains, Coop and Migros, are very important in market and price-policy (together they account for 70% of all food trade in Switzerland). Coop pushed the marketing of bio-products with a program in the beginning of 1994 and Migros followed with its own bio-program in 1995 (MigrosBio).

In 1997, only 8% of domestically grown vegetables in Coop were from bio-production (Lichtenhahn, 1997). In 1996, a share of 20-30% was expected some years later (Todt, 1996; Mäder, 1996). This was perhaps a quite optimistic estimation. Currently, pressure on bio-prices is increasing, especially on storable and transportable vegetables such as carrot and red beet (for example, imported from northern Germany; Lichtenhahn, 1997).

3.4 Environmental and ecological effects

In this paragraph, the environmental problems caused by intensive agricultural production are briefly summarised. Too intensive use of land and too high inputs of nutrients and pesticides are generally considered as problematic, and cause high emissions of nutrients and pesticides. In the other manuals, this topics and policy, legislation and label guidelines are treated in more detail: problems with nutrients in the Integrated and Ecological Nutrient Management manual (VEGINECO publication no. 3), problems with pesticides in the Integrated and Ecological Crop Protection manual (VEGINECO publication no. 4) and problems with biodiversity and landscape in the Ecological Infrastructure Management manual (VEGINECO publication no. 5).

Except for Switzerland, problems with nitrogen leaching are apparent. In the Netherlands, the emission of pesticides is well documented. In Italy and Spain, emission of pesticides is considered important, however documentation is scarce.

There is a continuous concern about the sustainability of production in terms of soil fertility (especially biological and physical soil fertility), and the long-term control options for soil-born pests and diseases. In addition, the development of resistance of pests, diseases and weeds due to a one-sided agrochemical approach raises concerns. More balanced approaches are necessary.

3.4.1 Nutrients

Nitrate in produce
Crops grown under poor lighting conditions and/or a high availability of nitrogen can result in risky, high nitrate levels in produce. For some groups in society, high nitrate levels can cause health problems.

In the Netherlands, nitrate levels higher than 2 500 mg l^{-1} sometimes occur in leafy vegetables grown in the winter in greenhouses or in open fields in autumn. Generally, nitrate content in Italian or Spanish products are lower compared to products grown in colder climatic conditions.

High nutrient inputs
Less than half of the minerals that are brought to a farm are utilised by the products. The remainder, the mineral residue, remains behind somewhere in the environment. The main effects on this overkill of minerals are:

Nitrate in and surface water and shallow groundwater
Especially because of the abundant use of animal manure, surface water has often been polluted with high levels of nitrate and phosphate, which causes abundant growth of algae and threatens biodiversity. Leaching causes an increasing hardness of groundwater. Nitrate levels in groundwater have increased and sometimes

exceed the EU-norm of 50 mg l^{-1}, which causes high costs to purify the water. In the Valencian conditions, although the rainfall is low, irrigation water can leach a high amount of nitrates from both mineral fertilisers and organic fertilisers.

High levels of phosphate and potash in the soil
Due to high nutrient inputs, high levels of phosphate and potash have been built up in the soil. The excessive accumulation of phosphorus in the soil can give rise to nutrient unbalance in plant uptake by antagonistic effect on for example copper and zinc. The excessive accumulation of potassium has a certain risk of leaching in some light soils. In addition, nutrient unbalances can occur, as the well-known antagonism on the magnesium absorption. For instance, thirty percent of the area in the Southwest region of the Netherlands has higher levels of phosphate and potash than agronomically needed and only five percent has too low levels. In the total country, the area with too high phosphate and potash levels is with 65% much higher.

Acidification
In the conditions of the Northern Europe, the volatilisation of ammonia from liquid manure causes acid rainfall that threatened the quality of woods and nutrient enrichment of vulnerable ecosystems.

Desiccation and water irrigation
In the Netherlands, the desiccation problem manifests itself primarily in the gradual lowering of the groundwater level. Therefore, an area of about 600 000 hectare in nature reserves is affected by drought. About 60% of the water loss is caused by the agricultural sector. In particular, the accelerated removal of rainwater exacerbates the situation.
In some areas of Italy, there is competition for water resources between agricultural use (irrigation) and human use (residents and tourists).
The negative difference between rainfall and evapo-transpiration in most of the Valencian community makes water irrigation one of the most important factors to take into account in agriculture. In fact, it is subject of frequent political and social conflicts and a very important part of the budget for agriculture. At this time, the water deficit is balanced by transferring water from the Tajo River to the Segura River. A new "transferral" project (from Ebro River) is planned. On the other hand, this "transfer" between rivers is questioned because of the environmental impact. The very high costs in infrastructure projects means that the irrigation water must be used as efficiently as possible. The water used for agriculture in the Valencian community is about 72% of total water used for consumption.

3.4.2 Pesticides

The limited number of crops on a farm results in short crop rotations and host crops growing all year round. Also large amounts of the same crops are present in a very small, geographical area. This causes high pest and disease pressures, stimulating intensive pesticide use. The high pesticide use is also "stimulated" by the need to meet ever-increasing, external "cosmetic" quality demands in the very competitive international markets. These factors lead to a high dependency on pesticides. The intensive use of pesticides is increasingly less effective because of the development of resistance against pesticides in pests and weeds.

Pesticide residues in produce
Pesticide residues on produce are not rare, although levels higher than allowed are not usually found (around 2-5% of samples).

Pesticide use
Pesticide use is high. In 1995, the annual input of pesticides per hectare was 4.5 kg of active ingredients per hectare in the Netherlands. This amount was made up of 40% fungicides, 30% herbicides and 20% insecticides. The pesticide use per hectare is higher than for other sectors as the use is 3.2% of the total and the cultivated area is only 2.2% of the total.

Pesticide levels in surface water and groundwater
Dutch surface water is highly polluted with pesticides. In a large-scale inspection in 1992 and 1993, over 66% of the inspected water contained pesticide levels that were higher than the maximum permitted level. These high pesticide levels threaten the quality of drinking water and decrease the biodiversity in aquatic ecosystems. Some pesticides (mainly herbicides) are found in concentrations over ten times higher than the normal level of 0.1 µg l^{-1}.

In the same manner, several studies in Spain show that this problem also affects the surface water and groundwater in diverse farming areas.

3.4.3 Biodiversity and landscape

Efficient large-scale agriculture has decreased the biodiversity in the main growing areas by removing the habitat and corridors for flora and fauna. The old landscapes formed by small-scale farming are rapidly disappearing, but even if small fields remain (the Valencian region in Spain), the hedges that used to separate each other can seldom be seen.

In Emilia-Romagna, too intensive use of land causes many erosion problems in hilly areas where fruit plantations and vineyards are normally located. This kind of problem is less important in vegetable production as these crops are normally grown in flat areas. These crops usually suffer from very widespread problems caused by soil-borne pathogens (soil-tiredness) and many different factors that not always well known.

4 Quantification of the themes: parameters and target values

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

4.1 Introduction

In paragraph 2.3.2, the parameters were introduced that are used in the VEGINECO project. In this chapter, the reasons why these parameters are chosen are discussed for each theme. In addition, target values for each parameter are given. Target values between countries are not always identical because of the different systems (for system-specific target values) or different conditions. In paragraph 2.3.2, the requirements of parameters and target values were already discussed.

4.2 Quality production

The theme 'Quality production' examiness quality and quantity of production. The potential for yield (weight unit per surface area unit) and quality (percentage of produce in quality classes) are very site-specific (pedologic and climatic conditions). Moreover, quantity and quality of different crops is not comparable. Therefore, indexes were developed to indicate to what extent quality and quantity (site or region specific) can be compared to Good Agricultural Practices (GAP). Quantity and quality, according to GAP, is established per region or site. The parameters 'Quality of Produce' (QLP) and 'Quantity of Produce' (QNP) are used:

QNP = achieved marketable quantity / site or region specific quantity according to GAP
QLP = achieved quantity of desired quality/ site or region specific quantity of desired quality

Each partner established their own values for the quantity and quality of yield (QNP, QLP), according to the Good Agricultural Practice yields and quality in their regions (Table 4.1).
Special attention to quality has to be given to harmful nutrient levels in vegetables. Especially nitrate content in leafy vegetables is important because nitrate can be converted to nitrite, which is in certain amounts toxic to humans, especially to young children. This is why the parameter 'Nitrate content in crops' (NCONT) is included in the VEGINECO project. The target value of NCONT is derived form EU-legislation and is set at 2 500 ppm. For Switzerland, the target value is based on national legislation, which indicates a target value of 3 500 ppm. The parameter is used only in leafy vegetables.

No attention was paid to pesticide residues on produce because integrated crop protection strategies are expected to keep pesticide use sufficiently below harmful levels.
In addition, pesticides are carefully selected, those with the lowest impact on humans and the environment.

4.3 Farm continuity

A farming system needs to be economically viable and manageable to be sustainable. In addition, the labour needed on the farm should correspond with labour available in the region.
The parameter 'Net Surplus' (NS) evaluates most of these economic aspects: the inputs and outputs are all priced and the difference between the outputs and inputs should be positive. In vegetable farming systems, labour is the highest cost. Costs for crop protection and fertilisation are relatively low.

Labour for growing crops can be divided into four categories: seeding and planting, weed control and crop nursing, and harvest and post processing. Within a given system and level of mechanisation, the labour is the most variable factor depending on the crops, weather and the success of the mechanical, physical and chemical weed control. Therefore, a parameter Hours Hand Weeding (HHW) is used in the Netherlands and Spain. As it strongly influences the labour needs, it is part of the theme 'Farm Continuity'.

4.4 Sustainable use of resources

The objective in this theme is to preserve natural resources by sound use of these resources. The theme can be divided in two parts: preservation of the soil as internal infinite but vulnerable resource, and the efficient use of non-renewable external resources such as water and energy.

Most of the attention in the theme is placed on the sustainable use of soil reserves. The specific objective of this part is to keep the soil reserves at agronomically desirable levels, which do not damage the ecology.

Parameters to quantify nutrient reserves are established for phosphate (P_2O_5) and potash (K_2O): the Phosphate Available Reserves (PAR) and Potash Available Reserves (KAR). These soil fertility reserves should be kept at agronomically desirable and environmentally acceptable levels. Therefore a target range is determined.
The reserve levels are soil, location and applied analytical technique specific (Table 4.2). When reserve levels are not within the limits, fertilisation should be changed (see PAB and KAB, Chapter 4.5). For nitrogen, no parameter is established to quantify the reserves because nitrogen reserves fluctuate dramatically during the year and between years. In addition, for micronutrients, no parameters are established as they are for most crops not limited.

Table 4.1 Target values for quantity and quality of production for integrated and organic systems (Spain integrated target values for ES INT3)

cntry	system	crop	cultivation method	target yield kg ha-1	target quality[1] % class 1
ES	INT	artichoke		15 000	75
ES	ORG	artichoke		13 000	75
NL	INT	barley	spring	6 900	100
NL	ORG	barley	spring	5 500	100
NL	INT	Brussels sprouts	mid-early	20 000	100
NL	INT	Brussels sprouts	late	14 000	100
NL	ORG	Brussels sprouts	mid-early	12 000	50
NL	ORG	Brussels sprouts	late	12 000	50
CH	INT+ORG	carrot		46 200	70
CH	INT+ORG	cauliflower	late spring	17 350	70
CH	INT+ORG	cauliflower	summer	17 350	70
ES	INT	cauliflower		21 600	80
ES	ORG	cauliflower		19 200	80
I	INT	cauliflower		25 000	85
NL	INT	cauliflower	summer	33 000	90
NL	INT	cauliflower	autumn early	33 000	90
NL	INT	cauliflower	winter	17 000	80
NL	INT	celeriac		57 000	100
I	INT	celery		55 000	90
ES	INT	fennel		21 000	100
ES	ORG	fennel		19 000	100
I	ORG	fennel		20 000	70
NL	INT	fennel	early planted	17 000	85
NL	INT	fennel	autumn sown	20 000	85
NL	ORG	fennel	early	16 000	85
NL	ORG	fennel	autumn	20 000	85
ES	INT	green bean		10000	90
ES	ORG	green bean		8 000	90
I	INT	green bean		8 000	90
I	ORG	green bean		7 000	90

cntry	system	crop	cultivation method	target yield kg ha-1	target quality[1] % class 1
CH	INT+ORG	leek		40 400	70
CH	INT+ORG	head lettuce	late spring	24 000	70
CH	INT+ORG	head lettuce	summer	24 000	70
I	INT	lettuce	autumn	28 000	100
I	INT	lettuce	summer	32 000	100
I	ORG	lettuce	autumn	25 000	100
I	ORG	lettuce	summer	28 000	100
NL	INT	iceberg lettuce	early	37 000	100
NL	INT	iceberg lettuce	early autumn	33 000	100
NL	ORG	iceberg lettuce	early summer	27 000	50
NL	ORG	iceberg lettuce	early autumn	23 000	50
I	INT	melon		30 000	85
I	ORG	melon		30 000	80
CH	INT+ORG	onion		40 600	70
ES	INT	onion		80 000	100
ES	ORG	onion		75 000	100
ES	INT	potato		42 000	100
ES	ORG	potato		38 000	100
NL	INT	potato	early	33 000	100
NL	INT	potato		56 000	100
NL	ORG	potato	early	32 000	100
I	INT	spinach		14 000	90
I	INT	strawberry		30 000	80
I	ORG	strawberry		18 000	90
I	INT	sugar beet		50 000	16
I	INT	tomato		55 000	5
ES	INT	watermelon		72 000	90
ES	ORG	watermelon		70 000	90
I	INT	wheat		8 000	80
NL	INT	wheat	winter	9 000	-
NL	ORG	wheat	spring	6 000	100

[1] quality expressed as percentage quality 1 (as a described quality class) or precentage of the net product quantity acceptable product for the processing of bulk product (celeriac, potatoes, barley, wheat)

Organic matter is important in many ways including its contribution to soil fertility, soil structure and soil health. However, the optimum organic matter content is not known. Therefore, the target is set to keep present organic matter content at the same level. To reach this target, organic matter decomposition has to be compensated with the input of an equal amount of effective organic matter. The parameter 'Organic Matter Annual Balance' (OMAB) is used to quantify this. The target value is set at one. When the organic matter content is considered too low or too high, OMAB should be respectively larger or smaller than one.

The 'Energy Input' (ENIN) determines the value of the energy expended in farming tasks and in the manufacturing of all additional products that are used such as fertilisers, machinery, tubes, pesticides, and so on. Most of this energy is obtained from non-renewable resources and therefore, ENIN presents another factor concerning the sustainability of the farming system. As this parameter was developed during the project, it was not used in the testing and improvement process. Water use and soil health were not assessed in the parameters.

4.5 Clean environment nutrients

In this theme, the important objective is to minimise nutrient emissions from the system. Most important nutrient emission routes in agriculture are leaching to groundwater

Table 4.2 Target values for Phosphate and Potash Available Reserves (PAR, KAR)

	Phosphate Available Reserves (PAR) Target value	Extraction method	Potash Available Reserves (KAR) Target value	Extraction method
Netherlands	20-30 mg P_2O_5 l^{-1} dry soil	P_2O_5-H_2O	20-29 mg K_2O 100 g^{-1} dry soil	K_2O-count (K_2O -Cl)
Italy	35-40 mg P_2O_5 kg^{-1} dry soil	P_2O_5-Olsen	144-216 mg K_2O kg^{-1} dry soil	K_2O -NH_4-ac
Spain	35-40 mg P kg^{-1} dry soil	P-Olsen	150-300 mg K kg^{-1} dry soil	K-NH_4-ac
Switzerland	4-8 mg P kg^{-1} dry soil	P-H_2O	20-40 mg K kg^{-1} dry soil	K-H_2O
	40-80 mg P kg^{-1} dry soil	P-NH_4-ac-EDTA	120-200 mg K kg^{-1} dry soil	K-NH_4-ac-EDTA

and surface water, and ammonia emissions to the air. Ammonia emissions in vegetable farming are not very important, so no parameter is set for this emission route. Emissions to ground and surface water are important and therefore, those need to be quantified. Emission of phosphate and potash are not directly related to agronomic activities because these nutrients are immobile. In addition, emission of potash is politically less important. For that reason, direct emission quantification is focused on nitrogen only. However, as emission measurements are expensive, time-consuming and have to be carried out by skilled people, these measurements are not very suitable for farming systems research. Therefore, they are not carried out and an additional parameter indicating emission has been defined: 'Nitrogen Available Reserve' (NAR). This determines the quantity of the mineral nitrogen in the soil at the start of the leaching season. The target value for NAR was set at 70 kg ha^{-1}. Switzerland used a target of 75 kg ha^{-1}. As the soil of the INT1 in Italy is very sandy, the target value for this system was lowered to 45 kg ha^{-1}.

To quantify phosphate and potash emissions, nutrient balances are used. With the aid of nutrient balances, information about possible losses related to inputs and outputs of nutrients can be represented in a simple way. Parameters containing balances are set for phosphate and potash: 'Phosphate Annual Balance' (PAB) and 'Potash Annual Balance' (KAB). For nitrogen, no annual balance parameter is set because emission and efficiency of use can be quantified with NAR. The target values for the PAB and KAB were set at one when the soil reserves of phosphate and potash (PAR, KAR) are within the target limits. When the soil reserves are too high, the balance values of PAB and KAB should be lower than one. This means that the input of nutrients is lower than the output. When soil reserves are too low, balance values should be larger than one to repair the nutrient deficit. The Netherlands accounts for unavoidable losses of 20 kg ha^{-1} for phosphate and 40 kg ha^{-1} for potash.

4.6 Clean environment pesticides

The use of pesticides is currently often quantified as the number of treatments, as kilograms of active ingredients (PESTAS) or as a relative number, expressing the ratio used dose/recommended full field dose. These parameters only quantify use and production technique. As pesticide input in kilograms of active ingredients is easy to assess and is often used in target levels for policy and label use, PESTAS is used as testing parameters in the VEGINECO project.

Active ingredients such as mineral oil, copper or sulphur, with lower environmental effects and higher concentrations in their formulations, are usually applied in a much higher dose per hectare than the synthetic pesticides. Therefore, mineral compounds usually make PESTAS much higher than synthetic active ingredients. Biological pesticides, whose concentration is measured in International Units, are difficult to be quantified by PESTAS. Therefore, the parameter PESTAS-Synth was established to quantify the input of synthetic active ingredients and the parameter PESTAS-copper to quantify the input of copper compounds. Copper compounds can have a remarkable effect on flora and fauna and on environment. As the ecological and environmental danger of sulphur is limited and in biological pesticides often not known, no parameters are set for these inputs.

Pesticide input gives no detailed information on how and to what extent pesticides are dispersed in the environment and what damage they do there on non-target biota (Figure 4.1). To quantify the emission to the (a-biotic) environment independently, PPO developed a concept called Environment Exposure to Pesticides (EEP). EEP is quantified by taking into account the active ingredient's physical

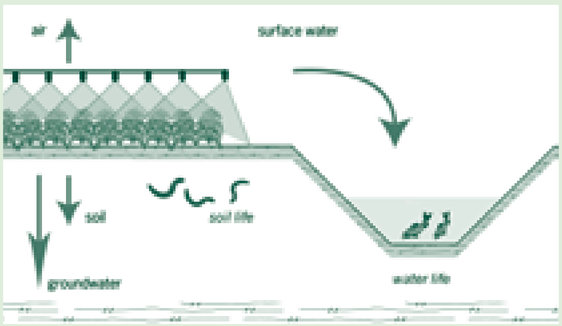


Figure 4.1 Main emission routes and main ecological effects of pesticide use

properties (DT50, soil half life; VP, Vapour pressure and Kom, bonding to organic matter) and the amount 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 the strategy that aims at minimising any potential effect of pesticides on flora and fauna. Therefore, the exposure of the environment to pesticides (EEP) should be minimised. This should be accomplished by minimising the pesticide requirements of farming systems (Integrated Crop Protection) and

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 $\sum_{1\text{-}n}$ 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}] = $\sum_{1\text{-}n}$ *(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] = $\sum_{1\text{-}n}$ *(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}] = $\sum_{1\text{-}n}$ *(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.

consequently, the careful selection of pesticides, while taking into account the extent to which the environment is exposed to pesticides. The approach of EEP, which is a basic preventative approach, is used as instrument in the VEGINECO project. Each year, a list was made of the highest scoring pesticides, then solutions were sought to prevent the use of these pesticides either by replacement with another pesticide or by changing the crop protection strategy.
Combining use, emission and effects on flora and fauna as one can establish the ecological risk of pesticide use. The environmental yardstick developed by CLM in the Netherlands is one of these approaches. The environmental yardstick calculates ecological risks for flora and fauna in water and soil. However, an overall comprehensive assessment of ecological risks is virtually impossible. Overall quantitative scores of 'ecosafety', therefore, may easily lead to unjustified classification of a pesticide as being safe. It is not said that additional ecological information is not useful. However, selection of pesticides only based on ecological effects may be misleading.

Ecological risks are not explicitly used in the testing and improving procedure in the VEGINECO systems. Focus is on prevention of emissions. Information on ecological risks is, however, in some cases taken into account as an additional criterion in pesticide selection.

Both PESTAS parameters and all EEP parameters are calculated on a system level. Therefore, they are very much dependant on the composition of the cropping plan. Target values are derived by defining reduction percentages on use and emissions in normal practice. The input/emission in normal practice is calculated from available or estimated inputs/emissions per crop. An average model of all practice applications (including product, dosage and type of application) has been described for every crop. The input and emission per crop has been calculated from this model. A model farm is set up with the same crop composition as the VEGINECO systems from the individual crops. The active ingredient input and emission on system level is calculated for this model farm. Reduction percentages for PESTAS-Synth are generally set at 50%. Reduction percentages for PESTAS-Cu and EEP-air and EEP-soil are set at 70%. For EEP-groundwater, EU-legislation is followed. The target level is set at 0.5 ppb, and therefore, no reduction percentage is set. Average practice inputs, reduction percentages and target levels for PESTAS and EEP-air and -soil are presented in Table 4.3.

Pesticide inputs in organic farming in the **Netherlands** have been very low or negligible in normal practice up until 2001. Therefore, target levels for input and emissions are set to zero. Copper is not allowed in Dutch organic farming and hardly used in integrated and conventional farming. Moreover, the risk of accumulation of copper is prevented. Therefore, the Dutch target for PESTAS-Cu is set to zero.

In **Italy**, the target in I INT2 is higher than in other systems because in comparison with I ORG synthetic products are used more and, in respect to the I INT1, there are more crops. The target for I ORG is considered as a reduction depending on the amount of active ingredient used in the same rotation in conventional farm practices. It is very difficult to fix a target for the organic farms because the number of farms is limited, and it is difficult to acquire data on the applications made.

Table 4.3 Pesticide inputs for the model farm following average practice, reduction percentages to be met, and target inputs and emissions. Target values for the Italian organic system are derived from conventional farming. Target values for the organic system in Spain are set at 10% of the integrated target values, except for PESTAS-Cu.

Country	System	PESTAS-Synth		PESTAS-Cu		EEP-air		EEP-groundwater		EEP-soil	
		kg ha^{-1}		kg ha^{-1}		kg ha^{-1}		ppb		kg days ha^{-1}	
General reduction percentage		50%		70%		70%		-		70%	
		av. pract.	target	av. pract.	target	av. pract.	target	av. pract.	target	av. pract.	target
Netherlands	INT1	11.9	5.9	0.00	0.00	1.51	0.45	6.23	0.50	801	240
	INT2	8.1	4.0	0.00	0.00	1.40	0.42	8.01	0.50	479	143
	ORG	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00	0	0
Italy	INT1	10.7	5.4	9.28	2.78	3.57	1.07	92.10	0.50	998	299
	INT2	6.2	3.1	4.77	1.43	1.17	0.35	16.00	0.50	432	129
	ORG	6.5	3.3	6.30	1.89	1.67	0.50	17.00	0.05	300	90
Spain	INT1	42.0	21.0	8.90	2.67	4.90	1.47	77.10	0.50	101	305
	INT2	13.4	6.7	2.90	0.88	2.00	0.60	50.10	0.50	610	183
	INT3	24.8	12.4	6.50	1.96	3.90	1.18	30.60	0.50	827	248
	ORG	24.8	1.2	6.50	0.98	3.90	0.12	30.60	0.05	827	25

Table 4.4 Swiss targets for pesticide input for a selection of crops

Crop	Dimension	Target	Applications for
lettuce	no. of treatments	≤ 4	pests and diseases
cauliflower / broccoli	no. of treatments	≤ 3	pests
leek	no. of treatments	≤ 7	weeds, pests and diseases
onion	no. of treatments	≤ 9	weeds, pests and diseases
carrot	no. of treatments	≤ 4	weeds, pests and diseases
all vegetables	kg ha^{-1} $year^{-1}$	≤ 4 pure copper	fungi of the Oomycetes e.g.

In **Spain**, the target values for the organic system (ES ORG) have been set that reduce the targets considered for the equivalent integrated system (ES INT3) by 90%. The target for copper use in ES ORG has been limited to half the target value in ES INT3 because the Spanish regulation in the near future is not clear. The huge difference in emission and use between the different systems in Spain is remarkable. In addition, the different crops are rotated, and the important reasons for this must be pointed out:

- Differences in incidence of pests and diseases in different areas due to climatic conditions and different intensity of use.
- Different conditions for pesticides applications: Dosage is always done in concentration of pesticide per spray liquid. This means the used amount of pesticide depends on the wash used per hectare (mean in developed crops: 2 000 l ha^{-1} in ES INT1, 1 000 l ha^{-1} in ES INT2 and 1 500 l ha^{-1} in ES INT3 and ES ORG).

In contrast to the other partners, the pesticide input on Swiss farms is calculated as a crop-specific number of applications. This replaces the parameters PESTAS and EEP. From the Swiss perspective, active ingredients alone are of very limited use. Very active compounds such as the synthetic pyrethroids are used in very low amounts of active ingredients per hectare but, nevertheless, can have very serious side effects. The Swiss partner defines the pesticide inputs and the pesticide emissions by the number of applications because of the known or unknown negative side effects. The targets are crop-specific and based on the results from the survey on integrated VEGINECO pilot farms in Autumn 1997 and the Good Agricultural Practices (Lüthi, 1995).

In addition to applications with synthetic or non-synthetic 'natural' pesticides, applications also include *Bacillus thuringiensis,* sulphur and copper. For a comparison with the other countries, the input of active ingredients is presented and separated into input of synthetic or non-synthetic 'natural' pesticides excluding *Bacillus thuringiensis* compounds, and in input of copper and sulphur. According to the requirements for organic vegetable production in Switzerland, a copper input of 4 kg pure copper per hectare and year is the maximum allowed. This value was taken as Swiss copper target for organic and integrated farms. Table 4.4 presents the Swiss targets for a selection of most important crops in the VEGINECO project.

4.7 Nature and landscape

There is a common concern about the decline in value of natural resources and the landscape in agricultural areas. However, the different countries look at the farm nature within a framework in different ways. The Italian and Spanish main motivating factors for improvement and preservation of the farming environment is the increase in natural predators of pests, which is an agronomy-focused interest. In the Netherlands and Switzerland, the aim is to increase biodiversity. Other motives in all of the countries is increasing the attractiveness for the local community and improving the physical conditions (erosion, windbreak). In general, every country has the same set of motives to improve on farm nature, but with different priorities. In the Netherlands, Switzerland and Italy, there are subsidies for improvement or preservation of on farm nature. In Spain, the need to combine agronomic and recreational (landscape) functions is very high in areas located near large cities.

In the Netherlands, a methodology has been developed to quantify the potential quality of on farm nature. The historical, cultural and present landscape values play an important role in the layout of the farming environment in the Dutch point-of-view. Parameters have been developed to make the quantification possible. The results of the measures taken to improve the quality of the farming environment may take a long time to appear. This is the reason that the parameters are more focused on creating the conditions necessary to achieve the potential quality of nature for a specific farm (region).

A second set of parameters is also needed to estimate to when the potential quality has become the actual quality (scoring aspects of biodiversity). These secondary parameters are, of course, necessary to check the efficiency of the initial set of parameters. However, within the scope of the VEGINECO project, this second set of parameters was not possible to develop and test.

Nine parameters have been developed and divided into

Table 4.5 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 1:5 000) = percentage at landscape level (scale 1:25 000). At the landscape level, the presence of larger woody elements in 250 x 250 meter squares is scored. At the farm level, the presence of individual trees in 50 x 50 meter squares is scored. For the landscape level, maps from 1970 are used. If rural development plans for the area differ from the actual landscape, target values may be adjusted
CoLE Connectivity Landscape Elements	Desired connectivity is reached if L ≥ ½N. N = Node: 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 movement of target species. A difference is made between woody links and herbal links.
CiLE Circuitry Landscape Elements	Desired circuitry is reached if the number of L ≥ N.
BTP Biotopes	50% of existing biotopes in the 6.25 km^2 surroundings of the farm must be present on the farm.
Environment	
BZI Buffer Zone Index	Length of buffer zones per length of ditches, waterways or woody elements between 1 and 2. For elements at the border of the farm, the index is 1, for internal elements the index is 2.
BZW Buffer Zone Width	The average width of the buffer zones = 4 meter. For the calculation of this parameter, buffer zones wider than 4 meter are fixed at 4 meter.
Agro-ecological layout	
EII Ecological Infrastructure Index	Percentage of the farm that 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 meter. FSI =(A1 * (W1-125)/At) with A1 the area of the farm with fields wider than 125 meter, W1 the average width of that part of the farm and At the total area of the farm. Every 25 units correspond to a 10% shortfall
BTS Biotope Target Species	Number of target species present in a biotope. For each biotope, 20 target species are chosen. These 20 species can be divided into 4 groups that correspond to a specific stage in the succession of the vegetation.

three categories: nature and landscape, environment, and agro-ecological layout (see Table 4.5). The parameters proposed for linking the farm to the landscape (PWE, CoLE, CiLE and BTP) have recently been developed and have yet to prove their suitability in different landscapes. PWE was developed to provide a guideline for how many woody elements on a farm reflect the landscape the farm is situated in. The same holds true for BTP. CoLE and CiLE were derived from landscape ecology where connectivity and circuitry are used to describe the functioning of networks (Forman & Godron, 1986). In this methodology, they are used to involve farms in creating corridors and connecting natural 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 positions have to be evaluated regarding the connectivity and circuitry in relation to existing networks.

BZI and BZW are based on pesticide drift reduction studies, which show that drift can be reduced to zero by using four-meter wide zones.

EII is the only parameter that was also used in the origi-

Table 4.6 Target values of on farm nature parameters for a selection of systems

	Parameter	Netherlands	Italy (I INT1)	Spain (ES INT2)	Switzerland
Nature and landscape					
1	Percentage of woody elements	30%	14%	44%	9%
2a	Connectivity woody elements	50%	25%	28%	33%
2b	Connectivity herbal elements	5%	25%	28%	33%
3a	Circuitry woody elements	100%	14%	20%	30%
3b	Circuitry herbal elements	100%	14%	20%	30%
4	Biotopes	3	2	3	4
Environment					
5a	Length of buffer zones/ length of ditches	1	1	x	1.48
5b	Length of buffer zones / length of woody elements	1	1	1	1.57
6a	Buffer zone width next to ditches	4	4 m	x	4
6b	Buffer zone width next to woody elements	4	4 m	4	4
Agro-ecological lay out					
7	Ecological infrastructure index	5%	5%	5%	5%
8	Field size index	<125 m	<125 m	<125 m	<125 m
9	Biotope for target species	-	-	-	-

nal prototyping methodology (Vereijken et al., 1998). FSI expresses the possibility for stabilising the agro-ecosystem for a specific farm. Expert judgement indicates that the optimal field size for natural predators of pests to reach the centre of the field is 125 meters (Booij; pers. comm.). BTS has so far only been developed for the management of dike grassland vegetation (Sprangers, 1999). Similar methods for other biotopes are now being developed.

For all parameters (except BTS), it is hypothesised that when the target values have been achieved, preconditions are present for a certain basic level of quality of the (agricultural) landscape. The ultimate desired quality depends largely on the management of the different elements. This can be evaluated with the BTS parameter.

Prototyping on farm nature management provides a tool to analyse and evaluate the achievements of nature management on a farm. This provides the farmer or researcher with clues how to improve the function and the quality of the nature on the farm and in the surrounding area. It is important to emphasize that the methodology presented evaluates if the conditions are present for a basic level of quality of the (agricultural) landscape. The achieved quality depends largely on the management of the different elements. Parameters for the evaluation of the latter will be developed in connection with the BTS parameter.

The target values for this theme are different for the partners, dependent on the nature values for the surroundings of the farms (Table 4.6). Only EI is included in the general circle diagram.

4.8 Summary

In Table 4.7, the parameters used in the VEGINECO project are summarised with a short definition and indication how the target value is established.

Table 4.7 Definition and target levels of parameters used in the VEGINECO project

Parameters	Definition	Target
Quality production		
1. Quantity of produce (QNP)	The extent to which good regional yield is met. QNP = actual yield (kg ha^{-1}) divided by a good regional yield (kg ha^{-1}).	All crops should have a yield equal to or higherthan good regional yields. QNP ≥ 1.
2. Quality of produce (QLP)	The extent to which good regional quality is met. QLP = actual amount in quality class 1 divided by good regional amount of quality class 1.	All crops should have a quality equal to or higher than good regional quality. QLP ≥ 1.
3. Nitrate content of crop produce (NCONT)	The nitrate content in leafy vegetables in mg per kg fresh matter (ppm).	All leafy crops should have a lower NCONT than the national standard. NCONT < x ppm.
Clean environment nutrients		
4. Phosphorus Annual Balance (PAB) 5. Annual Balances (PAB/KAB)	Potassium Annual Balance (KAB) Phosphorus and Potassium are phosphate and potash inputs divided by phosphate and potash reduction with the crop produced in one year.	The target value is dependent on the amount of the soil reserves (PAR/KAR) (see 13 and 14) • PAB/KAB > 1 when PAR/KAR is below the desired range, • PAB/KAB = 1 when PAR/KAR is in the desired range and • PAB/KAB < 1 when PAR/KAR is beyond the 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 to such value that the EU-norm for drinking water (50 ppm nitrate) should not be exceeded. NAR < x kg ha^{-1} x = 45 kg ha^{-1} for sandy soils x = 70 kg ha^{-1} for clay soils
Clean environment pesticides		
7. Synthetic pesticides input's 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's active ingredients 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 meet 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}

Table 4.7 Definition and target levels of parameters used in the VEGINECO project

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 (%).	EI > 5%
Sustainable use of resources		
13. Phosphorus Available Reserves (PAR) 14. Potassium Available Reserves (KAR)	P_2O_5 and K_2O reserves in the soil (kg per unit soil) available to plants.	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.	Input should be equal to or greater than output to preserve organic matter content. OMAB ≥ 1
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 hectare.	Gross revenues should be larger than total costs. NS ≥ € 0
Hours hand weeding (HHW)	The amount of hours needed for hand weeding per hectare as an 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}

5 Evaluation of the methodology as applied in the VEGINECO project

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

5.1 Introduction

The prototyping methodology of designing, testing, improving and disseminating new farming systems as described and used in the VEGINECO project is based on Vereijken (1999). 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. So far, the general concept of the methodology proofed to be useful. However, the methodology as developed by Vereijken, was mainly developed for arable farming systems. When going into details, adjustments need to be made to make the methodology fit for field-grown vegetable farming systems as was shown in Chapter 2.

5.2 Analysis and diagnosis

The analysis and diagnosis of the shortcomings in the present vegetable farming systems were the basis for the formulation of the system targets and the design. A new strategy was set up by dividing the analysis into three areas: farming practices, social demands and ecological and environmental effects. These areas cover all aspects of farming. In Chapter 3, no attention was paid to the agro-ecological state-of-the-art technology because this is described in the other method manuals (VEGINECO project reports 3, 4 and 5).

In the VEGINECO project, the analysis was done in the first year of the project. During this year, the systems were already running because the length of the project was limited. This means that in the VEGINECO project, the conclusions from the analysis and diagnosis could not be the basis for the design of the systems, as it should have been. In addition, the analysis was limited in detail because data was not available on some factors such as emission of nitrates and pesticide residues on produce. Sectoral statistics were often not available in sufficient detail. Lack of reliable and useful data for a complete analysis and diagnosis is a general problem that cannot be overcome.

In new projects, it is advisable to take sufficient time for analysis and diagnosis before starting the design phase. In addition, analysis and diagnosis should be updated during the project. From testing and improving, new questions arise and new information is needed to improve the design, to which analysis and diagnosis can contribute. The analysis and diagnosis should be as extensive as possible to have a complete picture of the problems in a region. Deficits have to be defined clearly to be able to resolve them in the other phases.

5.3 Design

In the design phase, the objectives and the set up of the system have to be determined. This phase is complete when a theoretical prototype with complete crop programmes is ready to be put into practice. First objectives have to be formulated. Next, parameters have to be developed with target values to be able to test the objectives. The system needs to be designed with the aid of state-of-the-art, multi-objective methods. Finally, this results in an evaluated and complete prototype that in theory can satisfactorily meet the objectives.

5.3.1 Objectives and themes

The hierarchy of objectives as described by Vereijken was converted to a set of themes covering almost all of the aspects of farming systems. The themes used in the VEGINECO project were quality production, clean environment, natural resources and landscape, sustainable use of resources and farm continuity. In addition to these themes, health could be defined as another theme. This theme is especially of importance in animal production systems.

5.3.2 Parameters

Parameters with target values were defined to evaluate the performance of the farming systems. A suitable set of parameters needed to be defined. In the opinion of Vereijken (1994), these parameters needed to be multi-objective. In the VEGINECO project, this was not a requirement; parameters were connected to a specific theme. In addition, parameters must be influenced by the farming practices. However, other factors influence the value of the parameters, for example, net surplus (NS) in which prices play an important role and nitrogen available reserves in autumn (NAR), where weather (rainfall, temperature) is an important factor.

New parameters were also developed. To evaluate specific pesticide damage to the environment, a parameter was developed for the potential emission of pesticides in addition to the existing parameter for pesticide use (EEP). This parameter was used during the project in the testing and improving process, and proved to be a good basis for the selection of the most harmless pesticides. The parameter energy input (ENIN) was developed as an indicator for fossil energy use and CO_2 emissions, which gives a good insight into energy use. This parameter was not used in the testing and improving process as it was in the developmental stage and too labour intensive. Standardised calculation methods were not available and the basis to define target values is still missing.

More research is needed to make the parameter suitable for practical use. For the theme nature and landscape, a complete set of new parameters was developed as is described in more detail in the manual on Ecological Infrastructure Management (VEGINECO project report no. 5).

In addition, the parameters on quality and quantity of the produce were redefined. Quality and quantity parameters can now be quantified at a farm level, and were compared between regions by making crop yield and quality relative to good regional yields and quality levels. Farm level quality and quantity is calculated from an area considered to be average in the relative crop quality and quantity. Making yields and quality relative to good regional yields made it possible to compare yield levels for regions. However, it is difficult to establish objective good regional yields and quality levels.

Some existing parameters seem to be inadequate such as soil cover index. In the VEGINECO systems, this parameter was not useful because the main reasons to have soil cover; prevention of erosion and leaching and nature aspects were not a problem in the systems (erosion) or were covered with other parameters (leaching and nature). In first instance, magnesium available reserves and the magnesium annual balance (MgAR, MgAB) were included as parameters. As magnesium availability appeared to be no problem in one of the systems, the parameter was eliminated. The same could have been done with the parameter for nitrate content in crop produce (NCONT). High levels were not encountered and the target value was reached in all systems. However, this parameter was not eliminated.

The total set of parameters should cover the entire farming system, or at least all the problems encountered for similar farming systems in the region. In the VEGINECO project, a parameter on water use was missing, although increasing efficiency of water use in most systems is an important item, especially in Spain. In addition, parameters were missing because of costs, for example, nitrogen leaching to ground and surface water. As measuring was too expensive, the available nitrogen reserves before the start of the leaching season (NAR) were used as indicators for nitrogen leaching.

5.3.3 Setting target values

Parameter target values should be ambitious and relevant. They can differ per system because of differences in legislation or system specific differences. Especially when target values are negotiated between stakeholders, differences can occur. Differences between target values between systems for the same parameter are very clearly visible for the quality of production parameters QLP and QNP. Yield and quality targets per crop are set, dependent on the good regional yields in the region. Another example is the different target values for the soil reserves (PAR/KAR) as they are dependent on the analytic technique used, which is different in each country.

Target values can be unattainable and/or not be based on good scientific data. This was the case for the nitrogen reserves before the start of the leaching season (NAR) in Spain. The target value set is based on a rainfall deficit of approximately 400 mm because in Spain the deficit is only 128 mm. Therefore, the target value is inadequate. Research is needed to derive a target value for NAR in the Spanish systems. Another option is that target values are attainable, but only in the long term as is the case for available phosphate and potash reserves (PAR and KAR) in Italy and Spain. It will be at least 10 more years before the values reach the target range. Within the duration of the project, the values will maximally show a tendency in the direction of the target.

Switzerland had problems with setting targets for their farms, in general, as these farms more heterogeneous in farm type and environment than experimental farms. Nevertheless, working with subjective elements is inevitable in this type of research and setting targets has proven very helpful in the improvement of farming systems.

5.3.4 Methods

Farming methods are used to construct the prototype. New, multifunctional farming methods are replacing the conventional, one-sided methods that only aim to increase production. Four of these methods are described in the method manuals (Multifunctional Crop Rotation (MCR) in this manual, Integrated and Ecological Nutrient Management (I/ENM) in VEGINECO project report no. 3, Integrated and Ecological Crop Protection (I/ECP) in VEGINECO project report no. 4 and Ecological Infrastructure Management (EIM) in VEGINECO project report no. 5). These methods are very much interlinked and, therefore, in contrast to what may be suggested in each separate manual, they cannot be viewed separately. The MCR method describes crop rotation. I/ENM takes into account all contributing sources in nutrient management and helps to determine fertiliser type, amount and optimal time to be applied. I/ECP is supporting crop rotation perfecting the crop protection strategies. In integrated systems, much attention is paid to pesticide selection. EIM places the rotation in its natural resource and landscape context, providing maximal positive interaction between the environment and the landscape.

In the VEGINECO project, little attention is paid to the methods Farm Structure Optimisation (FSO) and Minimum Soil Cultivation (MSC). MSC is not examine because few of the concepts are useful and specific for vegetable farming, and are not valid all over Europe. Attention is paid to soil cultivation in the Netherlands by testing the eco-plough and in Italy and Spain by using the rotary hoe. FSO is not examined because the project was aimed more at the agronomical side. However, for commercial farms, FSO is a very important integrating method because of the emphasis on the evaluation of economic aspects of farming. In the project, attention was paid to FSO with the economic evaluation, which was done in the last year. Extensive discussions on the different methods can be found in the method manuals.

5.3.5 Theoretical prototype

The results of the farming methods are used in the theoretical prototype. Using the objectives to evaluate the prototype guarantees that an optimal prototype has been developed. If the deficits are too large, the design can be changed before the prototype is put into practice. This can reduce the costs during the expensive testing and improving phase.

5.4 Testing and improving

Testing and improving consist of lying out and running the system in practice. Measurements are made to evaluate the system annually. A clear analysis of the reasons for the shortfall is the basis for improvement. Then, redesign of the system may be necessary. Those topics and methods that caused the shortfall need to be focused on. This is a difficult process because pinpointing the causes or source of shortfall can be difficult. If a source is found, it is often difficult to redesign the system because changing one part means that other parts may also need to be changed as well. Also in many cases, solutions are not available. For example, many fungi infections such as late blight in potato cannot be removed completely in organic systems. In years or regions with high infection pressure, infections can are inevitable. In addition, there are other barriers such as psychological, cultural, social or financial barriers to overcome in order to improve the prototype. Every researcher is more or less limited in vision by his or her environment. In addition, the right balance between being innovative and being accepted by the farmers has to be found. The discussions on the farms between partners have proven to be a great help to overcome these barriers.

The closer the parameters come to their targets, the more improvement of the methods will become a fine-tuning of them. The remaining shortfall can probably only partially be solved by a further fine-tuning of methods. To completely meet the demands for all year round sustainability, new instruments have to be created such as small-scale mechanisation, resistant varieties and a range of available pesticides with low ecological risks. This is especially important for the very intensive vegetable farms, even then it is questionable whether the remaining shortfall can be solved without drastic changes to the farm structure.

The right balance between being innovative and being accepted by the farmers has to be found. In the experimental settings, it is difficult to determine whether methods are acceptable and manageable for the farmers. For the experimental systems, it is essential to communicate with the farmers about the developed methods and to check whether methods are acceptable and manageable for the farmers. During the project, the on farm discussions between partners have proven to be a great help to overcome these barriers.
The work on the pilot farms in Switzerland, and also the intermediate form of experimental and practical farms in a number of the Spanish and the Italian organic systems, provided good opportunities for discussions and feedback.

5.5 Dissemination

Dissemination is the process of translating the results of the experimental farm into practice. This should not be the starting point of discussions with farmers, but merely the ending. Farmers should be involved in the whole prototyping process from the start of the project. Analysis of the current situation, design of the prototype and the testing and improving requires interaction with farmers to be certain that problems are solved in ways that are applicable for farmers. However, farmers are not the only stakeholders in the project. Discussions with other interested parties such as government; environmental organisations; and trade companies need to be held as well.

Dissemination can be done on a small scale and preferably followed by a large scale. The dissemination process can be accompanied with on farm research as this was done in Switzerland.

In the other countries, results were already disseminated during the project. In Spain and Italy, where systems were part of practical farms, the farm manager played an important role in this process. As the farmer was involved in the process, this person could explain and convince other farmers the necessity for the changes made in the systems. In the Netherlands, farmers were involved in the set up of and making changes in the systems. These farmers were very important in the dissemination process.

Part 2. Multifunctional Crop rotation

6 Multifunctional Crop Rotation (MCR)

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

6.1 Problems in crop rotation

6.1.1 Definition

Crop rotation can be defined as the ordered succession of crops that are repeated every certain number of years (Urbano & Moro, 1992). The Multifunctional Crop Rotation (MCR) plays a central role as major method both to preserve soil fertility and crop vitality. The preservation of soil fertility means to take into account its physical, chemical and biological properties. Crop vitality is the basis for sustaining quality production with a minimum of inputs (pesticides, machinery, fertilisers and support energy).

6.1.2 Current situation

European agriculture currently has a complex of problems, mainly caused by the one-sided development of farming with the emphasis on intensification and focusing almost exclusively on economic results. In this way, certain vegetable farming areas have become real "industries of farming production", with monoculture practices or rotations of two years in the best cases. Many areas with intensive vegetable growing throughout Europe have become "dependent" on the use of soil disinfectants such as methyl bromide. This causes serious effects on the environment and makes the growing of crops increasingly expensive. Moreover, these soils become commonly exhausted and useless in the meanwhile.

The levels of yield decline if the same crop is grown in the same field for a long time (monoculture systems). The main reasons are that roots always explore the same soil layers and demand the same proportion of different nutrients ("exhaustion" of soil). In this way, the continuous monoculture is the main cause of the high pressure and fast propagation of harmful species of weeds, pests and diseases.

On the other hand, as many of the pesticides used will soon be forbidden, the possibilities to protect the crops decrease in conventional farming systems, and therefore, the innovation in these systems is increasingly required. Crop rotation plays a central and crucial role in the basic design of sustainable farming systems. It is not only the major weapon to prevent and control pests, diseases and weeds, but it is also the basis for maintenance and improvement of soil fertility. In organic systems, correction with pesticides is limited as only few pesticides are allowed.

For farmers, the main objective of crop diversification is to obtain a higher profitability both in the mid-long term and in the short term. A well-designed crop rotation may guarantee more stable economic results because low prices for one crop can be compensated by higher prices for another. However, the market is increasingly oriented to buying produce in specialised production areas from specialised farmers. Therefore, the crop diversification, the implementation of the MCR requirements, contracting and taking part in a crop program, are compromised by the commercial sector.

6.1.3 Policy, legislation and label guidelines

Although there is no legislation in the EU for crop rotation, legislation for nutrients and pesticides does influence the set up of crop rotation. Limits on the use of nitrogen and phosphorus make it unattractive to have rotate crops with too high of a demand for nitrogen and phosphorus. The prohibition of certain pesticides can limit the choice of crops in certain regions due to a higher risk of certain pests and diseases, and insufficient possibilities to control them.

Integrated production

In label guidelines, there are only general and vague crop rotation guidelines. The new EUREP-GAP protocol, concerning Good Agricultural Practices for the year 2001, is a first attempt to standardise IP-labels throughout Europe. This protocol handles the topic of MCR in a general way and is, therefore, sensitive to different interpretations. Effectively, in this protocol, it is required that "growers must recognise the value of crop rotations and seek to employ these whenever applicable"; furthermore, "where rotations are not employed, growers must be able to provide adequate justification". Likewise, crop rotations, use of resistant varieties and the choice of appropriate crop for the location are some of the preventive measures included in a list of "basic elements of crop protection".

In the Netherlands, there are legal guidelines on cultivation intensity and choice of variety for some crops (potato, flower bulbs) if the soil is infected with specific soil-born pathogens. In addition, the regulations on soil disinfection, which is only possible once every five years and only with a permit, make longer crop rotations inevitable. In integrated guidelines, a four-year rotation is seen as the minimum.

In Italy, the integrated protocols for field-grown vegetables in Emilia-Romagna region are divided into two types: Integrated protocols for the application of 2078/92 EU rule (now 1257/99 UE rule) and integrated protocols for Emilia-Romagna Guidelines. The first one requires a minimum rotation length of four years; no stubble seeds are allowed and a minimum of three different annual crops has to be grown every four years. The Emilia-Romagna Guidelines fix a minimum interval between two cycles of the same species (variable from 2 to 3 years), but not required with to respect to rotation.

In Spain, IP Regulations in the region of Murcia sets a maximum frequency on certain regulated crops (melon, broccoli, cauliflower, celery and lettuce), and chemical soil disinfections are not allowed. Other label protocols only recommend the "long crop rotations" and forbid the monoculture of annual crops (NATURANE and AENOR guidelines for controlled production (UNE-155001-1)).

In Switzerland, according to the guidelines for integrated vegetable production, the intervals between the main crops have to be at least 24 months (crops grown more than 12 weeks are defined as main crops).

Organic production
Most labels for organic production in EU are based on EC 91/2092 revised by regulation EC 01/436. In addition, the directions for the MCR can be defined as subjective. According to this regulation, it is required by the "appropriate multi-annual rotation programme" to maintain the soil fertility as a first measure to control pests, diseases and weeds. In the same way, certain crops such as green manures, legumes cultivation and deep-rooting plants must be included in this rotation. The general term "multi-annual" (that is length more than two years) and the lack of other specifications such as number, sequence and frequency of crops, and species composition will surely lead to different interpretations in the different EU-countries.

In the Netherlands, the guidelines for organic DEMETER-label are more detailed. These guidelines indicate a maximum of 50% of the area can be planted with crops that have roots and a minimum of 16% of the area can be planted with green manures (crops that are not harvested). In addition, crops that demand a high level of nitrogen should be alternated with crop that have lower nitrogen needs.

The guidelines for organic vegetable production in Switzerland require a balanced and diverse crop rotation.

6.2 Theoretical background

6.2.1 Objectives
Crop rotation is the term used to express that crops are grown over time in a very specific order (for definitions of terminology, see Table 6.1). After a number of years, (length of the crop rotation) the cycle will be repeated. The crops grown in one year on the available area of a farm make up the cropping plan. If the crop rotation is consistent and unchanged, the cropping plan is the same every year. Crop rotation has a temporal aspect: crops are grown over time in a specific order (succession of crops in time); and a spatial aspect: the crops grown this year and their division over the available space. The interaction between spatial and temporal aspects can be used to strengthen the crop rotation concept. Rotating the crops on the available space is done so that a given crop is never grown next to a field with the same preceding crop (spatial crop rotation). This helps to prevent semi-mobile pests and diseases from surviving from one year to the next.

Table 6.1 Crop rotation terminology

crop rotation	Carefully designed sequence of crops in which succession is highly advantageous.
cropping plan	The partitioning of crops over the available area in a given year, often represented as the percentage of the area for each crop (space).
crop sequence	The succession of crops in time on one field in particular (time).
crop frequency	The frequency of growing the same crop on the same field, usually expressed as once in a number of years. For example: 1 out of 3, 1:3, meaning once every three years.
crop rotation block	One year of the crop rotation succession and the crop(s) in that specific crop rotation year.
agro-ecological layout of the farm	The layout of the farm over the available space, the partitioning of the area in fields, their shape and size, the spatial crop rotation and the ecological infrastructure of the farm.
ecological infrastructure	The network of natural and specifically managed areas on the farm to provide habitats and (transport) corridors for flora and fauna.
field adjacency	The proximity in space of the fields composing the crop rotation.
adjacency of subsequent blocks	The proximity, in both time and space, of the same crop or between crops belonging to the same group. An attempt is made to avoid cultivating a crop on a field adjacent to one in which the same crop has been cultivated the previous year.

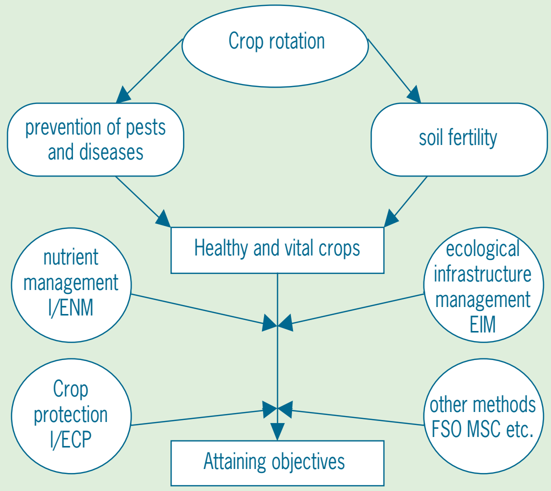


Figure 6.1 Actual results of objectives as a function of crop rotation and other methods

The main objectives of MCR are summarised as follows (Urbano & Moro, 1992):

1. To reduce the economic risk due to a greater crop diversity.
2. To avoid the exhaustion of soil as different species have different nutritional needs and colonise different soil layers.
3. To achieve a stable equilibrium of microbial life in soil by increasing the diversity or colonisation.
4. Reduction of pests and diseases, either aerial or soil-born.
5. Reduction of the competition with weeds.
6. Reduction of the seasonal employment on farms.

6.2.2 Relation with other farming methods

Crop rotation is the basis of any sustainable farming system. Its influence on different factors in the farming system such as soil fertility and soil health makes the MCR method essential to meeting most of the objectives. A poor design or the wrong choice of crops in the rotation can lead to serious increase in shortfall. Other methods support MCR in reaching the target values (Figure 6.1). The specific effect of the crop rotation on the different objectives is very much dependent on the farm, that is to say on the total set of main farming methods.

Farming methods discussed in the other method manuals are given in Table 6.2. Other methods that have not been used in the VEGINECO project are Minimal Soil Cultivation (MSC) and Farm Structure Optimisation (FSO) (see Chapter 2.3.3 and Annex 3 for a short description of all farming methods). All methods influence each other, and they must be used together to make farming systems as sustainable as possible.

6.2.3 Themes related to MCR

As the central method, crop rotation has a relationship with all the themes within the prototyping farming system.

- Crop rotation plays a central role in maintenance and improvement of soil fertility (sustainable use of resources).
- The better fertility and health of the farming soil obtained with the crop rotations will allow a lower use of pesticides and mineral fertilisers ("Clean environment").
- The same reasons will help to obtain a better quality-production and farm continuity. The latter is also influenced directly by the different growing costs depending on the chosen crops. Indirect influence through the potential reduction of expenses in crop protection and nutrient management.
- MCR also influences the theme of "farm nature" because biodiversity is increased with the crop diversification (both because of the crops and their associated flora and fauna).

Crop rotation influences all themes; but at the same time,

Table 6.2 Effect of crop rotation on the design of different farming methods

Method	Influence of crop rotation on the design of other methods
Crop protection	The choice of crops and/or cultivars will influence crop protection due to: • their genetic heterogeneity in time and space, • their capacity to reduce or control harmful species, • the tolerance or resistance of cultivars that are optimally used, • effects on the control of weeds (crops capacity to cover soil and how fast they develop).
Nutrient management	The chosen crops have different nutritional needs and this influences nutrient management (crops choice and order). Growing crops with different root systems will allow that every crop explore different soil layers, avoiding soil exhaustion. Likewise, the MCR design will influence in the supply of organic matter.
Ecological Infrastructure Management	Interactions between the ecological infrastructure and crops must be taken into account, mainly in the contact areas.

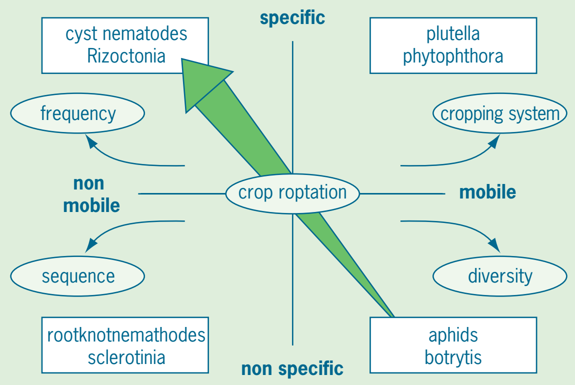


Figure 6.2 Crop rotation in relation to mobility and specificity of pests and diseases

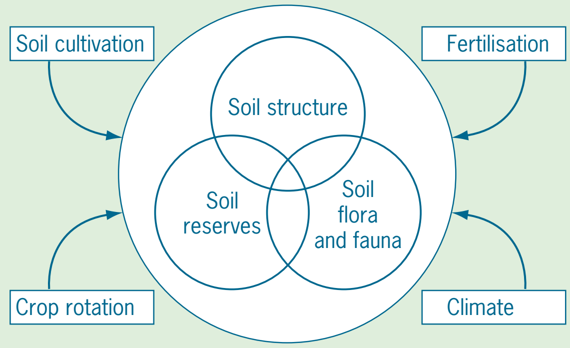


Figure 6.3 Soil fertility complex in relation to external factors

the themes are influenced by other methods. The influence of crop rotation on a theme can be variable depending on the specific agro-ecological conditions of the different farming areas. For example, crop rotation will have a greater influence on environmental effects of pesticides in areas with short rotations where soil disinfections are commonly practised.

The relationship between MCR and the other themes will be much stronger in the organic systems because the opportunities to correct any problem are usually fewer. For instance, if a crop is grown in a period with high pest or disease pressure, it is more difficult to control it in organic systems than in integrated systems.

6.2.4 Influence of crop rotation on prevention of pests and diseases, and soil fertility

Influence on prevention of pests and diseases
Figure 6.2 depicts the role of crop rotation for the prevention and control of pests, diseases and weeds (after Vereijken, 1994). Pests and diseases are placed along two axes. On the x-axis, the organisms range from non-mobile, mostly soil-born to very mobile, mostly airborne. On the y-axis, the organisms range from very specific (mostly monofageous) to non-specific (mostly polyfageous). Crop rotation is of increasing importance as the line moves from the lower right corner to the upper left corner.

1. Specific and non-mobile pests and diseases (upper, left corner): mostly soil-born, such as the cyst nematodes and Rhizoctonia spp. Low crop frequency of the organisms favourite crop, is usually sufficient to suppress these pests and diseases. The use of resistant and tolerant cultivars supports this approach.
2. Non-specific and non-mobile pests and diseases (lower left corner): this concerns also mostly soil-born pests and diseases like Sclerotinia and root knot nematodes. The composition of the crop rotation is important; which crops are grown and in which sequence. Support for this approach can be found in the cropping systems (sowing or planting date, cultivar choice) depending on the organism involved.
3. Specific and mobile pests and diseases (upper, right corner): concerns organisms such as Plutella and Phytophthora: classical crop rotation is not helpful here, although spatial crop rotation can contribute to the control of semi-mobile, specific pests and diseases. Other solutions might be found in the cropping systems (cultivar choice, sowing or planting date, crop structure). Control measures during cropping might be necessary.
4. Non-specific and mobile pests and diseases (lower, right corner): many pests and diseases. Crop rotation is of no use, although crop diversification might be helpful, especially when applied on a regional scale (diversification in space). Again, the design of cropping systems can contribute to prevention.

In these two last cases, natural predators might fulfil this function or pesticides will have to be used. Natural predators must be stimulated by a carefully designed and managed ecological infrastructure on the farm that offers year round shelter and food (functional biodiversity). Also factors such as shape and size of fields, and the total farm (parcel) layout become increasingly important: the agro-ecological layout of the farm. The control of pests and diseases is treated in the Integrated and Ecological Crop Protection manual (VEGINECO project report no. 4).

Influence of crop rotation on soil and nutrient management
Crop rotation plays a central role in maintenance and improvement of soil fertility in the broadest sense. This includes the physical (structure), biological (soil flora and fauna, positive and negative), and chemical factors (nutrient reserves and organic matter composition). The interaction between crops, soil, cultivation, fertilisation and weather determines the soil fertility, which is dynamic in time and space (Figure 6.3). The specific objective is to keep

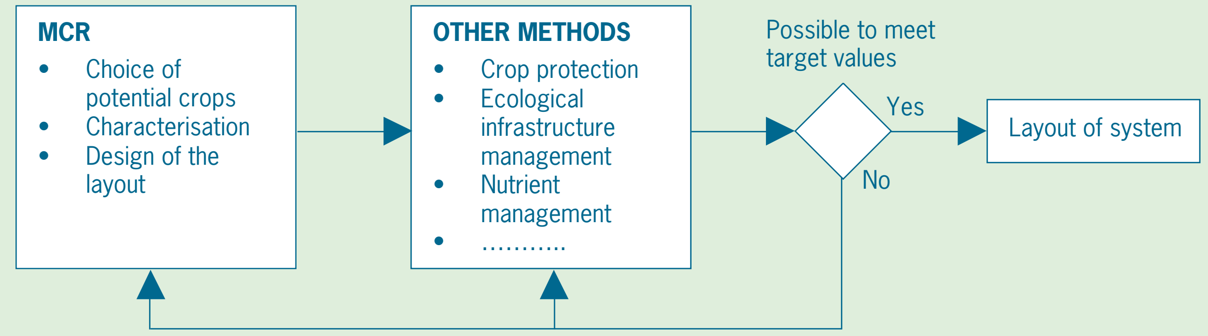


Figure 6.4 Process of designing farming methods and position of MCR in the design process

nutrients and organic matter reserves at agronomically desired levels and to minimise energy use.

Other factors such as the level of soil coverage by crops, the input of organic matter by crop residues contribute to the sustainability of soil fertility. Different characteristics and capacities of selected crops will define how long the soil is covered during rotation and protect it from erosive agents. The amount of crop residues in the rotation, which form a source of organic matter, is determined by the crops' characteristics.

6.3 The MCR design

6.3.1 The design process

The design of a crop rotation refers to the selection of crops and placing them in the correct order. The analysis, diagnosis and the objectives will provide some initial direction to the design process. For the design of a consistent MCR, three main steps have to be taken:

1. *Selection of potential crops* and their characteristics (Chapter 6.3.2).
   The procedure of this phase would be:
   - Set up a list of potential crops.
   - Characterisation of crops in their potential role in the MCR taking into account biological, physical and chemical aspects.
   - Choose main, secondary and tertiary crops.
2. *Setting up a crop rotation* with a maximum of positive and a minimum of negative interactions between the crops, which meet a multi-functional set of demands (6.3.3). First, the rotation length and number of crops in the rotation should be determined; secondly the order of crops is fixed.
3. The *design of an optimal agro-ecological layout* of the system in time and space (Chapter 6.3.4). There are factors concerning the layout such as field adjacency, field size and shape, field length and width, adjacency of subsequent crop rotation blocks (see Chapter 6.2.1, Definitions and Objectives), or the ecological infrastructure that ensure a maximum contribution of the MCR to the prevention of pests and diseases (Vereijken, 1994).

Once the MCR has been designed, all other methods (crop protection and nutrient management, mainly) must be reviewed. The review checks whether they fit properly into the designed MCR and whether the objectives have been properly set. In the case of a negative answer, the strategies of the 'other methods' have to be reconsidered or new MCR has to be designed. If all the methods fit together properly, the farming system can be laid out (Figure 6.4).

Completing the cycle of the prototyping methodology, the layout of the system leads to test and, if necessary, improve the prototype, by improving the methods (see Chapter 6.3.5).

6.3.2 Choice of potential crops

Selection of crops based on environmental and farm conditions

The selection of potential crops that will be in the MCR will be based on many different factors that can be divided into two groups:

1. Environment conditions.
2. The farm context (social, economical and commercial conditions).

The first selection is made of crops, which are adapted to the agronomic and climatic conditions of the area. Regarding climate, the most important aspects could be (Urbano & Moro, 1992):

- frequency, direction and intensity of winds,
- average temperatures throughout the year,
- dates of first and last frosts, if they occur,
- rainfall and its seasonal distribution,
- hours of sunshine and evapo-transpiration,
- possibility of hailstorms and
- occurrence of dew and snow.

The climatic conditions will be especially important to determine the best periods to grow a crop.

In relation to soil, the crops have to fit the biological, chemical and physical properties of the soil. Each soil

has a *different growing vocation*. Selected crops will have to be adapted to soil characteristics such as surface depth, acidity and structure, as well as fertility.
Once this first selection is made, there are certain preconditions to be considered so that a second crop selection will be made from the first list. These preconditions include: the characteristics of the farm, knowledge and capabilities of the farmer and advisors, and the trade and agricultural trends in the area. Crops that have no market potential at all are removed.

Characterisation of crops
After this second selection, the selected crops are characterised. As many crop characteristics as possible are included (see examples in Tables 7.2, 8.2 and 9.2). The table with crop characteristics will be adjusted to regional settings and to the objectives of the project: extra characteristics can be added while others can be removed.
The importance of certain characteristics can be different per region, depend on the objectives or the farming system type.

The organic and integrated farming systems differ in the weight that particular factors play in choosing the main crops in the rotation (different criteria). In the integrated systems, profitability and market possibilities are more important than in the organic systems. In the organic system, weed control, the availability of nitrogen, and the prevention of pests and diseases are more important factors.

The sustainability of any farming system will depend mainly on the economic results. Although a well-organised crop rotation is very convenient agronomically and can improve economic results in the long term, it will not be feasible if it is not profitable in the short term as well. Gross margin, input costs and the input of manual labour can be used to indicate the economic potential. The level of profitability and marketability of the different crops can be used to define the hierarchy in the rotation.

Agronomic, physical, morphologic and organic characteristics of crops are taken into account. Before organising the definitive rotation, it is necessary to know the length of the growing period of each crop. It is also essential to distinguish different botanic families because of their different sensitivity to pests and diseases, and their different influence on soil fertility. Influence on soil structure and sensitivity to poor structure is important. Root crops often leave a poor structure behind after harvest, while intensively rooting crops can improve the soil structure.

Concerning weed control, all crops have different capacities to cover the soil and how much mechanical control can be utilised during the growing season. The supplemental use of pesticides for each crop is useful as well. The need for continuous treatments against certain pests or diseases can have large negative environmental effects. In some cases, it may be necessary to check whether the required pesticides are authorised or not for specific crops. From an environmental point of view, it will be also critical that the MCR will not only be composed of crops that require a high number of pesticide applications.

Main and secondary crops
The role of a crop in the MCR can be derived from the characterisation. The team (crops in the rotation) should be more than the sum of the players. Some of the players can only score well, if others (preceding crops) carefully prepare the performance and in addition to defence against attacks (pests an diseases). The target of the crop rotation is offering appropriate, optimal and homogenous conditions to all the players in the team, but especially to those considered as "stars" (main crops).
It is advisable to identify more crops than necessary and to consider substitutions in order to prevent certain unexpected problems (commercial, environmental or organisational).

Crops can be classified in three different groups (main, secondary and tertiary group). Main crops can be defined as the most relevant crops in the MCR with especial attention to profitability, labour and mechanisation needed. Tertiary crops are included in the MCR to improve conditions for the main crops in the system and to improve overall system performance. Tertiary crops can improve soil structure, prevent leaching and reduce pressure of pests and diseases. Profitability is not their main priority. Examples of tertiary crops are green manures and cereals. Secondary crops are used to fill the crop rotation. They need to contribute to the profitability and to be compatible with the main crops.
After the classification, the definitive crop selection is not yet made, as interactions between crops still need to taken into account. The definitive selection takes place in the next step, the planning of the rotation.

6.3.3 Planning the crop rotation
During the MCR planning stage, the proper sequence of the different crops in the rotation must be set. It may take several attempts to set up the whole crop rotation. This is the most difficult and complex step in planning the rotation.

Defining the length of the crop rotation and number of crops
The main crops and the type of farming system (organic or integrated) are the two most important factors that determine both the length of the MCR as well as the number of crops in the rotation. In fact, the minimum frequency of the main crop(s) must be determined to prevent decreases in yield due to nutrient or phyto-pathological problems. If several main crops are selected for a specific MCR, the rotation length is based on the crop with the lowest frequency of occurrence in the rotation. Although

frequencies are difficult to determine for most crops, the minimum rotation length is at least four years. In organic farming, this may be longer (≥6 years) because the methods in crop protection and nutrient management are much more limited.

For example, under the Dutch conditions, potatoes should be grown maximally every four years to prevent nematode infestation in the potato crop. As in organic systems, the tools for control are much more limited, a margin of two years is set as a preventive measure. Then, the length of the MCR would be four years in integrated farming and six years in organic farming. Crops can occur twice in a rotation when the maximum frequency is equal to or higher than half the longest frequency in the rotation. For example, if the maximum frequency of wheat is once every two years. In combination with potatoes, wheat can be grown twice in an integrated four-year rotation.

In vegetable crops, especially in the Mediterranean region, more than one crop can often be grown in a year. This means that the number of crops selected can be as twice as high as the number of years in the rotation. Sometimes it is possible to have two or three plantings of the same crops, in a sequence. Then the frequency rule is applied to the all of the crops.

Planning the crop rotation: placing the crops
The crop grown in a specific year of the rotation (crop rotation block) will grow in the conditions created by the preceding crop and in its turn will contribute to the conditions for the next crop, as illustrated in Figure 6.5. In this way, every crop rotation block has its own identity and its own function: for example, restoring soil fertility, utilising the high nitrogen reserves from a preceding grass/clover year or offering excellent opportunities to control weeds before a crop that is not as competitive. The sequence in a model facilitates the choice of crops when changes have to be made in the crop rotation.

It can be necessary to include more than one crop in one crop rotation block. Then, crops should be chosen with

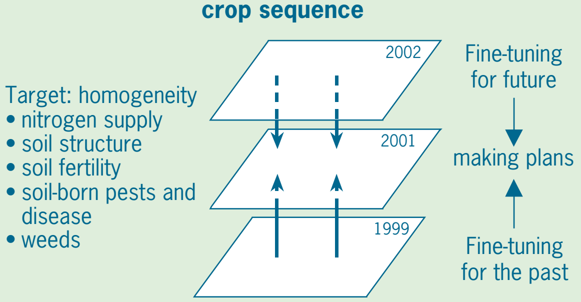


Figure 6.5 Planning of the crop rotation includes looking backwards and forwards in time

the same characteristics to make as little difference as possible between the starting times of the following crop.

It may be important to set up several rotation variations or substitute crops with equal or similar characteristics to those to be substituted, in case it is necessary because of labour capacity, market demands or any other reason. For example in the case of the Netherlands, two main crops, iceberg lettuce and Brussels sprouts, were selected as a basis for various alternatives with different secondary crops.

Main crops are placed first, followed by secondary and tertiary crops. Several criteria must be taken into account when planning the MCR concerning:
1. soil fertility,
2. botanic families, phyto-pathological groups and harvested part of plant (leaves, grains, roots),
3. competitiveness of crops with weeds and volunteer plants,
4. cultivar choice,
5. crop succession,
6. labour demands.

Soil fertility
Crop rotation interacts clearly with nutrient management because of the characteristics and specific role of crops and crop sequences in this process. This interaction is more important in organic systems because (mineral) fertilisers cannot be used. Therefore in organic farming systems, it is important to give more priority to crop properties as nutrient demand, efficiency of use in time and space, nitrogen fixation, amount and composition of organic residues, and nutrient transfer to the following crops.

Nitrogen fixation is especially important in the design of a rotation because nitrogen availability can often be limiting although inputs of phosphate and potash are already sufficient. Including nitrogen fixating crops or green manures can contribute dramatically to nitrogen availability.

In current organic farming practices, nutrient management is often not adapted to the specific limiting conditions and targets of sustainability. Maintaining an appropriate level of soil fertility does not mean increasing it to a level that is ecologically damaging, and using organic manure does not mean that nutrient losses are limited. Proper planning of crop rotation in accordance with nutrient management will help in adapting to these demands. Raising the organic matter input by choosing crops with large amounts of crop residues can improve soil structure. Deep and intensive rooting crops can improve physical soil properties as well.

Crop mix
The influence of MCR on pests and disease was already discussed in Chapter 6.2.4. However, crop rotation lay-

out is as important as the choice of crops for the success of crop protection. Not only the frequency limit for crops is important, but also the alternation of crops with different functions (leaf, root, flower, fruit) because they differ in susceptibility to pests and diseases.

Soil cover and weed control
Due to its importance in weed control, the capacities of crops to cover the soil and their rate of development must be considered when planning the rotation. Some crops are considered as "dirty" (non-competitive to weeds) and others as cleaner (competitive). For instance, onion is appropriate to follow cauliflower because the latter normally leaves a very low seed bank due to its high speed of development and high capacity to cover the soil.

Cultivar choice
Appropriate cultivars should be selected during the planning of the MCR. Cultivars are commonly selected on expected quality and yield. In addition, susceptibility to pests and diseases, and nutrient demands should be added as criteria. The choice of tolerant or resistant cultivars is preferred, especially in organic systems. This can mean a somewhat lower productivity. Between cultivars, there can be significant difference in nutrient demands. In organic systems, nutrient availability is often limiting and an appropriate cultivar choice can lower nutrient demands.

Crop succession
It is also very important in the design of the rotation to be aware of harvesting, planting and time between crops. For instance, tilling depends on soil humidity conditions and sufficient time has to be taken to do false plantings if necessary. Another important point is optimising the time between crops to maximise the nitrogen availability from mineralising crop residues.

Labour demands
The labour demands of the crops in the rotation should be tuned to one another. Labour peaks for one crop should coincide with low labour demands for other crops.

The resulting MCR (and their alternatives) should be as superior as any other crop rotation due to good short-term economic results and optimum fertility conditions of the soil in the long-term with minimum need of external inputs.

6.3.4 The design of the agro-ecological layout

When the rotation is planned, the layout of the MCR has to be designed in the agro-ecological context of the farm. The first step of the layout is to divide the farm into as many fields as the previous years. Next, the crops have to be divided over these blocks in such way that field adjacency is maximal and adjacency of subsequent blocks minimal (see Table 6.1 for definitions). Maximum field adjacency is desired to obtain an agro-ecological unity as a prerequisite for an agro-ecological identity. Soil and climatic conditions should be as homogeneous as possible. However in practice, only a small number of farms have adjacent fields. In addition, different conditions between fields are common. When this occurs, it may be advisable to set different crop rotations for different fields according to their conditions to maximise the performance of the system.

Planting or seeding crops adjacent to subsequent blocks should be prevented to prevent harmful semi-soil-born species from following their host crop during the crop rotation (Figure 6.6) (Vereijken, 1994). This can be more important when crops in the MCR are planted for two years or more because the same crop will be grown at the same time during a certain period in adjacent fields.

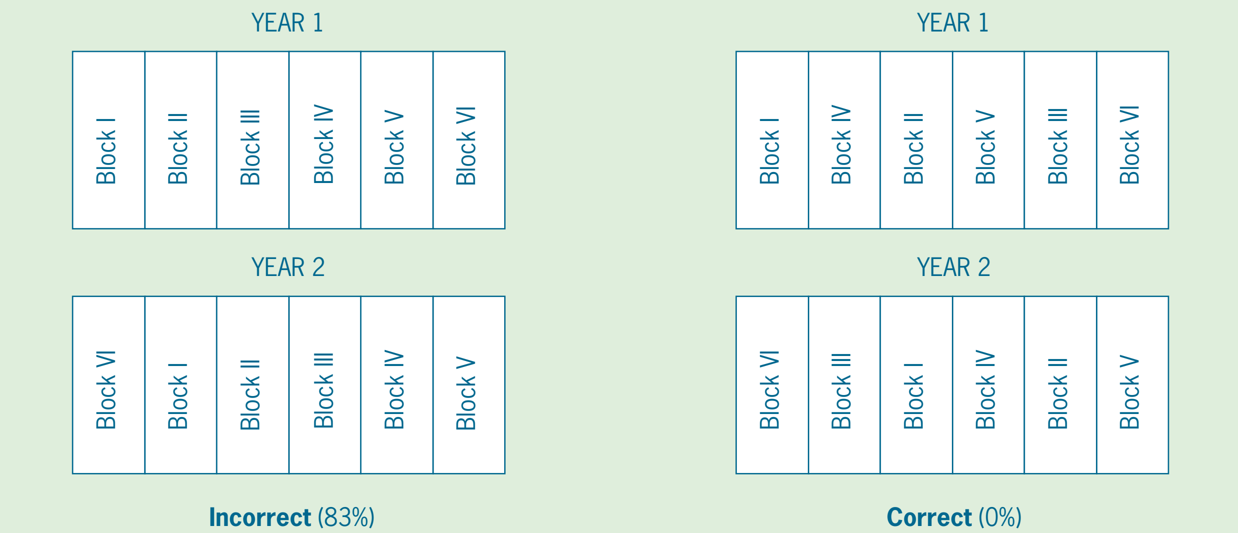


Figure 6.6 Examples of adjacency of consecutive blocks

The crop row distance is also an important element in the design of the layout, mainly for mechanical weed control. The distance must be adapted to the available machinery and tools.
The farm size and shape will also determine the length and width of blocks and, therefore, the influence the MCR layout. For instance, the narrower the fields are, the easier the pests and diseases can move between fields. Vereijken proposes for arable farming a field size of at least one hectare and field length/width ratio should be smaller than four.
In addition, the implementation of the ecological infrastructure (in quantity and in quality) will be largely influenced by these conditions. For instance, the small field size in Spain is a large obstacle for the creation of adequate natural areas because they can be obstacles for normal farming tasks.

Temporal aspects make the design of the layout even more complicated. Leasing land can also be an obstacle because it disrupts the necessary continuity over time that MCR requires to attain the proposed objectives. The crop rotation sequence should be continued on the same fields over the years. Commonly experienced difficulties are changes in crops or area per crop. This might be appropriate given the market conditions and opportunities. However, changes in crops should be done accordingly to the conceptual MCR model. Crops should only be substituted with comparable crops. Shifts in areas per crop from year to year threaten the homogeneity.

6.3.5 The review of the resulting prototype

The layout of the MCR along with the other methods implies testing and improving the prototype until the objectives have been attained. Because 'testing and improving' is the most laborious and expensive step, requiring at least a full rotation of the prototype on each field (at least 4-6 years), it will be crucial that all preceding steps have been followed with the greatest accuracy. Therefore, it is useful to take a critical retrospective view before laying out the resulting prototype (Vereijken, 1999). For example, checking incompatibilities of the MCR with the other methods used. If the resulting crop rotation contains a crop, which is grown in a period with high sensitivity to a certain disease or a virus, the rotation should be reviewed. The crop can be given another place or it can be removed from the rotation. Another example, often occurring in organic systems, is the replacement of a crop with a high nitrogen demand by a crop with a lower demand when nitrogen availability is limited.

The review of the prototype allows checking whether the desired results can be achieved for the parameters related to the method, or whether shortfall in any of them can be expected. The value of each parameter must be estimated. Estimations are based on literature and/or expert judgement. Estimations or calculations can be done on:

- Crop 'x' following crop 'y' can give a yield reduction/surplus of 5%.
- The effective organic matter input of the rotation.
- The average pesticide use in the rotation.
- The average economic value of the yield in the rotation.

Attention has to be paid to the benefits and strong points as well as the disadvantages in crop rotation. Crop rotation influences almost all parameters used to evaluate the farming systems (except those related to the 'Ecological Infrastructure Management'). However, in most cases, these parameters are more influenced by other methods. Therefore, MCR evaluation requires the determination of the relationship between possible shortfalls in parameters and the MCR design. This is often very difficult to point out. If shortfalls are due to the rotation design, obviously, re-design is necessary.

Chapter 4 explains which parameters are used and why these are chosen. In Table 4.7, the parameters used in the VEGINECO project are briefly defined. In Annex 2, a brief definition of these parameters together with the calculation procedure is given.

This chapter is the theoretical process in the design of a 'Multifunctional Crop Rotation'; it has been written with the experience gained from the farming systems of the VEGINECO project. Several of the steps and directions included in it are a consequence of this experience. Therefore, several of these directions were not followed in the first design of the MCR in all tested systems. This can be read in the following chapters, which present some practical examples of MCR design and results in testing and improvement.

7 A practical case of MCR in the Southwest of the Netherlands

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

7.1 Design of the MCR

7.1.1 Preconditions in setting up the rotations

Regional aspects
The main development in vegetable farming in the Southwest of the Netherlands, as described in Chapter 3, is the combination of arable and vegetable crops. Arable farmers include vegetable crops in their rotation while specialised vegetable farmers intensify their cropping plan by including arable crops. Therefore, the aim is to grow fresh market vegetable crops that highly profitable combined with the usual arable crops. The most important vegetable crops in the region were included in Table 3.2. The most important arable crops are potato, sugar beet and cereals.

The experimental farm
The PPO's experimental farming systems are located in Westmaas in the Southwest of the Netherlands (51°47' N.L, 4°30' O.L.) at two meters below sea level. The farm is on marine clay soil with a clay percentage of 32%, organic matter content of 2.3% and a pH (KCl) of 7.3. The groundwater table is at a depth of one meter. The maritime climate has a long-term mean temperature of 9.7°. The mean daily maximum temperature is 13.7° and daily minimum mean temperature is 5.9°. Average rainfall is 790 mm. In Table 7.1, an overview is given of the system's characteristics including the size and layout of the system.

7.1.2 Choice of crops
Fresh market vegetables are the main crops in the rotations. Two model crops are chosen which are representative for most vegetables: iceberg lettuce as labour intensive and Brussels sprouts as labour extensive cabbage crop. Iceberg lettuce is the model for the leafy vegetables group (endive, head lettuce, spinach and other lettuce types). These crops are combined with other vegetable crops, one arable cash crop and the rest crops in the organic as in the integrated system. In this way, the integrated and organic systems are somewhat comparable. The different economic and agronomic characteristics of the chosen potential crops are summarised in Table 7.2. The numbers in the table indicate the relative position; the numbers are explained under the table. Next, the crops are described, but only crops included in the rotation are described.

Brussels sprouts
Brussels sprouts are a very competitive crop that can easily suppress volunteer plants of potato. Mechanical harvest during late cropping activities can have a negative influence on soil structure. Brussels sprouts leave very little mineral nitrogen behind in the soil because they are deep rooting. Depending on the cropping activity, loss of nitrogen from crop residues can occur. It is not advisable to grow the crop in a short rotation together with sugar beets because of infestation by beet cyst nematodes. Pesticide use is high because the growing period is very long and various pests and diseases can threaten product quality. There has to be a continuous nitrogen supply for the crop. Irregular growth has a great influence on quantity and quality of the produce. In conclusion, the crop is hard to grow under purely organic circumstances because of its vulnerability to pests and diseases, and irregular nitrogen supply.

Cauliflower
Cauliflower is placed in the same sequence in the rotation of the integrated system as Brussels sprouts. In the Southwest, the crop is grown more and more on a large scale as winter crop. Harvest is mainly done by manual labour. Pesticide use is quite low because the pests and diseases do not threaten the quality or quantity. The crop is competitive against weeds and volunteer plants.

Iceberg lettuce
Specialised farmers grow the crop on a large scale mostly in rotation with arable crops. The crop is susceptibility to poor soil structure. An early harvest leaves a lot of mineral nitrogen reserves behind which the second crop can use. If iceberg lettuce is grown as a second late crop, the mineral nitrogen reserves can risk leaching after harvesting. Highly mechanised harvest in autumn can have negative effects on soil structure. Iceberg lettuce is very susceptible to aphids, which calls for high pesticide input. Even with this high input, it is not always possible to grow an aphid free crop. In addition, iceberg lettuce has a high risk of failures due to bad weather conditions.

Table 7.1 Overview of the system's layout characteristics of the prototypes in the Netherlands

	Integrated	Organic
System area (ha)	2.8	1
Rotation length (years)	4	6
Number of fields	32	12
Number of rotation blocks	8	2
Mean field size (ha)	0.08	0.075
Mean field length/width ratio	5.6	3.3
Field adjacency[1]	1	1
Adjacency subsequent blocks*	0.25	0.73

* means all fields are adjacent, if subsequent rotation blocks are fully not adjacent, then the rotation in space is optimal and the index is 1

Table 7.2 Potential crops and characterisation

Crop[1]		Iceberg lettuce	Cauliflower	Fennel	Brussels sprouts	Potatoes	Celeriac	Barley
Family/group[2]		1	2	3	2	3	4	5
Economic	Gross margin (k€)	8-10	6-8	6-8	4-6	2-4	2-4	0-2
	Input costs (k€)	6-7	4-5	5-6	3-4 1-2	1-2	0-1	
	Input labour (100 hours)	5-6	3-4	3-5	2-4	0-1	0-1	0-1
Agronomic	Length of growing period (days)	0-60	60-120	60-120	180-240	180-240	120-180	120-180
	Number of crops/year	2-3	2	2	1	1	1	1
	Cover in autumn/winter[3]	2	2	2	2	2	4	4
Soil structure	Rooting[4]	1	3	2	4	2	1	4
	Compaction[5]	0	0	0	3	3	2	1
Crop protection	Input pesticide (kg ha^{-1})	6-8	6-8	0-2	4-6	6-8	10-12	2-4
Weed control	Competitiveness[6]	3	3	2	3	1	4	3
	Mechanical control[7]	1	0	1	0	1	0	0
Fertilisation (N)	Average N- fertilisation (kg ha^{-1})	50-150	250-300	50-150	200-250	200-250	200-250	100-150
	N-off take (kg ha^{-1})	0-50	50-100	0-50	100-150	50-100	100-200	50-150
	Residual-N (kg ha^{-1})	50-100	100-150	50-100	100-150	100-150	100-150	50-100
	Transfer-N (kg ha^{-1})	50-100	50-100	50-100	-	-	-	-
	Transfer-N (kg ha^{-1})	0-50	0-50	0-50	0-50	0-50	0-50	0-50

1. Crops in order of profitability
2. Genetically and phyto-pathologically related groups: 1 = Compositeae, 2 = Crucifereae, 3 = Umbrellifereae, 4 = Solanaceae, 5 = Gramineae
3. 4 = no cover in autumn and winter, 2 = no cover in autumn or winter, 0 =all others; (green manure crops included)
4. 0 = poor superficial rooting, 4 = deep intensive rooting
5. Crop, cropping practices, soil, harvest time and harvest technique determine the intensity of compaction: 0 = very light compaction, 4 = intensive and serious compaction
6. 0 = very poor weed suppression, 4 = strong weed suppression
7. 0 = weed control completely mechanical, 4 = no mechanical weed control possible

Fennel
In the Southwest region, fennel is increasingly grown on a large-scale. Pesticide use in fennel can be quite low. Apart from an occasional aphid attack, there are no pests or diseases that seriously threaten the crop. The crop is not very competitive against weeds. Input of herbicides in combination with mechanical control is necessary to limit too much manual labour. After late harvests, mineral nitrogen reserves left behind combined with nitrogen from crop residues means a risk of nitrogen leaching.

Celeriac
The Southwest is a main production area for celeriac. In its early stage, the crop is not very competitive with weeds. However, weed control can be carried out completely mechanically. Fungal diseases can cause a need for high fungicide use.

Potato
Potato is the most profitable arable crop. This crop has the risk of leaving volunteer plants in the next crop. Therefore, preferably a highly competitive crop has to follow potato in the rotation. Late blight in potato calls for high fungicide input. In the organic system, this means that the crop has to be harvested early.

Barley and winter wheat
Cereals are not attractive as cash crop, but have a positive effect on soil structure because of their deep intensive rooting. The choice of a summer or winter cereal is dependent on the harvest time of the previous crop. Spring cereals allow the possibility of using a catch crop in autumn. In addition, under sowing of white clover is more successful in spring cereals (organic system). Winter cereals provide the advantage of soil cover in the winter.

Other crops are not feasible in the rotation. Carrots, although having a large acreage in the region, are not grown because the soil at the experimental location is too heavy. Papilionaceous crops (beans) are not chosen because the aim is for highly profitable fresh market crops. Potato is chosen as arable crop because of its

Table 7.3 Chosen variants for the integrated crop rotation, variant 1 and 2 differ in vegetable cropping activities, variant 8 is not irrigated

	Crop rotation variant						
year	1	2	3	4	5	6	7
1	potato	potato	potato	potato	potato	potato	potato
2	Brussels sprouts	Brussels sprouts	Brussels sprouts	Brussels sprouts	fennel	celeriac	cauliflower
3	spring barley	spring barley	spring barley	spring barley	winter wheat	winter wheat	winter wheat
4	fennel	fennel	celeriac	iceberg lettuce	iceberg lettuce	iceberg lettuce	iceberg lettuce

profitability and large acreage. Therefore, other arable crops (as sugar beet and onion) are not taken into account.

7.1.3 Planning the MCR

Cultivation intensity and choice of crop types
A four-year rotation is standard for conventional arable farms. The standard arable rotation is potato, sugar beet, cereal, and a fourth (mow) crop. When including vegetable crops in arable rotations, a four-year rotation is used as well. The usual combination of crops is 50% fresh market vegetables, 25% arable cash crops (potato or sugar beets) and 25% cereals. The rotations in the integrated system will be planted for four years with the above-mentioned set-up.

In organic farming, a six-year rotation is considered as optimal agronomically. This length of time is necessary for successful prevention of pests and diseases. Also, the possibilities for nitrogen input are limited. An optimal combination of highly demanding (mostly vegetables) and undemanding crops (cereals) has to be found. When the rotation is longer, this is more possible. Therefore, a six-year rotation has been chosen in the organic system. In this rotation, the aim is to include 50% of fresh market vegetables, 33% with tertiary crops (cereals) and 17% with arable cash crops.

To cover the most possible cropping activities and the most important crops, it is necessary to plan different variations. Seven variants in the integrated system and two variants in the organic system were set up. The following section explains how the rotations were set up.

Integrated systems
Brussels sprouts and iceberg lettuce were chosen as main crops in the integrated systems. Each variant contained one of these crops in combination with one other labour intensive or extensive vegetable crop. Fennel was chosen as intensive crop and celeriac as extensive crop. Both of these are umbellifereaous crops, which makes them representatives of a different plant family as the chosen main crops. There were two variants with Brussels sprouts and fennel in order to test different cropping activities. One variant consisted of iceberg lettuce and cauliflower. Each variant contained potato as arable cash crop and barley or winter wheat as cereal crop.

The most structure sensitive and most profitable crops such as iceberg lettuce and fennel are grown after cereals. When both crops are in the same rotation, iceberg lettuce is grown after the cereal. The Brassica crops are grown after potatoes because of the good possibility to control volunteer potato plants. Whenever possible, catch crops are grown. This is only possible when the field is clear before mid-August. Non-leguminous crops are chosen to lower the mineral nitrogen content of the soil in autumn.

After all factors were considered for the cropping plan and rotation, the rotation variations given in Table 7.3 were chosen. When discussing the results variant one to four are discussed together in system NL INT1 and variant five to seven are discussed together in system NL INT2. In Figure 7.1, the crop rotations over time for the integrated rotation variants are shown. In winter period, there is no soil cover. Other than winter wheat, there are no winter crops. Ploughing has to be done before winter because the soil is too wet in spring. Planting normally starts in the second half of March. Between two crops in the same year, there is a short fallow period of 2-4 weeks.

Organic system
The motivation for the choice of the crops in the organic system (NL ORG) is the same as for the integrated systems: iceberg lettuce is chosen as representative for the leafy vegetables and Brussels sprouts as a representative for the Brassica crops. The third vegetable crop is fennel as representative of a labour intensive crop from a different plant family. The rotation is completed with potato as arable cash crop and with two cereal crops to improve soil structure and to lower nitrogen demand. The two variants of the organic system only differ in the chosen cropping activities of the vegetable crops.

Minimising nutrient losses and optimising nutrient availability were leading factors in planning the rotation (see 7.2 and Integrated and Ecological Nutrient Management manual, VEGINECO project report no. 3). Therefore, nitro-

Table 7.4 Rotation and fertilisation of the organic system

Year	Crop	organic fertilisation	remarks
1	iceberg lettuce	before crop, liquid cow manure	two plantings
2	winter wheat or barley white clover	solid cow manure after cereal	under sowing of clover in cereal
3	Brussels sprouts	before crop, liquid cow manure	
4	fennel		one or two plantings
5	winter wheat or barley white clover	solid cow manure after cereal	under sowing of clover in cereal
6	potato vetch/grass		catch crop

gen-demanding crops are altered with undemanding crops. In addition, effective weed control and prevention of negative affects on soil structure were important aims in setting up the rotation. Whenever possible, catch crops were grown. This was only possible when the field was cleared before mid-August. Leguminous crops were chosen as green manures to bring extra nitrogen into the system. White clover was grown in combination with the cereal crop (under sowing) to add nitrogen to the system through nitrogen fixation. Vetch with grass was grown after potato.

The two cereal crops had to be divided equally over the rotation. The crops with potentially the most negative effects on soil structure were potato and Brussels sprouts. Therefore, these crops were equally divided over the rotation as well. Both iceberg lettuce and fennel probably leave some remaining weeds behind. Therefore, a cereal crop after these crops helps to control these weeds. Additionally iceberg lettuce and fennel leave a lot of mineral nitrogen and nitrogen in crop residues behind. This calls for a follow up of crops such as cereals with a deep and intensive rooting in order to use a part of this

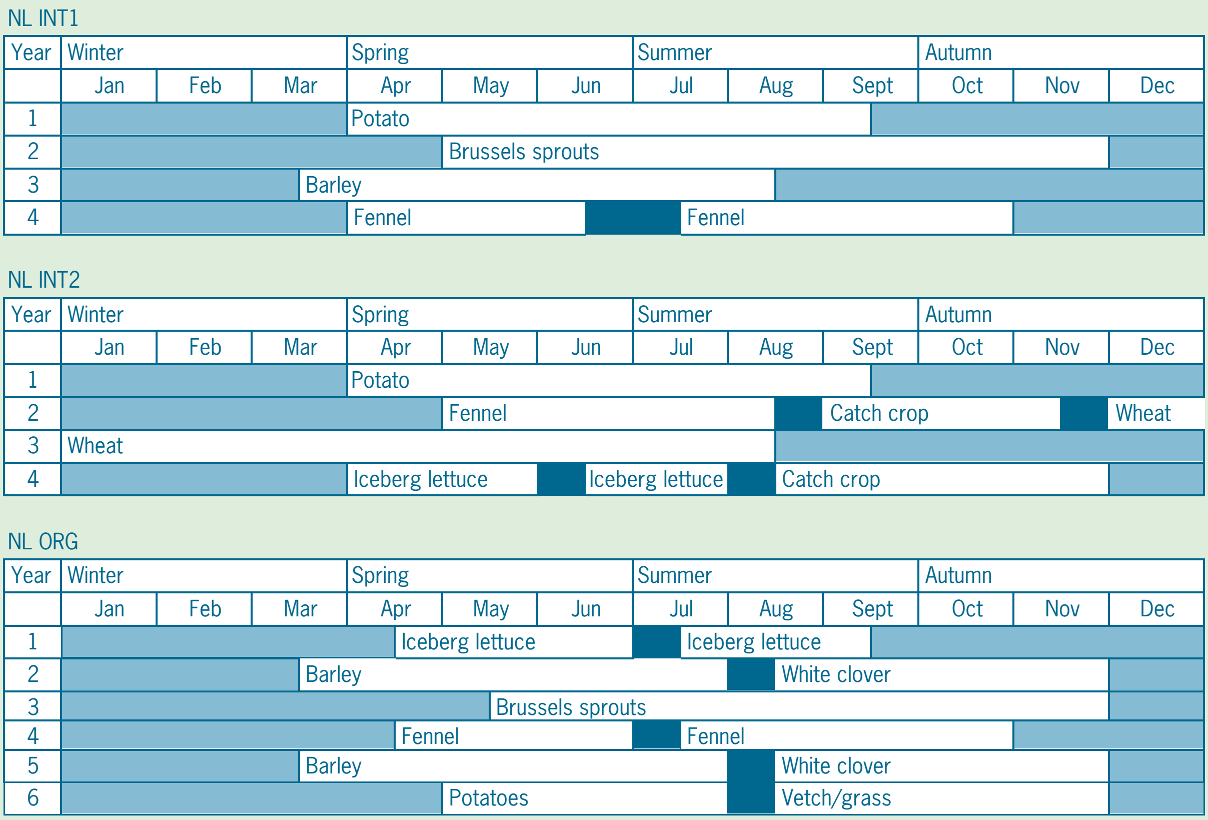


Figure 7.1 Examples of Multifunctional Crop Rotation represented over time of cropping variant 2 of NL INT1, cropping variant 5 of NL INT2, and cropping variant 1 of NL ORG

nitrogen in the next season. Fennel is not very competitive against weeds so this crop needs very clean conditions, which is possible after Brussels sprouts. Potatoes leave a lot of mineral nitrogen reserves and nitrogen in crop residues behind. Because the crop is harvested early, the cultivation of a catch crop was possible. The catch crop can also improve the soil structure after potato. The organic crop rotation is given in Table 7.4. The division of the crops over time is given in Figure 7.1.

7.1.4 Agro-ecological layout

Figure 7.1 shows the layout of the systems over time, Figure 7.2 shows the layout of the systems in space. As indicated in Table 7.1, all fields are adjacent. The different variations were mixed to make cultivation of the crops easier. As much as possible, fields with the same crops were put together. It was not possible to avoid placing subsequent blocks next to each other in both systems.

7.2 Testing and improving

7.2.1 Results per parameter

Almost all parameters have some relationship with MCR. In this paragraph, the parameters with close relationships to the MCR method are examined. In Tables 7.5 and 7.6, an overview of the parameter values is given for the NL INT1 and NL ORG.

Quality and quantity of production (QLP/QNP)

In the integrated systems, the actual levels for quantity and quality almost reached the desired levels. It is assumed that nutrient availability is sufficient to reach yield quantity and quality targets. Yield quantity and quality is most influenced by external factors (weather), diseases and plagues.

For organic farming, there is hardly any data available

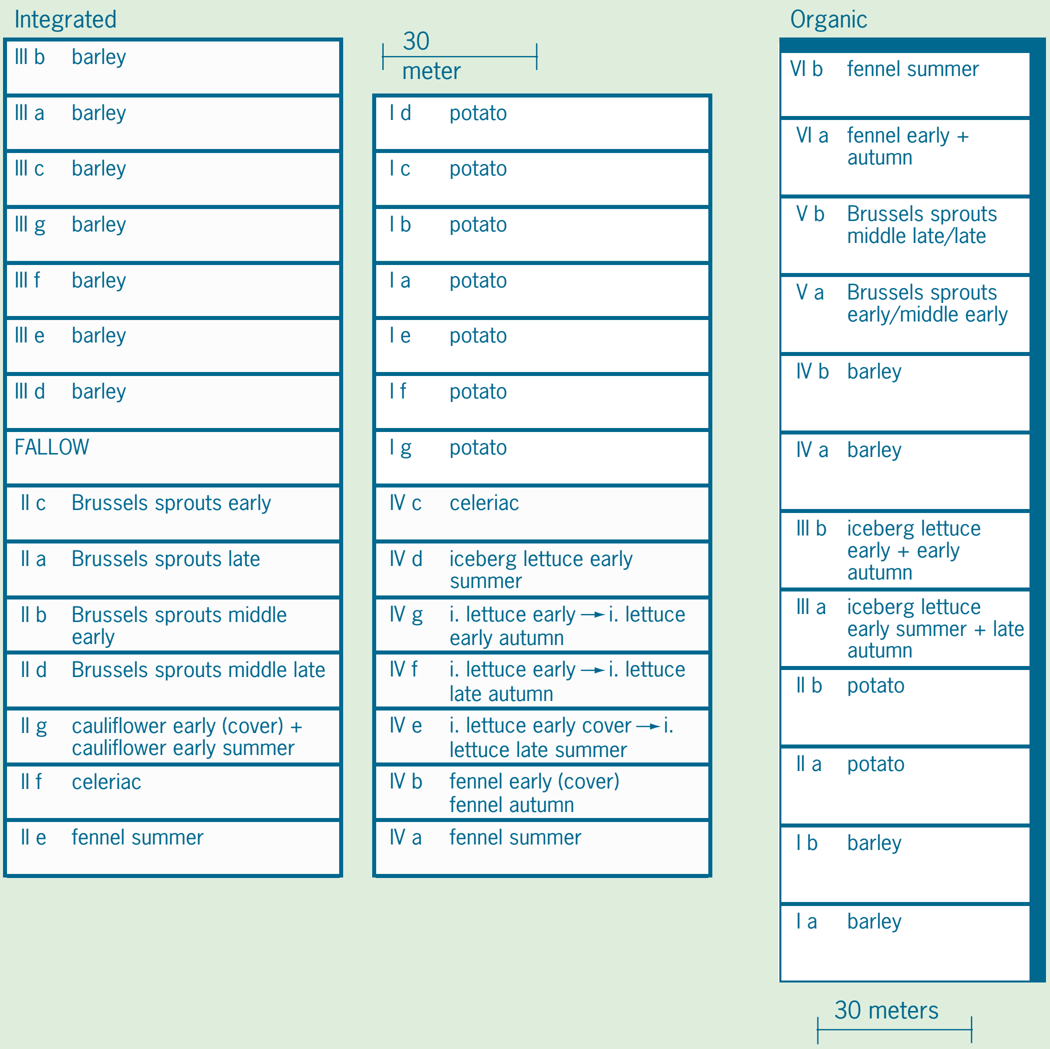


Figure 7.2 Map of the integrated and organic system Westmaas, I-VI = crop rotation block 1997, a - h = cropping variant, ▬ = part of ecological infrastructure

Table 7.5 Desired and achieved results for parameters in NL INT1 with close relationships to MCR

Theme	Parameter	Desired results	Actual results 1997	1998	1999	2000
Quality Production	QNP	1.0 (GAP)	0.95	0.71	0.90	0.96
	QLP	1.0 (GAP)	0.99	0.92	0.80	0.88
Farm Continuity	NS	>€ 0 ha^{-1}	-1 356	399	-2 040	-2 698
	HHW	<15 hours ha^{-1}	-	19	12	10
Sustainable use of Resources	PAR	20<Pw-count<30	30	28	29	24
	KAR	20<K-count<29	26	24	23	23
	OMAB	>1.0	1.5	1.7	1.5	1.4
Clean Environment Nutrients	PAB	1.0	1.15	0.91	0.81	1.06
	KAB	1.0	0.84	1.25	1.04	1.03
	NAR	<70 kg ha^{-1} (0-100 cm)	58	25	33	32
Clean Environment Pesticides	PESTAS	<5.9 kg ha^{-1}	3.3	1.9	1.5	2.5
	EEP-soil	<240 kg days ha^{-1}	250	226	155	167
	EEP-air	<0.45 kg ha^{-1}	0.64	0.57	0.51	0.66
	EEP-groundwater	<0.5 ppb	5.98	4.83	4.77	0.01

to support the quantification of the Good Agricultural Practices in terms of yield and quality. The calculated QNP and QLP are averaged over all the crops in one system. QNP varied from 66 to 89% of the target values and QLP improved over the years by 10%. In addition, problems in crop protection and nitrogen supply needs to be improved for all crops to reach target values.

In the integrated systems, quantity of production did not reach targets for iceberg lettuce and cauliflower. Quality of production is too low for almost all crops except celeriac and the cereals. In the organic system, the most problematic crops were Brussels sprouts and iceberg lettuce. Except for Brussels sprouts, quality in the organic system reached target values. Quality of Brussels sprouts is very low because of slugs and insufficient nitrogen availability. These causes have no direct relationship with MCR.

Differences between integrated and organic systems were small for most crops. Only for Brussels sprouts (quality and quantity), potato (quality) and cereal (quantity) are the differences large. Variation between years is, however, large.

Net surplus (NS)

The calculations of net surplus are based on a farm size of 47 hectare for NL INT1 and 28 hectare for NL INT2 and NL ORG. The gross revenues are yield times actual price. Fluctuating product prices mainly influenced the fluctuation in the gross revenues. Unfortunately, the average price level in the testing period was very low which negatively influenced the economic performance. The organic farm has higher costs per hectare, but still had positive net revenues mainly because of the higher prices for organic produce.

Hours hand weeding (HHW)

In the integrated systems, hours of hand weeding almost

Table 7.6 Desired and achieved results for parameters in NL ORG with close relationships to MCR

Theme	Parameter	Desired results	Actual results 1997	1998	1999	2000
Quality Production	QNP	1.0 (GAP)	0.72	0.73	0.85	0.61
	QLP	1.0 (GAP)	0.49	0.64	0.65	0.71
Farm Continuity	NS	>€ 0 ha^{-1}	2 439	2 837	1 167	-2 135
	HHW	<15 hours ha^{-1}	-	26	34	62
Sustainable use of Resources	PAR	20<Pw-count<30	29	29	29	23
	KAR	20<K-count<29	25	24	25	25
	OMAB	>1.0	1.4	1.3	1.4	1.4
Clean Environment Nutrients	PAB	1.0	0.70	0.93	1.19	1.42
	KAB	1.0	2.62	0.93	1.77	1.85
	NAR	<70 kg ha^{-1} (0-100 cm)	80	14	52	41

reached target values. However, in the organic system, there is still too much manual labour. Mechanical weed control needs to be further improved. In addition, a thistle and cale infection from previous cultivations at the start of the system made extra manual weeding hours necessary.

Sustainable use of resource parameters (OMAB)
Some crops contribute much more to the effective organic matter input because of a large amount of crop residues (Brussels sprouts, cereals) or because of the input of paper pots in which they are planted (iceberg lettuce, fennel). In addition, green manure crops bring effective organic matter in the system. The input of effective organic matter with crop residues, paper pots and green manures is more than sufficient to compensate for decomposition of a soil's organic matter in both types of systems. MCR has great influence on the input of effective organic matter in these systems.

Nutrient parameters (NAR)
In most years, the NAR was lower than the target level of 70 kg ha-1 in NL ORG as well as in NL INT1. The NAR on farm level is very dependent of the type of crops in the rotation. In the integrated system (Brussels sprouts), no crop had a high NAR, thus the farm level is relative low. In NL INT2, the actual level is close to the desired level (69 kg ha-1) because of the high NAR after the cultivation of iceberg lettuce. This indicates that MCR can have a great influence on the NAR of the system. In the organic system, iceberg lettuce and potato caused a high NAR. Iceberg lettuce had a high NAR because of low efficiency and large amounts of crop residues. Potato in the organic system had a high NAR because it was harvested too early due to late blight.

7.2.2 Optimisation of the MCR
This section describes the improvements made to the MCR while testing to make the system perform better and reducing the parameters' shortfall.

NL INT1
Over the four years of testing and improving, the Multifunctional Crop Rotation for the integrated systems were only slightly altered. Extra catch crops, whenever possible, were placed in the rotation although possibilities were limited because of weather conditions and harvest times. By growing these catch crops, the amount of mineral nitrogen in autumn could be lowered. After iceberg lettuce, cauliflower and fennel, phacelia, white mustard, Italian ryegrass or fodder radish was grown. Between two cultivations in one year of iceberg lettuce, a little more time was taken in order to increase the supply of nitrogen from crop residues from the first crop. The reason for this measure was the amount of mineral nitrogen in autumn was lowered as well. Finally, varieties were changed in order to have crops that have a better yield (quantity and quality) or that are more resistant against pests and diseases. Other varieties were chosen in fennel to reduce the cracking of bulbs, and in Brussels sprouts for a better resistance to aphids, Albugo candida and mildew.

NL ORG
More changes were made in the MCR of the organic system. The most important change was the replacement of one cereal crop with white clover under sowing by grass clover. This was done because the amount of nitrogen brought into the system by the clover was limited because the under sowing was not working very well. The grass clover mixture reduced the risk of failure due to nitrogen fixation. In addition, in the grass clover there were fewer slugs because it was mowed.

The replacement of the leguminous vetch with a non-leguminous catch crop after potato was the second important change. It appeared that the mineral nitrogen content after harvest of potato was very high. Therefore, it was more important to prevent the mineral nitrogen for leaching than bringing extra nitrogen into the system by fixation. Different kinds of catch crops were tested (white mustard, phacelia and fodder radish.

In the integrated systems, extra catch crops, whenever possible, were placed in the rotation and the time between two cultivations in one year of iceberg lettuce was longer to lower the mineral nitrogen content in autumn.

Brussels sprouts varieties were changed to varieties with better resistance to diseases and lower nitrogen demands. Barley was replaced by spring wheat in some systems to have better results with under sowing of clover. Varieties of grasses, clover and other green manure crops were judged on the attractiveness for slugs. The grass clover mixture was changed to more white clover and other grass varieties were chosen with better resistance to crown rust.
Finally, planting distance of iceberg lettuce was increased to get better product quality, better nitrogen availability and fewer problems with downy mildew.

8 A practical case of MCR in Emilia-Romagna, Italy

V. Tisseli & L. Rizzi
Centre for Plant Production Research (CRPV), Cesena, Italy

8.1 Design of the MCR

8.1.1 Preconditions in planning the crop rotation

Regional aspects
Emilia-Romagna, Italy has almost 4 000 specialised farms and 35 000 non-specialised farms that cultivate 54 000 hectare of vegetables. On the large farms (5-20 ha), the main crops are tomatoes, green beans, melons and onions. On the small farms (2-5 ha), the main crops are lettuce, fennel, spinach, celery, potatoes, melons and cauliflower. Controlled quality production guidelines (QC) are available for 19 vegetable crops. To support the conversion of farms to integrated and organic production and to make further progress in the exploration of these systems, a structural, farm level-oriented research effort is considered of major importance for the region.

The experimental farms
The experimental farms are located at the eastern part of Emilia-Romagna region, The "Integrated Industry System" (I INT1) in Ravenna and the "Integrated Fresh Market System" (I INT 2) and the "organic system" (I ORG) in Cesena (see Annex 1).

I INT1
The farm is an experimental farm of 55 hectare. The farm employs three technicians and many farm workers. The soil is sandy-loam with a loam percentage of 63%, an organic matter content of 1.2% and a pH (KCl) of 7.8. The average rainfall is about 600-700 mm. The groundwater table is 2 meter below the surface and the altitude is 6 meter above sea level. The farm has machinery for soil cultivation, spraying and weed control.

I INT2
The farm is located on a clay-loam soil with a clay percentage of 41%, an organic matter content of 1.8% and a pH (KCl) of 7.7. The groundwater table is at 1.80 cm of depth and the altitude is 22 meter above sea level. The average rainfall is about 600 mm.

I ORG
The private farm has a surface area of 2.5 hectare. Manual labour is used. The machinery for soil cultivation and weed control consists of two tractors, a cultivator and a rotary hoe. The farm is located on a clay-loam soil with a clay percentage of 38%, an organic matter content of 2.2%, and a pH (KCl) of 7.9. Average rainfall is about 700 mm. The groundwater table is at 1.20 cm of depth. The altitude is 8 meter above sea level.

8.1.2 Choice of crops
In the eastern part of Emilia-Romagna, vegetable farms can be divided in two groups based on size and cropping systems. Small farms grow especially intensive vegetables (south-eastern part near Cesena) while medium-sized farms grow vegetables mixed with arable crops (Ravenna and Ferrara provinces). The choice of the crops is made based on the economic, agronomic and phyto-sanitary factors.

Melon
Melon is the most important cucurbitaceous crop in the eastern part of the region. This crop has middle-high to high production costs. Shelf-life varieties have been introduced to harvest all produce in a short time span. The new varieties' resistance or tolerance to Fusarium, powdery mildew, and aphids makes reduction in pesticide use possible. Plastic mulch prevents the need for herbicides. The use of drip irrigation makes use of water and nitrogen more efficient. The peak for farm labour during harvest is in a period that the demands for labour from other crops is lower. Melon requires a good sowing bed that permits good mulching conditions. Until recently, the marketing of the product was quite easy due to private traders and co-operatives. Over the past few years, marketing has been more intensive due to the competition from the products imported from other countries and other regions in Italy.

Spinach
This crop is very interesting for this area, as there are several processing factories. Spinach is normally grown in spring, but sometimes it is planted in November with the aim to harvest earlier in spring. Sowing in this period provides soil cover during autumn and winter. Crop residues provide nitrogen for the following crop. The crop is grown in a period when no other crops are cultivated. The use of pesticides can be reduced because of the availability of resistant varieties to downy mildew. Weed

Table 8.1 Overview of systems layout characteristics for the prototypes in Italy

	I INT 1	I INT2	I ORG
System area (ha)	2	1.6	1.46
Number of fields	4	4	4
Rotation length (years)	4	4	4
Mean field size	0.5	0.35	0.35
Mean field length/width ratio	5.6	4	5.4
Field adjacency*	1	1	1
Adjacency of subsequent blocks	0.25	0.25	0.5

* 1 means all fields are adjacent, when subsequent rotation blocks are fully not adjacent, then the rotation in space is optimal and the index is 1

Table 8.2 Potential crops and characteristics

Crops[1]	Strawberry	Lettuce	Celery	Fennel	Green beans	Melon	Cauliflower	Potato	Tomato	Sugar beet	Spinach	Peas	Wheat
Family/group[2]	6	1	3	3	7	8	2	4	4	9	9	7	5
Economic													
Gross margin (k€)	22-24	4-6	8-10	8-10	4-6	4-6	6-8	6-8	4-6	0-2	0-2	0-2	0-2
Input costs (k€)	15-16	3-4	4-5	1-2	2-3	3-4	1-2	3-4	3-4	2-3	1-2	1-2	0-1
Input labour (100 hours)	30-40	5-6	4-10	4-7	0-2	5-6	2-5	1-2	0-1	0-1	0-1	0-1	0-1
Agronomic													
Length growth period[3]	4	0	1	1	0	1	1	2	1	4	1	1	4
Number crops/year	1	3	1	1	2	1	1	1	1	1	2	1	1
Cover[4]	0	4	2	2	4	4	2	4	4	4	2	4	0
Rooting[5]	0	0	2	1	1	3	1	0	3	1	1	2	4
Compaction[6]	2	1	1	1	2	1	1	2	3	3	3	2	1
Crop protection													
Input pesticide (kg ha^{-1})	8-10	4-6	4-6	4-6	2-4	2-4	8-10	8-10	8-10	2-4	4-6	2-4	2-4
Competitiveness[7]	0	0	2	1	2	2	2	0	2	2	2	2	4
Mechanical weed control[8]	1	3	3	3	2	1	1	3	2	2	4	4	2
Fertilisation (N)													
N-fertilisation (kg ha^{-1})	100-150	100-150	250-300	200-250	50-100	100-150	100-150	150-200	100-150	100-150	100-150	50-100	150-200
N-off take (kg ha^{-1})	0-50	0-50	200-250	100-150	0-50	0-50	100-150	50-100	100-150	50-100	100-150	0-50	150-200
Residual- N (kg ha^{-1})	100-150	100-150	50-100	100-150	50-100	100-150	0-50	100-150	0-50	50-100	0-50	50-100	0-50
Transfer- N (kg ha^{-1})	14	10	-	-	35	13	-	20	22	-	10	35	-40
Transfer- N (kg ha^{-1})	-	-	24	24	-	-	13	-	-	22	-	-	-

1. Crops in order of profitability.
2. Genetically and phyto-pathologically related groups: 1 = Compositeae; 2 = Crucifereae, 3 = Umbrellifereae, 4 = Solanaceae, 5 = Gramineae, 6 = Rosaceae, 7 = Leguminoseae, 8 = Cucurbitaceae, 9 = Chenopodiaceae
3. 0 = 0 - 60 days, 1 = 60 - 120 days, 2 = 120 - 180 days, 3 = 180 - 240 days, 4 = 240 - 300 days etc.
4. 4 = no cover in autumn and winter; 2 = no cover in autumn or winter, 0 = all others, (green manure crops included)
5. 0 = poor superficial rooting; 4 = deep intensive rooting.
6. Crop, cropping operations, soil, harvest time and harvest technique determine the intensity of the compaction: 0 = very light compaction, 4 = intensive and serious compaction
7. 0 = very poor weed suppression, 4 = strong weed suppression
8. 0 = weed control completely mechanical, 4 = no mechanical weed control possible

control is difficult, as the industry does not accept any weeds. There are no particular problems concerning soil-born parasites. Fertilisation with nitrogen has to be split in two or three doses to prevent leaching problems. The harvest, done by the processing factories, is completely mechanised.

Tomato

Tomato is the most important vegetable crop in Emilia-Romagna. This crop is almost totally mechanised and has a high market value (€ 5 500 – 7 000 ha^{-1}). In Emilia-Romagna, the large market consists of 30 tomato-processing factories. The most important pests and diseases are wire worms, downy mildew and Alternaria. Forecasting models make it possible to reduce the number of treatments against downy mildew. Normally, weed control is done with one or two applications after transplanting, particularly against Solanum nigrum. Graminaceous species often needs to be treated specifically in combination with two mechanical applications. Growing in spring or summer and the use of fert-irrigation reduces or eliminates the risk of nitrogen losses. The quality, evaluated through refratometric solid residues, influences the price.

Wheat

Wheat is the most important cereal crop and normally cultivated at all arable and mixed farms. It has a low market value, but production is completely mechanised. Reductions in herbicides and pesticides applications can be made. The mechanical weed control is possible due to spiked chain harrows. Fertilisation management, planting density and tolerant varieties allow controlling diseases such as powdery mildew and rust with reduced pesticide use. Wheat is sown in autumn and covers the soil during winter period. The ploughing of crop residues (straw) increases the amount of organic matter in the soil.

Green beans

Green beans, having a short vegetative cycle (2 months), can be cultivated as a second crop and this provides an additional income to the farm. The crop is completely mechanised. Chemical weed control is always necessary; if the produce is grown for the processing industry, manual weeding is necessary also because of Ostrinia nubilalis. Pesticides use is low, as diseases are not a large problem. This leguminous crop does not need nitrogen from fertilisers in normal conditions. However, a small application can be necessary if the crop follows a cereal with a negative residual fertility. The crop leaves a lot of nitrogen in the soil behind because of nitrogen fixation. The crop is normally grown on contracts with the processing factories.

Sugar beet

Sugar beet is cultivated in all regions of Region Emilia-Romagna on about 90 000 hectare. The crop is grown on contracts with the sugar refineries. Sugar beet requires a wide rotation. Among the extensive crops, it has a high market value. Weed control is done with a multi-row miller and low dose sprayings of herbicides. The number of disease treatments can be reduced with varieties resistant to Cercospora. Sugar beet can have problems with nematodes and BNYVV-disease (rhizomania), especially on sandy soils. Specific treatments may be necessary against wireworms. The crop leaves soil with good fertility for the following crop. Harvest in late summer prevents soil compaction.

Lettuce

Lettuce is the main crop at many farms in the Cesena area. Prices are sometimes low and produce cannot be sold. Nevertheless, the crop is profitable over the year as farmers plant every week a small area. Transplanting and weed control could be mechanised, but at small-sized farms, this is hardly feasible. The use of resistant varieties to Bremia permits the reduction of applications against downy mildew. Nevertheless, every four or five years, the resistance is reduced. Often, there are some years without resistant varieties available. Generally, farmers use too much nitrogen fertilisers, which causes nitrate losses. Lettuce is frequently irrigated. Using fert-irrigation can lower nitrogen losses. Aphids often cause great problems in spring and autumn. Sclerotinia can cause problems when rotations are short.

Strawberry

Strawberry demands a lot of labour, but a high market value (€ 35 000 – 45 000 ha^{-1}) as well. Normally, it is necessary to use methyl bromide to disinfect the soil (practiced widely on specialised farms). With a four-year rotation and resistant varieties, it is possible to avoid soil disinfection. Fert-irrigation permits the reduction of nitrogen losses and improves the efficient use of fertilisers. The use of varieties tolerant to diseases such as powdery mildew allows reduction in the use of pesticides. Due to the strawberry's long growing cycle (from August to June), the soil remains covered for 10 months. As there is no compaction, the soil structure is improved. The utilisation of mulching as weed control makes herbicide use not necessary.

Celery

Celery has a high market value (€ 9 000 – 15 000 ha^{-1}), especially when grown for the fresh market. However, high labour demand is high, particularly at harvest. Celery, if transplanted in summer period, has a vegetative cycle of nearly three months. High nitrogen inputs are needed and research is being done to lower the nitrogen demand by using fert-irrigation. The crop leaves a large amount of crop residues. Usually, weed control is done chemically and by manual labour. It would be necessary to improve the mechanisation and/or other physical methods for weed control in the rows. The most important disease is Septoria apiicola, which not easily controlled by chemical applications in open fields. The most important pest of celery is Liriomyza huidobrensis, which not easily controlled by Dygliphus isaea and chemical applications.

Cauliflower

Cauliflower is often used as the second crop in the year. The availability of early varieties (60-90 days of vegetative cycle) allows harvesting before the autumn frost. Weed control is necessary only in early stages. This is done with one chemical application and one mechanical removal before the plant covers the space between rows. Fungal diseases (Peronospora, Alternaria) are not particularly dangerous. Crop rotation and healthy seeds are necessary to prevent infections of Xantomonas campestris. Bacillus thuringensis is effective against caterpillars of Pieris brassicae. Treatments with pyrethroids are necessary against flea beetles only if there is great pressure on young plants. The crop needs a lot of nitrogen. This is done in split applications to reduce the risks of nitrogen losses.

Main, secondary and tertiary crops

The choice of the crops was made considering their role in term of profitability, optimal use of manual labour and machinery, and their function to prevent environmental losses.

In I INT1, the main crops were tomatoes for factories, green beans and sugar beet. Melon and spinach were chosen as secondary crops to increase the profitability.

In addition, spinach has the advantage to maintain nitrogen during the winter period. Cover crops (mixture of vetch, barley and horse bean) and wheat were introduced to reduce nitrogen demand and nitrogen leaching.

In I INT2 and I ORG, the main crops were lettuce, strawberry and celery (replaced by fennel in the organic system). The secondary crops were green beans (useful for profitability and for sustainability), melon and cauliflower (only during the first year in organic system). Cover crops (mixture of vetch, barley and horse bean) were introduced especially in the organic system to reduce the demand for nitrogen fertilisation and nitrogen leaching.

8.1.3 Planning the MCR

Cultivation intensity and choice of crop types
Generally conventional farms use crop rotations in order to earn higher incomes. For this reason, the choice of crops is limited and crop rotations are short (generally 2 or 3 years). In the VEGINECO project, all rotations have a length of four years to improve soil's health and quality, and to reduce the presence of soil pests and diseases.

In I INT1 and I ORG, the rotation consists of vegetable crops only to test small intensive vegetable systems. In I INT1, arable crops occupy about 50% of the surface area and about 33% of the total crops. This rotation scheme is more applicable on medium-sized farms with little manual labour available.

The rotation has been set up to optimise the farm's organisation in order to utilise the available machinery and manual labour. At the beginning, rotations of both I INT2 and I ORG were similar, while in I INT1 the choice was for other crops, typical for this system.

The rotation plan for the fresh market systems (I INT2 and I ORG) was designed by choosing species of different plant families. The sequence of the crops was based on the length of the vegetative cycle and the leguminous species were put before species with high nitrogen demands. The rotation was designed rather intensively to guarantee a large profit.

I INT1
In I INT1, the choice of the crops was made in order to integrate industrial vegetables and arable crops. Wheat and sugar beet are the most important arable crops in the area and spinach, green beans and tomato the more interesting vegetables for the processing industry. The choice to grow melon was made to improve the revenues of the farm and because its importance in this part of Emilia-Romagna Region. The allocation of the crops in the rotation was made based on the agronomic requirements of each crop, the planting or transplanting dates, length of the vegetative cycles, and opportunity to plough the fields in good condition to prepare the crop beds. Spinach leaves crop residues and available nitrogen for tomato. Wheat after tomato maintain the residual nitrogen from the first crop. Green bean after wheat is a traditional crop succession that allows a second crop to grow and to prepare a good crop bed before sugar beet. A catch crop (mixture of barley and vetch) after sugar beet reduces the risk of nitrogen leaching from the sugar beet crop residues.

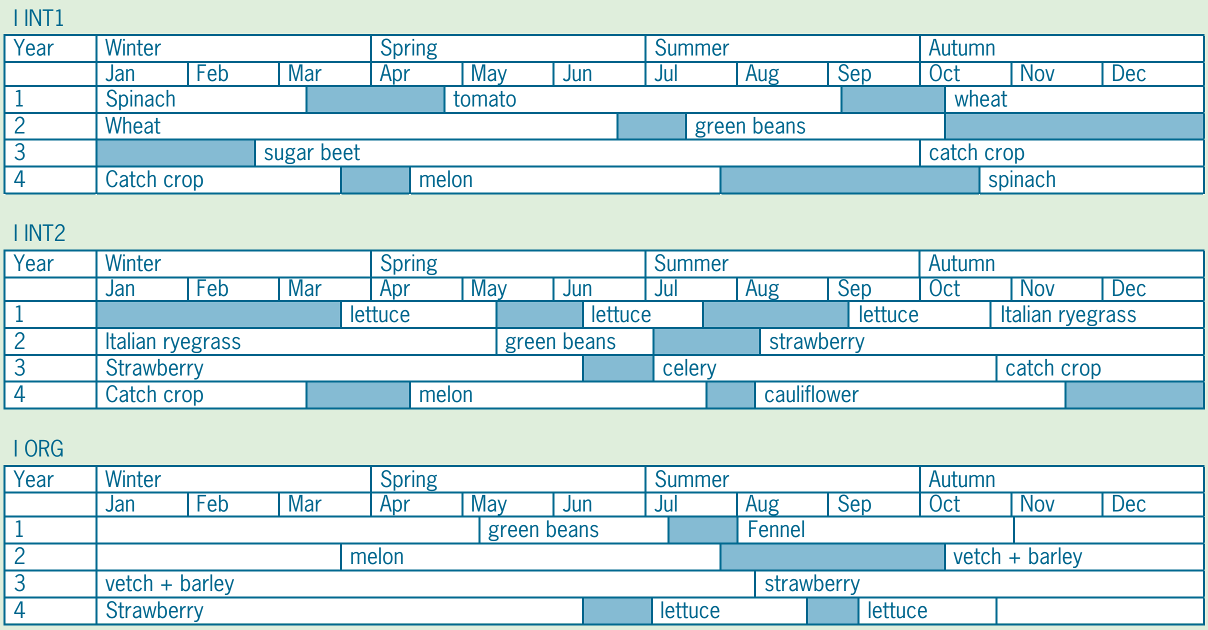


Figure 8.1 Examples of Multifunctional Crop Rotation in Italy

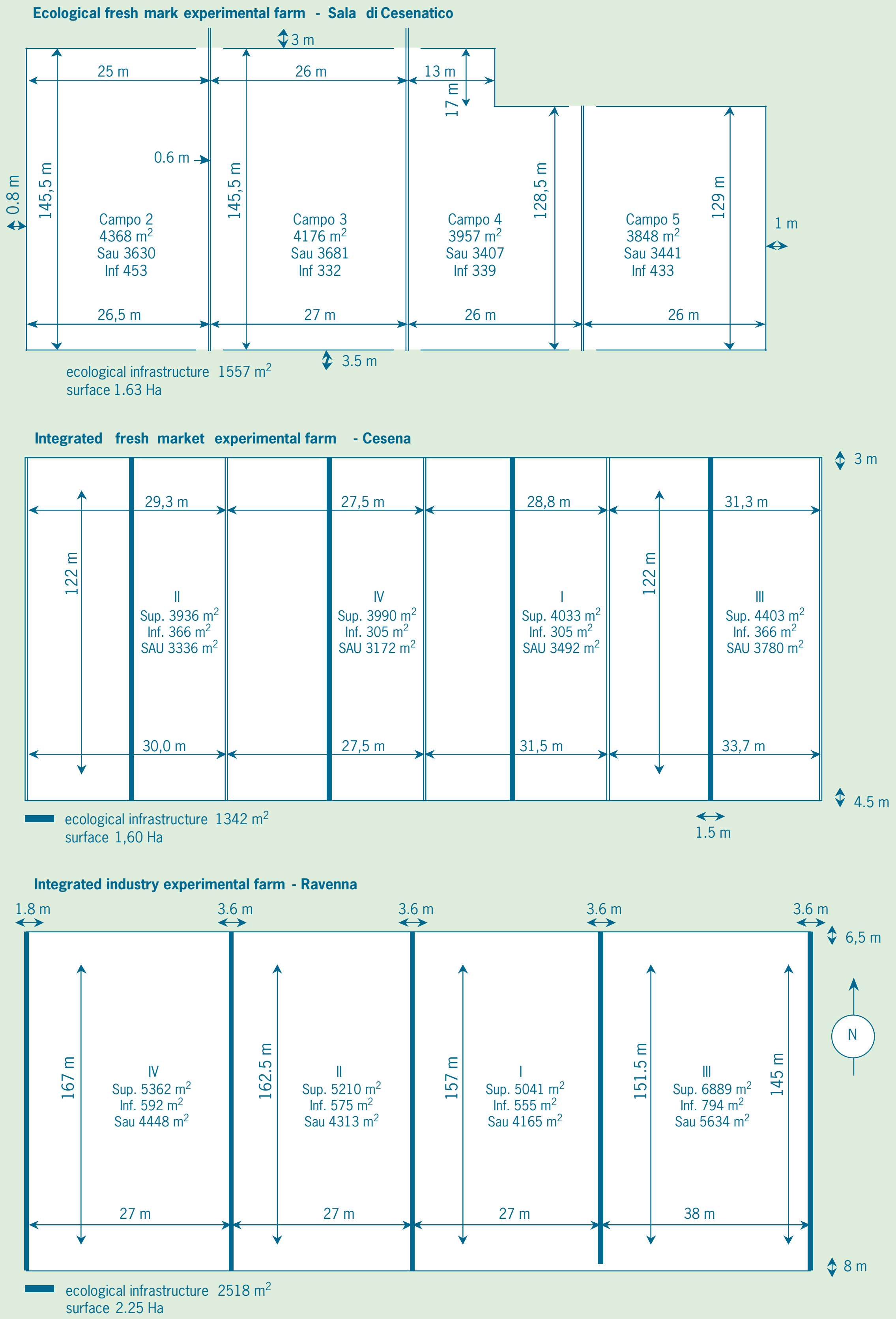


Figure 8.2 Maps of I INT2 (Martoranos experimental farm Cesena), I ORG (Bastoni farm Cesenatico) and I INT1 (Marani experimental farm Ravenna)

I INT2
The I INT2 consisted of four fields with a rotation length of four years. Lettuce began the rotation, as it is an important crop for the area near the experimental farm. Three cycles were grown in one year, as the growth cycle is short. Green bean was inserted before strawberry in order to reduce the nitrogen input for strawberry. Strawberry demands a lot of manual labour and provides a higher profit. Therefore, it is one of the best crops for small farms, which the family provides the available labour. Celery was chosen as a typical crop for small farms. Melon represents a new crop for the experimental farm; the importance is low in the area near the farm, but more interesting in the northern part of the region. Melon is common to all systems because it has no negative influence on other crops and it is typical for a small size farm as well as for the larger farms. Cauliflower was chosen as the best cruciferous specie for the market.

I ORG
In this system, the same rotation and crops were chosen as I INT2 with one difference: fennel instead of celery to reduce nitrogen inputs and fewer problems with pests and diseases. The intensive rotation is necessary to provide sufficient income on the normally small farms. In addition, by choosing the same crops and rotation, it was possible to compare the results of I ORG with I INT2.

8.1.4 Agro-ecological layout
Figure 8.1 shows the layout of the systems over time. Figure 8.2 shows the layout of the systems in space.

8.2 Testing and improving

8.2.1 Results per parameter
Almost all parameters have an influence or a relationship with MCR. In this section, the results of the parameters are treated in connection with crop rotation. The other parameters are explained in other manuals. The results of I INT1 and I ORG are discussed as an example.

Overview
In the Tables 8.3 and 8.4, the desired and achieved results of the parameters are presented which are influenced by MCR.

Quality of production (QLP) and Quantity of production (QNP)
In I ORG, quality of the produce was good and quantity was high during all the years of the project. Crops that had problems reaching target of QNP were:

- autumn lettuce due to the absence of resistant varieties to Bremia lactucae,
- strawberries due to:
  - problems of spring frost during flowering season in 1997 and 1998,
  - plant death in 2000, caused by catch crop cut down in 1999 that produced during decomposition toxic substances for this strawberry crop.

Melon is the crop that has attained the best results for QLP and QNP during the project. This crop is easy to grow on an organic farm.
In I INT2, values of QNP have always been lower than the targets. However during the project, an increase in the yields was visible. QLP reached a good level but somewhat lower than the target. The cause of the low value of QNP is due to the previous farm management, which has negatively influenced the soil structure and weed control. Lettuce showed problems during the first year for all three cycles, in spite of a normal input of fertilisers. Green beans and celery yields were low in all years. Celery in particular had a lot of disease problems

Table 8.3 Desired and achieved result, of parameters of I INT1 with close relationships to MCR

			Actual results			
	Theme Parameter	Desired results	1997	1998	1999	2000
Quality Production	QNP	1.0 (GAP)	0.93	0.97	0.96	0.95
	QLP	1.0 (GAP)	0.98	0.99	0.90	0.99
	Farm Continuity NS	income/€ 100 costs >100	99	85	80	80
	HHW	<20 hours ha^{-1}	32	53	39	47
Sustainable use of Resources	PAR	30<ppm P_2O_5<35	15.4	33	50	21
	KAR	120<ppm K_2O<180	99	148	171	108
	OMAB	>1.0	0.7	1.0	1.0	0.9
Clean Environment Nutrients	PAB	1.0	1.9	3.2	1.3	1.0
	KAB	1.0	1.4	1.2	0.9	0.5
	NAR	<45 kg ha^{-1} (0-100 cm)	144	163	78	73
Clean Environment Pesticides	PESTAS	<3.1 kg ha^{-1}	2.7	2.1	2.1	1.4
	EEP-air	<0.35 kg ha^{-1}	0.43	0.44	0.50	0.37
	EEP-groundwater	<0.5 ppb	8.3	9.4	10.1	9.0
	EEP-soil	<129 kg days ha^{-1}	190	199	210	145

Table 8.4 Desired and achieved results of parameters of I ORG with close relationships to MCR

Theme	Parameter	Desired results	Actual results 1997	1998	1999	2000
Quality Production	QNP	1.0 (GAP)	0.83	0.79	0.86	0.79
	QLP	1.0 (GAP)	0.98	0.99	0.90	0.99
Farm Continuity	NS	income/€ 100 costs >100	90	87	104	147
	HHW	<40 hours ha^{-1}	150	68	86	111
Sustainable use of Resources	PAR	35<ppm P_2O_5<40	98	251	220	156
	KAR	144<ppm K_2O<216	499	650	553	480
	OMAB	>1.0	1.2	0.8	0.7	0.8
Clean Environment Nutrients	PAB	0.25	3.0	4.5	1.5	2.0
	KAB	0.25	1.0	0.8	0.2	0.3
	NAR	<70 kg ha^{-1} (0-100 cm)	302	220	160	146
Clean Environment Pesticides	PESTAS	<3.3 kg ha^{-1}	1.2	0.2	0.1	0.03
	EEP-air	<0.5 kg ha^{-1}	0.31	0.03	0.01	0.01
	EEP-groundwater	<0.05 ppb	0.0	0.0	0.0	0.0
	EEP-soil	<90 kg days ha^{-1}	7	3	1	0

(Septoria apiicola), which stopped the harvest of this crop in 1999.

In I INT1, high values of QNP and QLP were registered constantly for tomato and spinach and for sugar beet during the 1999 and 2000. Low values of QNP registered on melon and green beans were caused by negative environmental influence that did not permit a regular growth of these crops. Problems in green bean consist of flower dropping and irregular fruit setting. Melon plants interrupted their growth during the hot period, not setting sufficient fruits.

Net surplus (NS)
The results in the theme farm continuity are quantified with the system parameter Net Surplus. In I ORG, considering the global result for the four years, the target has been reached while in I INT1 the income has not covered the total costs (see Table 8.5).

Good results for the organic system are due mainly to a good market trend for biological products, which have a higher price higher (on average 30-40%) than conventional and integrated ones. This market situation has been constant during the four years of the VEGINECO project and the perspective for the future are good because of increasing demands. The income of I ORG permitted to cover completely the total cost and to expect a remuneration of manual labour (high number of hours particularly for weed control) higher in respect of the local manual labour tariff. The reduction of hand weeding costs through mechanical weed control is not practicable because of small farms and the clay soil.
In I INT1 and I INT2, input and the machinery costs (concerning also agricultural contractors) are more important than manual labour. In this way, positive economic results can only be realised on larger farms with a more efficient machinery use and a reduction of the use of agricultural contractors. Comparing I INT1 and I INT2, I INT1 has fewer prospects as direct costs are relatively large and are difficult to reduce.
MCR has a large influence on NS due to the crop choice. The market price and selling opportunities of the crops are influencing NS the most. Changing crops in the rotation can improve NS, for example melon in both systems and probably a lettuce crop in I INT2.

Table 8.5 Farm economic results of I INT2 and I ORG

	I INT2 2000	I INT2 Average 97-00	I ORG 2000	I ORG Average 97-00
Surface area farm (ha)	4	4	4	4
Gross revenues (yield x price) (€)	80 040	69 784	120 964	97 492
Total direct costs (€)	93 334	84 174	75 540	85 009
Labour income (€)	-13 294	-14 390	45 424	12 484
Labour input (hours)	5 387	4 585	4 503	5 324
Net surplus (€)	-19 034	-19 774	38 429	5 252
Financial yield per € 100 costs	81	79	147	107

Sustainable use of resource parameters (OMAB)
The organic matter balance was negative in I ORG and I INT1. In the first case, this is due to the aim to reduce PAR and KAR. Because of that, only a small amount of organic manure was used. In I INT1, it was difficult to find organic matter sources of high quality. MCR can have a large influence on OMAB trough the insertion of cover crops in the rotation. Soil cultivation was done with the aim to reduce the organic matter losses by substitution of ploughing with other cultivation machines as the grubber and miller. The maintenance of the crop residues on the soil was a choice to improve the organic matter balance. A reduction of cropping activities is not useful to reduce the organic matter decomposition but a substitution of a marketable crop with a cover crop can improve OMAB.

Nutrient parameters (NAR)
The leaching season is variable from year to year. However, NAR-values decreased strongly during the project. In I INT2, the result is fluctuating through the years. In I ORG, the trend of decreasing NAR can be seen in all crops except strawberry. For this crop, the high values of NAR can be due to the catch crop before strawberry that is ploughed down. In I INT1, the target has been reached in 1999 and 2000. In 2000, only wheat had a too high value. This value is probably due to the high quantity of tomato crop residues ploughed down. In I INT2, the target has been reached in 1999, while the value obtained in 2000 was too high because of celery (267 kg ha^{-1}). This value is not easily attributable at the input of fertilisers (equal at previously years) and at the particular type of soil (mineralisation of organic matter).
The decrease in NAR values was directly caused by the fertilisation strategy and the distribution technique of fertilisers and soil management. The external factors did contribute because these could not be influenced.

Pesticide parameters
The crop rotations have permitted to obtain good results on PESTAS and EEP. The use of resistant varieties, when possible, against the more important pest and disease permitted the reduction of the number of treatment and of active ingredient input. No negative effects were seen in transferring pests and diseases from one crop to the successor. In I INT1, some problems remain on EEP-groundwater due to the use of Lenacil (chemical herbicide).

8.2.2 Optimisation of the MCR

I INT1
The optimisation of the rotation was made possible by the choice of new varieties coming from the experimental trials realised in Emilia-Romagna with the aim to reduce the external inputs mainly the fertilisation ones. Varieties of melon and spinach were changed principally to improve the disease and pest resistance. The results have been improved as well by small changes in sowing and transplanting dates.
The rotation includes crops that can be well mechanised. The manual labour demand is lower than in I INT2 and I ORG. Green beans as a second crop can cause some problems of NAR, but its presence is important for the farm income.
The spinach in winter cycle gives soil cover in winter and reduces nitrogen losses. Problems in weed control decrease during the next years because the crop rotation limits the build up of the weed population. Except melon and wheat, sale of other crops is assured by contracts with the industry.

I INT2
In the I INT2 system, as much attention was paid to the variety choice as in the I INT1, especially for lettuce, cauliflower and strawberry. It was not possible to take up more cover crops in the rotation because the autumn crops (lettuce, cauliflower and celery) were harvested too late to sow them.
The crop rotation adopted in I INT2 is completely feasible in terms of planting and harvesting time. The main problem is the manual labour need. This can be solved partly by using the same machines for weed control in different crops (lettuce, celery, and cauliflower).

I ORG
In this system, the major changes took place. During first year, it was clear that the crop rotation plan was too intensive and requested a very high nitrogen input, causing excessive nitrogen losses and phosphate enrichment. In addition, no time was available to sow cover crops. In the second year, another rotation was designed by excluding cauliflower and one lettuce cycle and by repositioning the crops in the rotation. The results of these changes were a reduction of nitrogen input due to a better development of cover crops and the reduction of pesticide use (particularly for the aphid control in lettuce). Variety choice has played an important role, especially in melon. In strawberry and lettuce, positive results have been reached in some years because of negative influence of weather conditions and the development of new Bremia races. The use of a flamer in seedbed preparation and in green beans post emergency treatment permitted to obtain a better weed control and a reduction of manual labour hours. At last, the use of a new pipe irrigation system has permitted to improve the fertilisation efficiency.

9 A practical case of MCR in the Valencian community, Spain

H. Gómez, F. Pomares & A. Garcia Diaz
Institute for Agricultural Research (IVIA), Valencia, Spain

9.1 Design of the MCR

9.1.1 Preconditions in the setting up the rotations

Regional aspects
The Valencian community (VC) has always been a traditional area for vegetable crops in Spain. In 1998, the final value of this group of crops was € 276 500 000, the second group in economic value after citrus. The area of vegetable crops is about 34 610 hectare. A lot of manual labour is used on vegetable farms, making about half of the production costs and employing many people. Vegetables are complementary to the citrus crop, because the demand for manual labour in vegetables is in periods of low activity in the citrus crops. This contributes very favourably to a better distribution of labour and fix costs of facilities for both sectors. Green houses are continuously expanding in the south, field-grown vegetable crops are more important in the Centre and North of the Valencian community.
The farms in the VC are small, hardly mechanised and a lot of manual labour is used. The average size of farms in the VC is about 4.5 hectare. More and more, they are dedicated both to vegetable crops and other kind of crops in which manual labour needs are lower, such as citrus or other fruits orchards.

The most important crops, according to production amounts are tomato, potato, onion, watermelon, artichoke, lettuce, melon, pepper and cauliflower. The South of the VC is one of the most important areas in Europe for tomato.
The field-grown vegetable farms in the Valencian community usually have a two to three year crop rotation. Each area has its own particularities and they are usually specialised in three or four crops with some of them predominating. The latter ones are usually repeated every two years, and in between, the farmers alternate the rest of the usual crops in the area. There are several standard "rotations" currently practised in several areas of the Valencian community:
- North: artichoke / cauliflower – lettuce - watermelon / lettuce – cabbage (three years),
- Centre: Potato – fallow / fennel - watermelon (two years),
- South: Little gem – Little gem - pepper / celery – watermelon (two years).

In Table 9.1, an overview of the systems in Spain is given. There are three integrated and one organic system. Two of the three integrated systems were developed at pilot farms (systems ES INT1 and ES INT2). The other integrated and the organic one (ES INT3 and ES ORG) at an experimental station.

9.1.2 Choice of crops
Fresh market vegetables are the main crops in all the rotations. The vegetable crops were combined with the potato crop (considered as arable crop) in one of the three areas (two of the four systems). A green manure crop was included in all systems before the most important of the main crops. ES INT3 and ES ORG are easily comparable because the same MCR was designed for them and they are in the same experimental station. The different economic and agronomic characteristics of the chosen potential crops are summarised in Table 9.2.

Cauliflower and broccoli
Cauliflower and broccoli have the same place in the rotation of the integrated system. In ES INT1, market conditions are more adapted to broccoli, which is grown on a large scale both in autumn and in winter instead of cauliflower. Harvest is done by manual labour. Pesticide use is

Table 9.1 Overview of systems layout of the Spanish systems

	ES INT1[2]	ES INT2[2]	ES INT3[3]	ES ORG[3]
System area (ha)	1.256	0.6	0.42	0.47
Rotation length (years)	4	4	4	4
Number of fields	4	4	4	4
Number of rotation blocks	4	4	4	4
Mean field size (ha)	0.314	0.15	0.107	0.117
Mean field length/width ratio	1.77	2.4	1.18	1.29
Field adjacency[1]	1	1	1	1
Adjacency subsequent blocks[1]	0.5	0.25	0.75	0.75

1. "1" means all fields are adjacent, when subsequent rotation blocks are fully not adjacent, then the rotation in space is optimal and the index is 0
2. Pilot farms
3. Experimental station

quite low because there are not much quality or quantity threatening pests and diseases. High light intensity can make non-marketable cauliflower heads because of a yellow colouring. The crop is competitive and covers the soil quickly, which makes volunteer development more difficult.

Celery

The southern part of the Valencian region is a main production area for white, green and Chinese celery. Its grows too slow to suppress weeds. Therefore, soil herbicides must be used. Fungal diseases as Sclerotinia or Septoria sometimes cause the need for high fungicide use. Liriomyza trifolii is not a problem in autumn-winter cycles because harvested leaves are not affected. Other important pests are caterpillars (planting in the end of summer) and aphids (harvest in springtime).

Fennel

In the area close to Valencia City, fennel is increasingly grown. Pesticide use in fennel can be quite low. Apart from an occasional aphid or caterpillars attack, there are no pests or diseases seriously threatening the crop. The crop

Table 9.2 Potential crops and their characteristics

Crop[1]	Pepper	Tomato	Celery	Cauliflower	Fennel	Little gem lettuce	Green bean	Broccoli	Watermelon	Onion	Sweet corn	Roman Lettuce	Iceberg lettuce	Artichokes	Potatoes	Green manure
Family/group[2]	4	4	3	2	3	1	8	2	6	7	5	1	1	1	4	5-8
Economic																
Gross margin (k€)	14-16	10-12	8-10	6-10	4-6	4-6	2-14	2-6	2-6	2-6	2-4	0-6	0-6	0-6	0-4	0-2
Input costs (k€)	3-4	5-6	5-6	1-2	2-3	3-4	1-3	2-3	3-4	3-4	2-3	1-2	3-4	4-5	1-2	0-1
Input labour (100 hours)	20-21	23-24	6-7	3-4	4-5	4-5	20-21	3-4	3-4	9-10	3-4	4-5	5-6	6-7	2-3	0-1
Length of growing period[3]	2	2	2	1	1	0	1	1	1	2	1	0-1	1	4-5	2	2
Agronomic																
Number of crops/year	1	1	1	1	1	2	1	1	1	1	1	1-3	1	1	1	1
Cover[4]	4	4	0	2	2	0	4	2	4	4	4	0-2	0	0	2-4	0
Rooting[5]	2	3	2	3	2	1	2	3	3	1	2	1	1	3	1	4
Compaction[6]	3	3	1	1	0	1	2	1	1	1	1	0	1	3	2	0
Crop protection																
Input pesticide	16-18	16-18	40-42	6-8	0-2	6-10	4-6	6-8	4-6	6-8	10-12	6-8	6-10	12-14	2-6	0-2
Competitiveness to weeds[7]	2	2	1	3	1	2	2	3	3	1	2	1	1	2	2	3
Mechanical weed control[8]	4	2	3	2	3	3	2	1	1	2	1	2-3	2	1-2	1	0
Fertilisation (N)																
Average N- fertilisation[9]	2-3	1-2	3	1-2	1	0	0-1	2-3	2	1-2	1	1-2	1	2-3	2	0
N-off take[10]	2	0-1	2	1-2	0-1	0	0	1	1	1	0	1	1	0	2	0
Residual-N[11]	0	1	1	0	1	0	1	2	1	0-1	1	0	0	2	0	0

1. Crops in alphabetical order of financial turnover
2. Genetically and phyto-pathologically related groups: 1 = Compositeae, 2 = Crucifereae, 3 = Umbrellifereae, 4 = Solanaceae, 5 = Gramineae
3. 0 = 0 - 60 days, 1 = 60 - 120 days, 2 = 120 - 180 days, 3 = 180 - 240 days, 4 = 240 - 300 days etc.
4. 4 = no cover in autumn and winter, 2 = no cover in autumn or winter, 0 =all others, (green manure crops included)
5. 0 = poor superficial rooting, 4 = deep intensive rooting
6. Crop, cropping operations, soil, harvest time and harvest technique determine the intensity of the compaction: 0 = very light compaction, 4 = intensive and heavy compaction
7. 0 = very poor weed suppression, 4 = strong weed suppression
8. 0 = weed control completely mechanical, 4 = no mechanical weed control possible
9. In kg ha^{-1} 0 = 0 - 50 kg, 1 = 50 -100 kg, 2 = 100 - 150 kg, 3 = 150 - 200 kg, 4 = 200 - 250 kg etc.
10. N - export from the field in produce in kg ha^{-1}: 0 = 0 - 50, 1 = 50 - 100, 2 = 100 - 150; 3 = 150 - 200; 4 = 200 - 250 etc.
11. = 9 - 10

is not very competitive against weeds and input of herbicides is necessary to prevent too much manual labour. There are no soil herbicides authorised in this crop.

Potato

Potato is the most profitable arable crop. The crop gives the risk of volunteer plants in the following crop. Preferably, a high competitive crop has to follow potato in the rotation. Complete mechanical control of weeds is feasible. Late blight, Alternaria sp. and Anthracnose call for high fungicide input. In addition, resistant varieties against Late blight must be used. Choosing resistant varieties, is the best option to reduce disease risks in the organic system. Most important pest is Agriotes spp. It can provoke very serious yield damage. Leptinotarsa decemlineata can need control depending on the infestation level and the development stage of the crop. Occasionally, aphids need special attention.

Artichoke

Artichoke could be considered as arable crop because of the long cropping period –from one to three years–. Sown varieties usually have many problems with powdery mildew. This disease is not very important in planted varieties as White of Tudela. The highest problem, seedling failures, is related with Rhizoctonia sp, Verticilium spp. and soil exhaustion. The main pests are caterpillars in the first plant stages and aphids in springtime. In two or three-year crop cycles, Gortina xantenes' control call for an extra pesticide input. To include artichoke in a four-year crop rotation, only the one-year crop was considered. Harvesting must be done by hand once or twice a week from November until May. Cropping time starts in summertime (planting time in july-august) and finishes at the end of springtime. Artichoke is not a competitive crop in the first months after planting and some mechanical or chemical weed control with located herbicide sprays must be done.

Tomato

There are several options in field-grown tomato growing cycles. In the VEGINECO project, the planting was done in mid July and harvest from mid September to end of November. Harvest must be done once or twice a week. High input of manual labour is needed during training, pruning and harvesting activities. Pests, caterpillars, Aculops licopersici and white flies call for high pesticide input. Main problems are viruses although resistant varieties to TSWV can be used. Weeds can be controlled by located herbicide application and mechanical control.

Sweet corn

The south of the Valencian community is the main sweet-corn cropping area in the region. The high crop density calls for black polyethylene mulch for weed control. 85% of the production is going to the fresh market and the other 15% is going to the processing industry. Harvesting must be done by hand twice or three times in the last phase of the crop. The main pests are caterpillars, red spiders and aphids. Caterpillars must be controlled from the first crop stages. Low nitrogen inputs can help farmers to control red spiders and aphids attacks.

Iceberg lettuce

Specialised farmers grow iceberg lettuce from autumn until springtime. The crop is susceptible to poor soil structure. Early croppings leave a lot of mineral nitrogen behind, which can be used by the next crop. Harvesting is done by hand. Iceberg lettuce is very susceptible to N. ribisnigris (mainly in end-winter and springtime), as well as to caterpillars and fungi, which requires high pesticide input. Some resistant varieties to N. ribisinigris are available. In addition, iceberg lettuce has high risks of cropping failures due to TSWV and Big Vein virus in cycles of end-summer and spring.

Roman lettuce

Specialised farmers grow Roman lettuce in the whole year. However in the months July and August, it is difficult to obtain good yields due to several physiologic diseases (tip-burn, premature flowering or double bud). Selecting the best varieties, adapted to the specific period and controlling the irrigation dose in summertime are the best strategies against physiopathologies. Roman lettuce has high risks of yield failures due to TSWV and Mildew. There are crop cycles that are especially sensitive to the TSW Virus (plantings in springtime and end of summer, mainly). Some fungal diseases could appear in wet and rainy time (mainly downy mildew but also Stemphilum sp.). Roman lettuce is very susceptible to caterpillars (mainly in the end of summer and autumn) and aphids (mainly N. ribisnigirs in end-winter and springtime), which can require high pesticide input. Harvesting is done by hand. Weeds can be controlled mechanically and/or by herbicides.

Little gem lettuce

Pests and diseases are very similar to those in the Roman lettuce crop. This crop is probably more sensitive to tip-burn in late spring and summer. The crop grows quickly (about 30 days in September- October) and pest control calls for strategic pesticide inputs (the right pesticide at the right moment). Harvesting and planting must be done by manual labour. Black polyethylene mulch can be used for weed control.

Pepper

Pepper is the most important crop in the south of the region and is cropped all over the year: into greenhouses in wintertime and out of greenhouses in summertime. Many different varieties are cropped in the south of the region. In the spring-summer cropping cycle, a micro-tunnel using mesh is made to obtain precocious fruits and to protect plants from early infestation of TSWV vector insect, Frankiniella sp. Caterpillars can produce fruit damages and eventually aphids and spider mites. Another important disease is powdery mildew, which can be controlled with sulphur applications. Harvesting must be done by manual labour and black polyethylene mulch can be used for weed control.

Onion

Onion crop is not very competitive and weeds must be controlled with a herbicide application before planting or ten to fifteen days after planting. Semi-mechanical harvesting is usually done for dry-onion in the Valencian cropping conditions, whereas manual harvesting has to be used for green onion. Onion is normally planted from autumn to spring. Different varieties are used in each season. Trips is the main pest in green-onion and its control calls for an extra pesticide use because esthetical damage is done by brown colouring of leaves. For dry-onion production, trips are not a problem. Another serious pest is Delia spp., which in the first crop stages can provoke the total loss of yield. Downy Mildew must be controlled when the whether is wet and/or rainy. Due to the high crop density (from 300 000 to 600 000 plants per hectare), high manual labour input is necessary for planting and harvesting activities.

Watermelon

In watermelon, planted in low densities of 3 300 plants per hectare, mechanical weed control is possible between the crop lines. Black polyethylene mulch is used for weed control in these lines and mesh covers are also used to obtain a quick development of the plant in early cycles. When plants are developed, the field is full covered and weed control is not necessary if volunteers have been properly controlled. Two varieties must be planted at the same time: a pollinate variety and a triploid seedless variety. The ratio of these two is ? and ? respectively. Caterpillars can produce an esthetical damage in fruits but the main pests are aphids and spider mites. Oidium is the most important disease, which can be controlled with sulphur applications.

Green bean

Green bean is a typical plant of hot climate and low temperatures can disturb the normal development of the plant. In addition, temperatures higher than 28-30 °C can get down flowers and small fruits. Plants grow up in fresh soils with a good drainage and an optimum pH from 5 to 7.5. In soils with pH values higher than 7.5, nutrient deficiencies can appear. Herbicides must be used before planting or after seeding. When plants are developed manual labour must be used for weed control. This is a crop with low pressure of pests and diseases although spider mites, aphids, leaf miners or caterpillars eventually may need to be controlled. Rizoctonia sp. may also require fungicide applications. Some varieties should be grown with training systems. Fruits are harvested by hand preferably twice a week and its destiny is the fresh market; high manual labour input is needed.

Barley, oat and vetch as green manure

Cereals have a positive effect on soil structure because of their deep intensive rooting. The choice of a summer or winter cereal is dependent of the harvest time of the previous crop. Winter cereals have the advantage of soil cover in winter and they usually do not need to be irrigated. The mixtures with vetch are used as green manure and make possible the soil nitrogen fixation. A high seed density is used to get a maximum of vegetal biomass. A good composting in the soil before ploughing is necessary. A complementary action of weed control can be achieved by the competence of the cover crops with weeds.

Other crops such as cucumber, eggplant, spinach or endive are not chosen because of profitability or commercial reasons, or simply because the farm managers did not have experience with them.

9.1.3 Planning the MCR

Cultivation intensity and choice of crop types

It is assumed that a crop rotation of four year is long enough to avoid soil exhausting and problems with soil-born diseases and pests, both for organic and integrated farming. In standard rotations of four years, there could be many variants depending on the region, mainly due to the variability of vegetable crops and microclimate conditions. However, even in the same area, there could be several variants of rotations depending on the different circumstances of the farms. Therefore, in the Spanish systems, a standard crop rotation per farming area is set. Normally, all crops are grown for the fresh market, although part of the yields can go to the processing industry because of poor quality or poor market conditions. The number of crops can differ very much because of differences in growing span; from one to three crops can be grown every year.
In organic farming, a four-year rotation is considered agronomically optimal. In this kind of farming it will be even more important than in integrated one, to place the different crops carefully along the four years to have a maximum prevention against pests and diseases. Due to the high crop density and intensity, a good combination of crops with high and low nutrient demands is needed.
In the three models, several crops (four-five) are considered as main crops, looking at profitability and labour need. Other less profitable crops, but most of the times frequently grown in the corresponding area, have been chosen as secondary to complete the rotation. Green manures are also included, usually before the most important crop, trying to improve soil conditions and to enhance soil cover. Furthermore, climatic conditions of every area, crop climatic requirements and the duration of crops have determined the cropping plan of the three variants chosen (see Table 9.3).

The climate conditions and corresponding climatic crop requirements are the first criteria to place both the main crops first and, secondly, the secondary ones in certain periods of the year. For instance, pepper or watermelon are crops that can only be grown in summer (although

Table 9.3 Selection of main crops and secondary crops

	INT1	INT2	INT3/ORG
Main crops	pepper celery watermelon little gem	artichoke lettuce cauliflower tomato	artichoke potato watermelon onion fennel
Secondary crops	sweet corn onion	green bean onion	cauliflower lettuce broccoli

planted in springtime). Other crops prefer cool or moderately cold weather such as cauliflower, broccoli, onion, fennel, artichoke or even lettuce. These crops are not placed in summertime (although part of its cycle is in this season); there are some crops requiring hot or cool weather such as sweet corn or tomato. Finally, celery or potato crops can be grown both in summer and winter cycles.
On the other hand, the cropping cycles with higher sensitiveness of crops to certain pests and diseases are eliminated if possible. For instance, in spring and at the end of summertime, TSW Virus incidence is usually higher and sensitive crops such as pepper, tomato or lettuce can be seriously affected. The crops composing the rotation are from different botanical families. In general, crops with different nutrient demands and belonging to different phytho-pathological groups are alternated. Between two different crops, there is a short fallow period (from 2 to 4 weeks) to do different cropping activities.

ES INT1
Main crops in ES INT1 are pepper, little gem, celery and watermelon. The most important of them is pepper. Therefore, a green manure crop is placed before pepper, preparing an optimal structure and soil fertility. Two croppings of little gem follow pepper because they belong to different phyto-pathological groups and autumn and winter cycles have a low risk for the TSW Virus. In addition,

INT1 Pilar de Horada

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

INT2 Benicarlo 1998

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

INT2 Benicarlo 1999, 2000

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

Figure 9.1 Crop rotations examples

lettuce is much less nutrient demanding than pepper. On the other hand, the same plastic mulching is used for both little gem croppings because they are successive. Celery is placed in autumn-winter cycle because of profitability reasons, and also because in this cycle, it is less sensitive to aphids and Liriomyza sp. However, the sensitiveness to caterpillars is much higher. Watermelon is placed in the next summer because its nutrient demand is much lower and it belongs to a different phyto-pathological group as celery. As in the former system, the gaps are filled with secondary crops, alternating those with different nutrient demands and belonging to different phyto-pathological groups.

ES INT2
Artichoke, lettuce, tomato and cauliflower are considered the main crops in ES INT2, although the first one must be highlighted because of the obtained quality and the market conditions. Therefore, a green manure crop is placed before Artichoke to improve soil fertility and structure. The lettuce crop was grown twice as it is an economically important crop in the area and no soil exhaustion or phyto-pathological problems are expected from lettuce. Because this is an area with very serious problems of viruses (TSWV and CMV, mainly), growing periods with low incidence of these diseases were selected (autumn and winter). Although in the hottest months in summer, the TSWV incidence may be not so high either; there are other physiological diseases and profitability reasons to avoid this last cycle. Resistant or tolerant cultivars to TSWV are selected for tomato; the cycle of summer-autumn is chosen due to profitability reasons (better prices, usually). As in the other systems, secondary crops have been placed alternating crops with different nutrient demands and belonging to different phyto-pathological groups.

ES INT3
Marketing possibilities were regarded to choice the different crops in the different zones. In ES INT3, potato, onion, artichoke and watermelon were considered the main crops. Potato is sown in wintertime to obtain good prices at the middle of springtime. Pest control can be a handicap for following crops due to Agriotes spp. The choice of a resistant cultivar to late blight is the best alternative to pesticides. Artichoke is placed in the following year before a green manure crop because artichoke is a very soil-exhausting crop. Lettuce and artichoke precede onion, to leave a clean starting situation for onion. Watermelon is placed in the last year of the rotation, after the onion crop. The plastic mulch used in watermelon for the weed control and an easy mechanical control in the first crop stages can solve an excess of weeds coming from onion crop. Fennel is placed in autumn when better prices are expected. The gaps in the crop rotation are filled with species belonging to different botanical families, and alternating crops of different phyto-patholog-

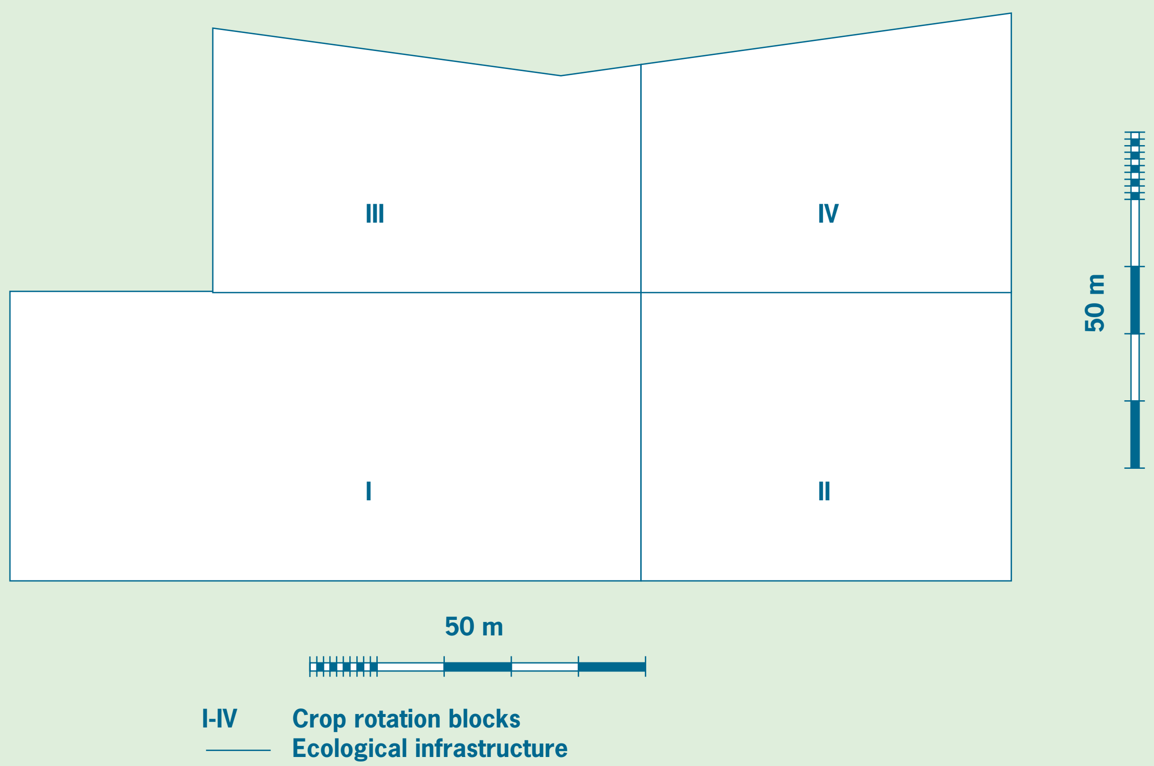


Figure 9.2 Agro-ecological layout of INT1, Pilar de Horada

ical groups with different nutrient demands. Only lettuce is repeated because of its short cycle and expert knowledge about a low risk of soil exhausting or appearance of soil-born diseases.

ES ORG

The motivation for the construction of crop rotation in the organic system is the same as in ES INT3. ES INT3 and ES ORG were designed as parallel systems to obtain comparable results. To improve soil structure a green manure crop was included in both systems. Due to high nitrate content in irrigation water, leguminous plants were not used as green manure. Instead cereals as barley or oats were sown. Minimising nutrient losses and optimising nutrient availability have been leading factors in the rotations of these systems. Nitrogen needs were met by the nitrate in the irrigation water.

9.1.4 Agro-ecological layout

Figure 9.1 shows the croprotation of the systems ES INT1 and ES INT2 in time. Figure 9.2 shows the layout in space of ES INT1. As indicated in Table 9.1, all fields are adjacent. In ES INT3 and ES ORG, subsequent blocks of ES INT3 are placed in front of the corresponding subsequent blocks in ES ORG so that they were perfectly comparable.

9.2 Testing and improving

9.2.1 Results per parameter

MCR had some influence on most of the parameters used to evaluate the farming systems in the VEGINECO project. However, most of the parameters were also related with other methods and, therefore, difficult to evaluate the different effects of crop rotation. It must be taken into account that in Spain, the VEGINECO project lasted only two and half years, this made it much more difficult to evaluate long-term parameters.

In Tables 9.4 and 9.5, an overview of the parameter values is given for the integrated and organic system in Paiporta (ES INT3 and ES ORG). These systems are easily comparable because they have the same crop rotation at the same experimental station.

Quality of production (QLP) and Quantity of production (QNP)

The quantity and quality of the yield was much more influenced by the I/ECP strategies, climatic conditions or incorrect farming practices than by the MCR. The cases of soil-born diseases could not assumed to be a failure in the rotation design because the time it was in use was too short. In the Spanish systems, the two more “problematic” crops were lettuce (because of downy mildew, TSWV and N. ribisnigris) and tomato (because of viruses).

Net surplus (NS)

Net surplus was more influenced by other methods and circumstances than by the MCR. In fact, although an important part of the chosen crops are based on their economic characteristics, the results were much more related to prices and the results of the crop protection (see VEGINECO pulbication no. 4. Integrated and Ecological Crop Protection manual).

Variability of prices was the main cause for differences in net surplus in 1999 and 2000 (Figure 9.3). In general, labour (about 65%), seeds and plants (about 13%) and costs of land (about 9%) were the main important expenses. In integrated systems, expenses due to pesticides are less important (from 3% to 8%, depending on the crops). In ES INT3 and ES ORG, the modifications of MCR were also

Table 9.4 Desired and achieved results for parameters of the ES INT3 with close relationship to MCR

Theme	Parameter	Desired results	Actual results		
			1998	1999	2000
Quality Production	QNP	1.0	0.71	0.73	0.93
	QLP	1.0	0.73	0.92	0.93
Farm Continuity	NS	Income / € 100 costs >100	-	77	101
	HHW	<21 hours ha^{-1}	-	147	143
Sustainable use of Resources	PAR	30<Pw-count<45	122	97	87
	KAR	150<K-count<300	599	471	353
	OMAB	>1.0	2.5	2.1	1.2
Clean Environment nutrients	PAB	1.0	2.7	0.5	0.0
	KAB	1.0	1.1	0.3	0.0
	NAR	<70 kg ha^{-1} (0-100 cm)	-	410	252
Clean Environment pesticides	PESTASsynt	<12.4 kg ha^{-1}	-	5.6	2.2
	PESTAS-Cu	<1.96 kg ha^{-1}	-	1.9	1.3
	EEP-air	<1.18 kg ha^{-1}	-	1.14	0.44
	EEP-groundwater	<0.5 ppb	-	14.0	33.0
	EEP-soil	<248 kg days ha^{-1}	-	370	271

Table 9.5 Desired and achieved results for parameters of ES ORG with close relationship to MCR

Theme	Parameter	Desired results	Actual results 1998	1999	2000
Quality Production	QNP	1.0	0.65	0.64	0.89
	QLP	1.0	0.74	0.95	0.92
Farm Continuity	NS	Income / € 100 costs >100	-	237	335
	HHW	<200 hours ha^{-1}	-	341	370
Sustainable use of resources	PAR	30<Pw-count<45	118	92	87
	KAR	150<K-count<300	733	513	353
	OMAB	>1.0	2.3	1.7	1.1
Environment Nutrients	PAB	1.0	2.61	0.62	0.00
	KAB	1.0	1.08	0.39	0.09
	NAR	<70 kg ha^{-1} (0-100 cm)	-	324	223
Environment Pesticides	PESTASsynt	<0.98 kg ha^{-1}	-	0.3	0.22
	PESTAS-Cu	<1.2 kg ha^{-1}	-	1.3	1.16
	EEP-air	<0.12 kg ha^{-1}	-	0.31	0.04
	EEP-groundwater	<0.05 ppb	-	0.00	0.01
	EEP-soil	<25 kg days ha^{-1}	-	0	3

important in the variability of incomes. In 2000, lettuce was not planted because of viruses and Nassonovia ribisnigris. In 1999, lettuce crops did not have positive incomes. Those circumstances and changes were made to obtain positive incomes in the ES INT3 in the year 2000.

In the organic system, incomes were positive in 1999 and 2000 because of the high prices were obtained. For some produce, the prices for organic produce were ten times higher than the prices for conventionally produced vegetables. The selection of organic produce and an increasing demand for organic produce are the causes for high prices paid to the farmers.

Hours hand weeding

The MCR had very little influence on manual weeding in practice, but the crop protection strategy was much more related with the attained results (see Integrated and Ecological Crop Protection manual, VEGINECO project report no. 4). As in the previous parameter, the choice of crops can be important in choosing crops that can provide a lot of soil cover and do not demand a great deal of weeding, but this was not the case for the Spanish systems. In Figure 9.4, the number of manual weeding hours per system is shown in the stable strategy. The strategies were satisfactory in tomato, watermelon, celery, sweet corn, potato, cauliflower and broccoli. In some cases, these strategies would need certain adjustments (lettuce, green bean and artichoke crops). The poor results obtained in onion, pepper and fennel crops indicate that the strategy needs to be modified.

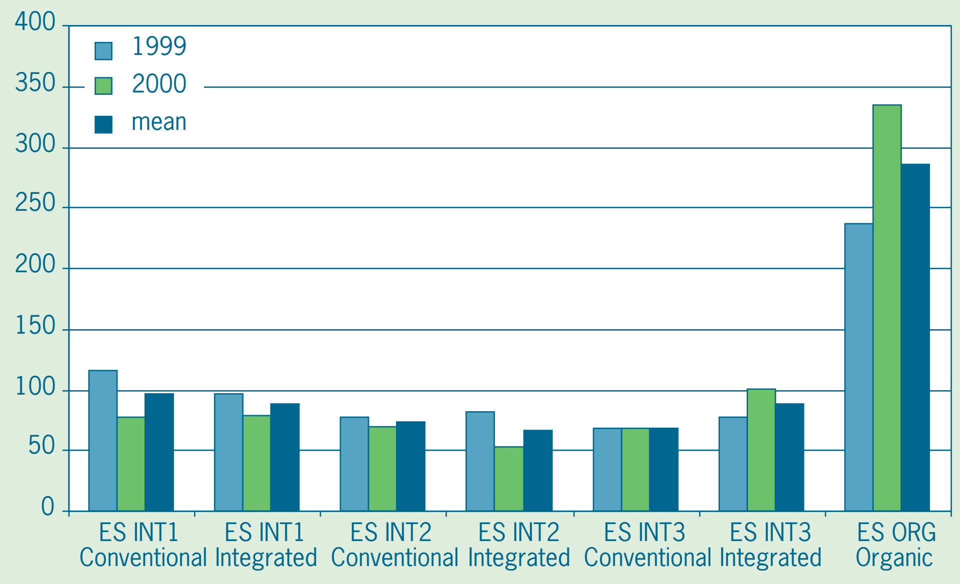


Figure 9.3 Income per € 100 costs of conventional, integrated and organic farming systems for the different locations

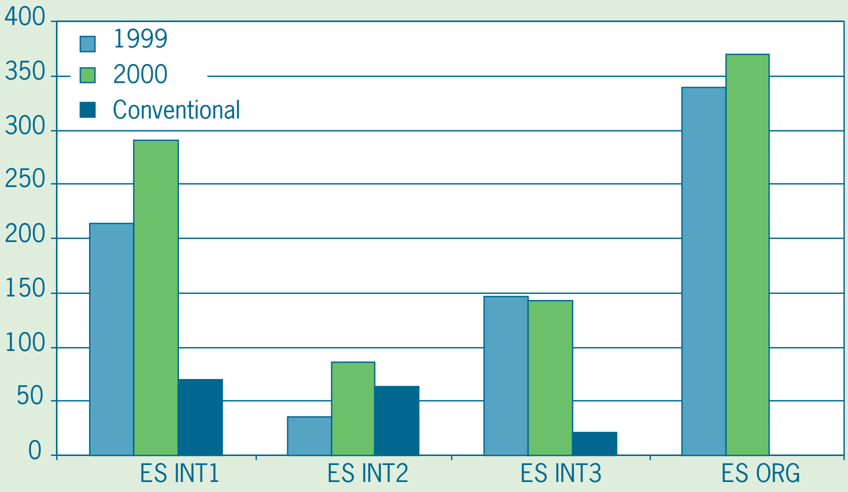


Figure 9.4 Hours of manual weeding per system compared to conventional

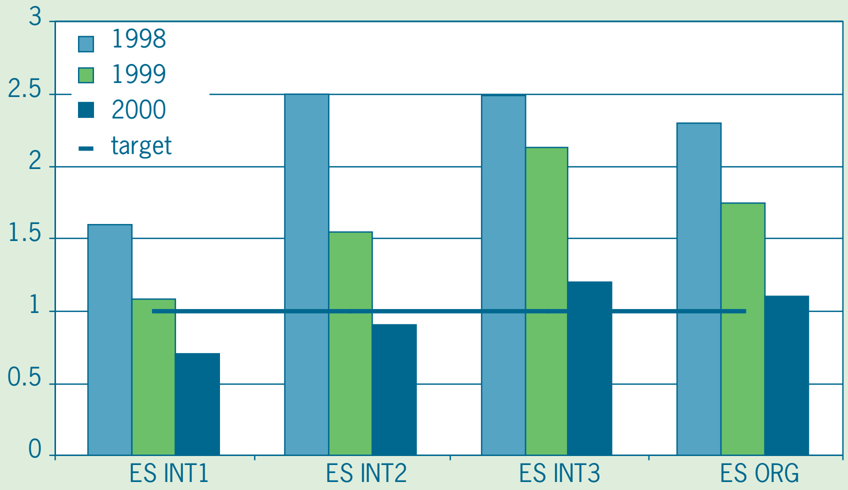


Figure 9.5 Organic matter balance (input of effective organic matter divided by estimated decomposition)

There was only one case in which there was not enough (systems ES INT1 and ES INT2 in 2000).

Nutrient parameters (NAR)
The NAR was higher than the target level of 70 kg ha-1 in all systems. The NAR at a farm level is very dependent on the type of crops in the rotation, the amount of minerals and the quality of the water. High nitrate content in water makes difficult to obtain the target value, mainly in the two systems in Paiporta (ES INT3 and ES ORG). When crops were not harvested because of poor market conditions or phyto-pathological causes (lettuces in most of the cases), NAR increased as well. This is due to the high amount of crop residues and the high amount of minerals of the organic matter stimulated by high temperatures. The nutrient management method influenced NAR more.

9.2.2 Optimisation of MCR

The Multifunctional Crop Rotation of INT1 was not altered during the three years of testing and improvement. The first design ran very well. It may be better to plant iceberg lettuce before broccoli to avoid growing lettuce during the spring cycle (more sensitive to Nassonovia ribisnigris).

In INT2, onion was removed from the crop rotation because it holds up the correct planting date of the following crop. The green manure was changed in the first year (corn instead of vetch-oats) because it was too late to seed oats.

In INT3 and ORG, all lettuce crops were removed. The autumn crop was eliminated because the crop was too sensitive to the TSW Virus (it was substituted by green bean). The spring cycle was removed to give the green manure crop more time. The summer cycle was removed because of physiological diseases and feasibility reasons.

Sustainable use of resource parameters (OMAB)
There are many crops that greatly contribute to effective organic matter input due to a large amount of crop residues (artichoke, cauliflower, broccoli, green manure and sweet corn, mainly). In addition, most vegetable crops in the Valencian community are planted (not sown). Planting adds a lot of organic matter through the substrate pots. The input of effective organic matter as a result of crop residues, substrate pots and green manure were normally high enough to compensate for the minerals of organic matter in all systems (see Figure 9.5).

10 A practical case of MCR in Switzerland

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

10.1 VEGINECO strategies in Switzerland

10.1.1 Preconditions in setting up the rotations

Regional aspects
In Switzerland, vegetable farms with both greenhouse and field production are widespread. Specialisation in greenhouse vegetables is an exception and only typical in the cantons of Tessin and Geneva.

The main vegetable area in Switzerland is the Seeland region, which is located between three lakes (Bielersee, Neuenburgersee, Murtensee) that are on average at an altitude of about 450 meter above sea level. The region once was a swamp and was drained about 100 years ago. Due to intensive production in some places, the soil has sunk up to 5 meter. Thus, the soil conditions are very heterogeneous and an organic matter content of up to 30% is widespread, especially in the region “Grosses Moos”. This region is a part of the Seeland with about 600 vegetable farms producing 25% of the Swiss vegetable production (Hormes, 1996). The very intensive farming is mainly for fresh markets and only a small part is sold to industry. A large diversity of different crops is produced on these often quite small family farms. Specialisation is not very advanced. Nevertheless, some farmers have started to reduce their assortment. An interesting characteristic of the Seeland is the high number of vegetable trading companies selling to supermarket chains.

In the Zurich area, vegetable farms are not as concentrated as in Seeland. Thus, crop rotations with arable crops are much more widespread and, consequently, pressure of pests and diseases is lower. Soil conditions are heterogeneous and the average organic matter content is lower than in the Seeland. Production for the canning factory can be found and rationalisation and specialisation is more advanced. Some of the farms are large (>50 ha). The produce often goes to supermarket chains (Migros, Coop) or directly to the consumer.
The VEGINECO analysis in Switzerland was concentrated on the five most important field-grown vegetables in the country: head lettuce, cauliflower, carrots, leeks and onions.

The pilot farms
Integrated and organic farming systems are already well established in Switzerland. In 1999, 95.3% of the agricultural area was cultivated organicly according to the Swiss regulation “Ökologischer Leistungsnachweis” including 7.3% of 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 10.1).

Vegetable production in Switzerland is very heteroge-

Table 10.1 Data on the most important field-grown vegetables in Switzerland in 1996 (Lüthi, 1996)

Crop[1]	Area Switzerland ha	area canton Bern ha	area canton Zurich ha	production Switzerland ton	market value Switzerland 10^6 sFr	import value Switzerland 10^6 sFr	% national production[3] %
carrot	1 080	208	110	53 459[2]	49.6	3.4	94
head lettuce	774	107	206	18 608	43.3	7.4	85
onion	714	189	39	32 435[2]	32.8	3.4	90
cauliflower	453	41	80	9 145	13.9	13.9	50
leek	378	76	73	12 314[2]	20.1	4.3	82
iceberg lettuce	355	29	136	4 866	8.8	10.8	45
fennel	306	51	73	5 092	8.0	10.2	44
corn salad	286	39	85	3 324	43.0	1.2	97
celeriac	264	49	39	10 897	16.7	0.5	97
endive[4]	206	33	74	8 846	11.9	17.8	40
total	4 816	822	915	158 986	248.0	73.0	77

1. crops according to statistics (different types of lettuce are indicated separately and not as a complex ‘lettuce’)
2. completely registered Swiss vegetable quantity = Wochenmeldungen + Lagergemüse (carrot = Karotte Bund + Karotte + Karotte Pfälzer, celeriac = Knollensellerie ohne Stangensellerie, onion = Zwiebel + Zwiebel rot + Zwiebel-Gemüse, leek = Lauch gebleicht + Lauch grün)
3. there is almost no export of vegetables (only sometimes overproduction of stored vegetables are exported)
4. endive = broad and curly leaf endive

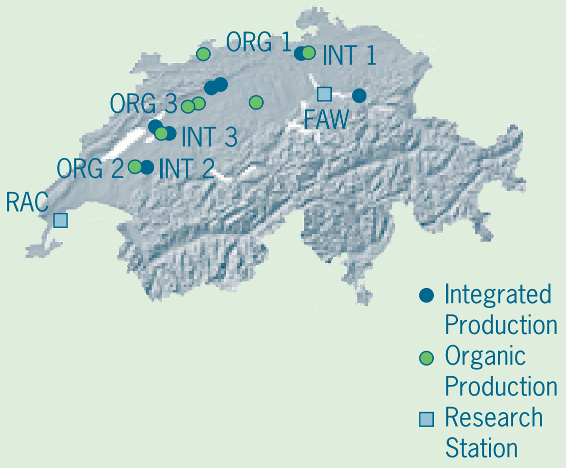


Figure 10.1 Location of the 14 pilot farms in Switzerland

neous and small in structure, which often makes it difficult to compare individual farms. Table 10.2 gives an idea of the diversity in location and structure of the 14 pilot farms.

Large vegetable farms often sell a high percentage of their produce to wholesale distributors, which have high quality standards. At these farms, a certain amount of specialisation is possible. Small farms, however, can only survive if a high percentage of vegetables sold directly from the farm. This results in better prices, but requires a larger amount of crops grown. At the pilot farms, the average number of crops per farm was 30 at integrated and 40 at organic farms, with a higher variation in organic production. When the wholesale distributors (Coop, Migros) started to promote organic food, the demand for this produce increased. The higher prices were an incentive for farmers to convert to organic farming.
The characteristics of the three integrated and the three organic farms, which were selected from the 14 pilot farms for analysis in the VEGINECO final report, are given in Table 10.3.

10.1.2 Choice of crops, cropping plan and rotation

Length of crop rotation
As shown in Figure 10.2, the length of the crop rotations of the pilot farms varied from a minimum of three years (farm 2) to a maximum of 12 years (farm 3) with an average of 5.4 years. The means for crop rotation length were almost similar for the two groups: 5.7 years for integrated and 5 years for organic pilot farms.

Three main crop rotation types were found on the 14 pilot farms:

1. farms with traditional vegetable crop rotations over three to four years:
   Four integrated pilot farms and two organic pilot farms chose the traditional crop rotation type:
   1st year: Cruciferae (crops sensitive to soil-born fungi)
   2nd year: Liliaceae (crops sensitive to nematodes)
   3rd year: Umbelliferae (crops sensitive to nematodes, Erwinia and Rhizoctonia crocorum)
   4th year: Compositae/Leguminosae/Gramineae ("insensitive" crops)
2. Farms with crop rotations of six to twelve years with a high proportion of arable crops (inclusive ley or green manure): two integrated farms grew vegetable crops over two or seven years successively. Then, five to eight years with arable crops followed. Two organic farms cultivated vegetables for the fresh market and vegetables for storage in different points in the crop rotation, especially after ley or fallow crop. After vegetable crops grown for one to two years, arable crops followed for one to two years in crop rotations over six to eight years.
3. Farms with different crop rotations of vegetables for the fresh market and of vegetables for storage:

Two organic farms grew vegetables for storage within a crop rotation of arable crops at sites far away from the farm. In contrast, vegetables for the fresh market were cultivated mainly in vegetable crop rotations on fields close to the farm. Both farms sold their vegetables directly at the market. The integrated pilot farm 1 and the organic pilot farm 9 also distinguished between different sites. Vegetables for the fresh market were cultivated on sandy or mineral soils whereas vegetables for storage were cultivated mainly on heavy soils or histosols.

Table 10.2 Diversity of the 14 pilot farms (data 1997)

	minimum		median		maximum	
	CH INT	CH ORG	CH INT	CH ORG	CH INT	CH ORG
altitude (m) above sea level	300		460		700	
precipitation (mm $year^{-1}$)	700		1 000		1 600	
total agricultural area (ha) (incl. vegetables)	1.8	9	16	14	50	150
total vegetable area (ha)	1.0	1.5	9.1	8.0	31.6	15.0

Table 10.3 Characteristics of six selected pilot farms in Switzerland

farm	canton	total size (ha)	vegetable area (ha)	purchasers
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

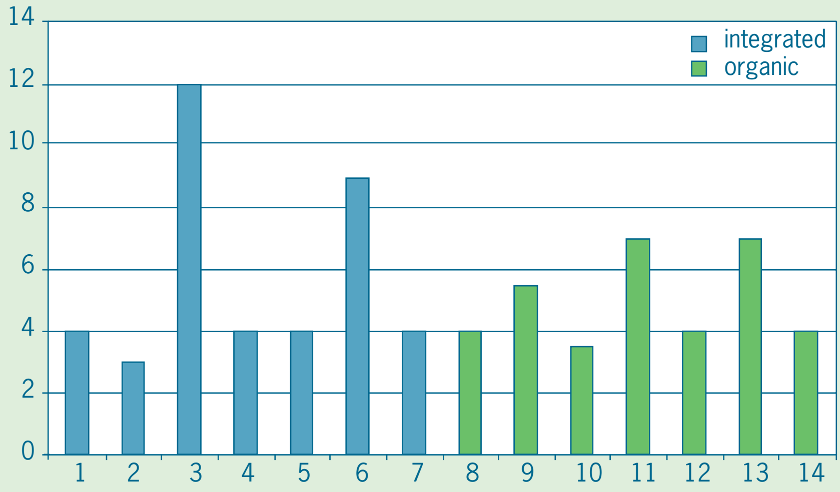


Figure 10.2 Length of crop rotation at seven integrated and seven organic pilot farms in Switzerland. X-axis pilot farm number; Y-axis number of years

10.2 Testing and improving

10.2.1 Results per parameter

Quality and quantity of production (QLP/QNP)
Quality and quantity of produce in the VEGINECO project are compared with the production according to Good Agricultural Practices (GAP). The production levels are comparable to average yields in the region. Based on official Swiss data or expert opinion, QLP and QNP target values were defined.

50% of the pilot farms had problems with Plasmodiophora brassicae in certain plots (5 integrated and 2 organic farms). In the year 2000, up to 20% yield loss was recorded at ORG1. In Switzerland, it is recommended to stop the production of cruciferous crops for 5 - 7 years if the soil is heavily infested with this fungus. Calcium cyanamide is used for soil disinfection even if the target for nitrogen input is reduced. If planting on the infested plot is unavoidable, Swiss farmers grow a crop only in spring because low temperatures are unfavourable for this fungi species.

In addition, fungi of the bottom decomposition complex and bacteria caused up to 85% yield loss mainly in head lettuce, especially in summer crops and on organic soils. In a field trial on increased planting distance of head lettuce (3 rows), the use of a black mulch plastic layer and ridging, no effect on the infestation by Rhizoctonia was observed (Kesper et al., 2000). In 2000, yield and quality of the vegetable crops at INT2 reached or even exceeded the Good Agricultural

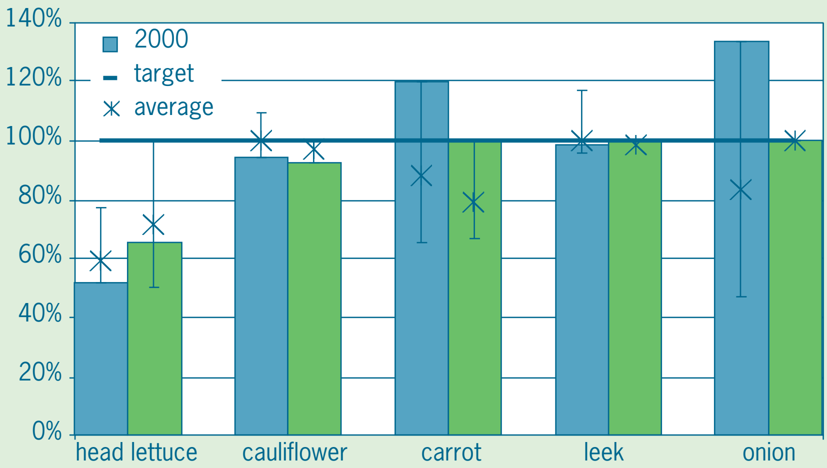


Figure 10.3 Comparison of Good Agricultural Practice (GAP) and quality production of integrated farm CH INT2 in the year 2000 (variation 1998-2000)

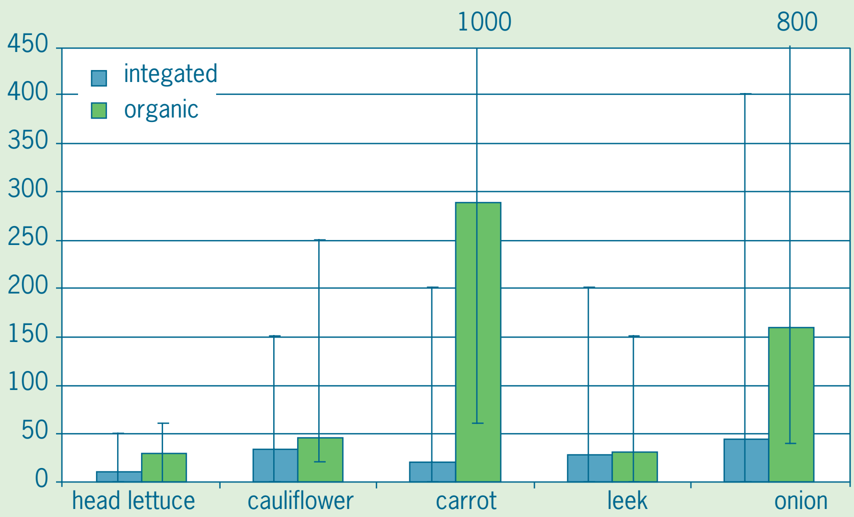


Figure 10.4 Hours of manual weeding per hectare at seven integrated and organic pilot farms in 1997 (average for normal weed pressure, maximum for high weed pressure)

Practice level (GAP), except for head lettuce. INT2 reached 91.5% of the GAP on average for the five crops. The high yield varied over the years because of a large impact of pests, diseases and extreme weather conditions. The shortfalls in quantity of head lettuce at INT2 were caused by bottom rot and hail (Figure 10.3). Caterpillars, cabbage aphid and cabbage fly reduced the yield in cauliflower. Muddy soil and hail led to poor germination and high yield variation in carrots. Onions also showed a lower yield after hailstorms.

Hours of hand weeding

In contrast to pests and diseases, there was no negative impact due to weeds on quality production identified. For comparison with the VEGINECO partner countries, the hours of manual weeding per crop are presented in Figure 10.4. (Farmers' assessment 1997).

The success of the weed control strategy was quantified with the use of this parameter. Weed control in lettuce, cauliflower and partially in leeks is done mechanically in both farming systems. Therefore, the manual labour input was comparable in these crops. However, in crops such as carrot and onion, the time for manual weeding was up to ten times more at the organic farms than at integrated farms that used herbicides. In general, in both farming systems, weed pressure is higher in crops grown on organic soils and can cause a greater manual labour input than on mineral soils.

Nutrient parameters

Due to the high precipitation in Switzerland, the conservation of soil fertility and the reduction of soil erosion and leaching are important, especially in winter. Therefore, Swiss farms need a soil cover index in winter, which is farm specific and depends on the proportion of arable to vegetable crops on the farm in a particular year (Figure 10.5). Nine out of 14 pilot farms grew green oats or grass clover during the winter, and all integrated and organic pilot farms met their soil cover index targets.

Intensity of land use

The intensity of land use was calculated as a ratio of the sum of all areas of arable crops, vegetable crops and ley to the arable land of the farm. The minimum is 1.0 crop (pilot farm 6) and the maximum is 2.1 crops (pilot farm 3, 14) were grown on the same field per year (Figure 10.6). For two farms (number 5, 10), this data was not available. On average, 1.5 crops per year and area unit were cultivated at both integrated and organic farms.

10.2.2 Optimisation of the MCR

The crop rotation was determined by the farmers because in Switzerland the work on the VEGINECO parameters was done at commercial pilot farms instead of at experimental farms.

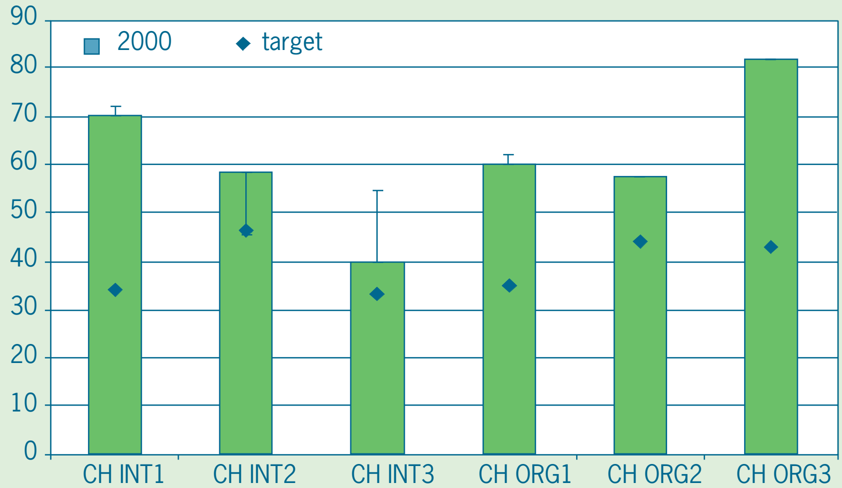


Figure 10.5 Soil cover index in winter 2000 and variation 1998-2000 of six Swiss pilot farms (for ORG2 and ORG3 only data of 1999 were available)

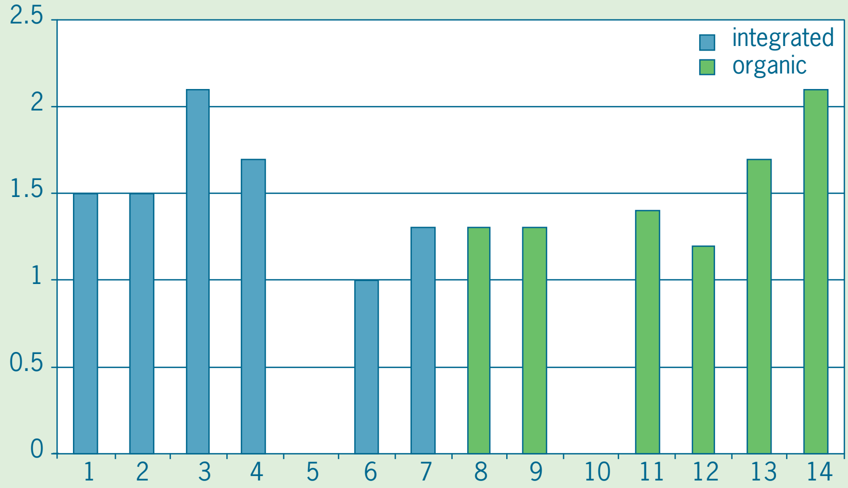


Figure 10.6 Land use intensity of seven integrated and seven organic pilot farms in Switzerland 1997. X-axis pilot farm number, Y-axis number of crops per year per area unit.

11 Discussion

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

11.1 Introduction

The cultivation of field-grown vegetables in Europe has a complexity of problems. Short crop rotations or monocultures are the causes of these problems. Minimising inputs and eliminating applications make implementation of crop rotation more important. In addition, the possibilities of soil chemical disinfection are disappearing.

Crop rotation plays a central and crucial role in the basic design of sustainable farming systems. It is not only the major weapon to prevent and control pests, diseases and weeds, but it is also the basis for maintenance and improvement of soil fertility. Crop diversification can have economic advantages as well by for instance a better use of mechanisation and labour. However, farmers are usually insufficiently aware of the concept of crop rotation and have too little experience with its benefits. In addition, specialisation in a few crops is because the market and knowledge is still increasing.

Crop rotation, as a central part of agronomy, has become less significant in the farming technology (machines, pesticides and mineral fertilisers), and even in integrated and organic guidelines, crop rotation is only described in vague terms. The importance of MCR increases from conventional to integrated farming systems, and from integrated to organic farms because the optimal relationships between crops in rotations can drastically reduce the need for inputs and corrections.

11.2 Testing and improving in the VEGINECO project

Limitations in the VEGINECO project
The first limitation is the limited length of the VEGINECO project. Four years is too short to check most of the benefits of well-designed crop rotation. This is even more valid when we take into account that the important point in this period was 'to test and improve'. Crop rotations were altered or adjusted in almost all systems. This was especially the case in Italy and Spain; the Netherlands was more focussed in optimising the rotation.

Generally, the crop rotation is the method that determines how long takes to test and improve an entire prototype. A rule of thumb is that the rotation should be constant for the length of a rotation. Therefore, after a period of testing and improving, changing and adapting the rotation, a complete rotation should follow in order to monitor and to test if results are stable.

Another limitation is the fact that annual results had to be compared from year to year ('Testing and Improving'). When the rotation is altered too much, data from the previous years cannot be used to conclude if a system meets target values or is ready to put into practice because of the large differences in type of systems. Then, it is more difficult to draw conclusions as they are based on only one or two years of data. Probably, some of these "necessary" changes could have been predicted if the theoretical process of the MCR design had been followed strictly.

The initial conceptual model and structural changes
From the initial conceptual model of the MCR, it must be clear which type of crops can be grown in a specific year. In this way, crops can be substituted as long as their characteristics are suitable for the position in the crop rotation. Not following the functionality of a crop rotation block will always lead to problems. It is necessary to follow all the steps in the initial process of the MCR design in order to ensure a successful rotation. Before the layout of the rotation is complete, all the involved factors must be reconsidered. Otherwise, the necessary changes can break the initial objectives. On the other hand, the resulting MCR should be as flexible as possible because it is not possible to predict all incidents.

Some structural changes were made in the first years of the MCR layout such as changing a crop, removing crops or even reconstructing a new MCR. For example, in Italy, the number of crops in the organic system was reduced after the first year of the layout. This was mainly done to reduce nitrogen demand and nitrogen losses, but also to reduce excessive phosphate reserves and to have more time to plant cover crops. It was, therefore, necessary to construct the rotation from the beginning. In Spain, lettuce was seriously affected by TSWV when planted at the end of summer. It was replaced by green beans in INT3 and in the organic system. This was necessary because delaying the lettuce crop was impossible without distorting the entire MCR. In both cases, the initial MCR design did not form a sufficient basis for the other methods (nutrient management in Italy and crop protection in Spain).

At other times, although a specific incidence was predicted in the MCR design, the solution may not work as expected. For instance in Spain, the use of resistant varieties of tomatoes against the TSW virus did not prevent the serious infection of other viruses. The crop should have bee replaced or another MCR should have been designed because of the high growing costs and the high risk of viruses. However in this case, the lack of an alternative MCR or a substitute crop and the need to continue with the original MCR design, made this change impossible.

In the MCR design, varieties were chosen based on their tolerance/resistance to pests/diseases, as well as their capacities for quantity and quality yield (adaptation to specific agro-ecological conditions). In Italy, the varieties of spinach and melon were changed mainly to improve the disease and pest resistance. In the Netherlands, other fennel varieties were chosen to lower cracking of bulbs. In addition, other Brussels sprouts varieties were chosen that had a better resistance to aphids, Albugo candida and mildew.

Testing and improving: possibilities for small changes
In Italy, the Netherlands and in Spain, some fine-tuning in the planting time was done to diminish the sensitivity of crops to certain pests and diseases with the subsequent reduction of pesticide use. The delay in planting the watermelon crop in Spain prevented all sprayings against aphids, for example.

Concerning nutrient management, the leguminous green manure after potatoes was replaced by a non-leguminous catch crop in the Dutch organic system because of the high nitrogen content of the soil after harvesting. In this system, nitrogen availability and nitrogen reserves in autumn are not sufficient yet for an environmentally successful system. Economically, the system was unsuccessful as well. A possible option to improve the economic result is to replace wheat or grass-clover with a more profitable leguminous crop (beans), although this cannot solve the problem sufficiently.

The Spanish organic system has another specific problem that is not solvable in the short-term. With a nitrate content of about 100 ppm in the irrigation water and no other nitrogen input, the leaching of nitrogen is too high, although obviously, the nitrogen availability is optimal.
In the integrated and organic farming systems of the Netherlands, the time between two crops of iceberg lettuce was increased to allow the second one to more easily acquire the mineralised nitrogen provided by the remains of the first one (50 kg ha-1 estimated).

Due to the high precipitation in some countries, the conservation of soil fertility and the reduction of soil erosion and leaching are important, especially in winter. In the Swiss systems, farms grew green oats or grass clover during the winter; all integrated and organic pilot farms met their soil cover index targets.

In the Spanish conditions, the green manure obtained higher quantity of vegetable mass when sown in autumn than when sown in springtime, mainly due to a lack of rains in the spring. In addition, nitrate losses are reduced, organic matter is added to the soil, the soil is protected from erosive agents and helped in weed control because of the high competition.
The climatic conditions prevented the predicted layout of the MCR several times. For example in the Netherlands, it was not possible to grow all planned catch crops because of weather conditions and harvest time. In I INT2, the delay of the harvest time for autumn crops made the growing of cover crops impossible.

Legislation affecting MCR
The presence in the MCR of crops with restricted authorised pesticides was a limitation in some systems. In Spain, the authorised herbicides in fennel are not selective, difficult to use in this crop and compromising its profitability. Other solutions were not sufficiently effective. Removing this crop in the initial choice of crops could have solved the problem. However, a solution has to be found as fennel is sometimes grown in practice using unauthorised pesticides.

Difficulties in establishing the effect of MCR on parameter values
The assessment of the crop rotation is always a problem because all themes and parameters affected by the MCR are usually more affected by other methods. This makes it very difficult to determine to what extent MCR is involved in the shortfalls or achievements. For instance, MCR influences weed control by altering different types of crops. In addition, weeds are controlled mechanically, physically or chemically. It is difficult to determine whether weed control is not successful because of crop rotation or crop protection strategies. This is important to know as the cause of the shortfall determines the possible solution. The set of crops chosen influences many other parameters, and it is often difficult to change crops without changing other parameter values as well.

11.3 Theoretical shortfall

The lack of scientific knowledge and tools to utilise this knowledge can be considered as the first and main obstacles for the development and implementation of crop rotation in commercial vegetable farms. Research and extension should reassess the value of crop rotation. However, this seems to be rather difficult because it also requires more general and architectural skills, a skill that has been lost in the intensification race. Too many researchers are focused on limited research and do not have a sufficient overview of cropping systems.
Therefore, many modern crop rotation experiments suffer from insufficient scope. To develop and implement these more sustainable farming systems, new concepts in research, technology development and knowledge transfer are needed.

An optimal characterisation needed to make the correct choice of crops, is usually very difficult or even impossible. This is because a complete agronomic view for every crop composition in the MCR is usually not available. For instance, the huge variability of prices complicates a good economic description, or the pesticide input needed per crop is usually difficult to estimate. In other cases,

the construction of the MCR is done without knowledge of the interaction between two consecutive crops and, because of this lack of knowledge; the effect of the crop rotation on certain pests and diseases is usually unknown.
Important aspects taken into account in crop rotation are the influence on crop protection and on the nutrient management. However, this influence is often insufficiently known. For instance, nutrient management in organic farming is not yet adapted to the specific limiting conditions and targets of sustainability. Maintenance of the appropriate soil fertility level does not mean increasing it to a level that is ecologically damaging, and using organic manure does not mean that nitrogen losses are limited. When nutrient management has to be adapted to these requirements, the need for a proper planning of crop rotation in accordance with nutrient management will dramatically increase. Farmers in organic farming will have to be supported by skilled experts.

11.4 Disseminating crop rotation to practice

When specific prototypes are put in practice, an initial layout to 'test and improve' is usually not very complicated for an experimental farm, providing the potential supervising committee and the farm manager think it is acceptable and manageable. However, much more time may be needed to design a first layout for pilot farms. These farms are considered an essential step for adequate transfer of knowledge. In fact, the work with pilot farms allows this transfer to be more efficient and effective. It is very helpful to set up one or several variations of the MCR for each pilot farm with the help of the farmer. The different MCR models will have to be as manageable as possible for every farming situation. The MCR may not appear ready for use because of interference of several factors to such an extent that the method needs to be revised. The leasing of fields, for instance, can be a serious obstacle for the implementation of proper crop rotations.

Another important obstacle for farmers in implementing a multifunctional crop rotation is the possible lack of profitability. The market is oriented to special produce in different areas. Farmers grow what it is most easily sold. Therefore, different farming areas have become specialised in a restricted number of crops. Due to the great variation of prices in vegetable crops throughout the year, the profitability of crop rotation will dependent on the role of commercial sector in the planning of this rotation. In these conditions, the crop diversification and the implementation of crop rotations requires marketers to cooperate in this strategy, contracting and taking part in the programming of the crops. Given the great variation in prices in the present vegetables market, the contracts ensure a minimum level of income. In I INT1, all crops were cultivated under contracts with factory, except melon and wheat.

Setting up a good rotation plan is difficult, however, correct implementation under varying conditions found in real farming practices is even more difficult. Fitting the crop rotation in the given physical conditions of the farm is often a challenge. The number and size of the available fields and the limitations of use are some of the barriers. Several crop rotations are often needed when the farm has several different soil conditions. The temporal factor makes it even more complicated. The crop rotation sequence should be followed in each of the fields over several years. Commonly experienced difficulties are changes in crops or area per crop. This might be appropriate given the market conditions and – possibilities. However, changes in crops should be done according to the conceptual MCR model. The functionality of the crop rotation should always be checked carefully in practice. One of the potential dangers is that the designed rotation is out of balance with respect to one of the factors mentioned earlier such as prevention of pests, diseases and weeds or maintenance of soil fertility. The imbalance might originate from short-term economical interests that overshadow long-term sustainability.

As a part of the layout, the ecological infrastructure of the farms can become very important for the biodiversity and landscape. Farms should stress these factors in their multifunctional role in modern societies. Farmers are often reluctant to use agricultural soils for natural resources and landscape. Governments could stimulate the development of natural resources with subsidies or reforesting neutral areas. The size of the farms is and essential factor in the layout of an optimum natural infrastructure. The larger the farm, the easier it is to include natural zones. Natural zones are not intended to meet the same objectives under the different farming conditions; therefore, different ways of evaluating different conditions are needed (see Ecological Infrastructure Management manual, VEGINECO project report no. 5). In Spain, some difficulties were the result of the small size of fields; hedgerows can be obstacles for daily farming practices. However, perhaps, the largest difficulty is to convince the farmer of the value of hedgerows on their farms.

References

Bourgeois J. 1995. Ab 1. Juli wird das GATT umgesetzt. Der Gemüsebau 10/1995: 3

Butler Flora C. (2000). Sustainability in agriculture and rural communities. In: M. Härdtlein, M. Kaltschmitt, I. Lewandowski & H.N. Wurl (eds). Nachhaltigkeit in der Landwirtschaft, Landwirtschaft im Spannungsfeld zwischen Ökologie, Ökonomie und Sozialwissenschaften. Erich Schmidt Verlag GmbH & Co. Berlin. p 191-207.

Forman R.T.T. & M. Godron. 1986. Landscape ecology. John Wiley & Sons, Inc. New York. 619 pag.

Hormes E. 1996. Das grosse Moos – ein Hauptanbaugebiet für Gemüse in der Schweiz. Gemüse 10/1996: 582

Hurni F. 1996. VSGP-Jahresbericht 1995. Der Gemüsebau. 7/1996: III

Hurni F. 1997. VSGP-Jahresbericht 1996. Der Gemüsebau. 6/1997: II

Hurni F. 1998. VSGP-Jahresbericht 1997. Der Gemüsebau. 3/1998: 35

Kesper C., B. Reller, K. Schmid und C. Hippe 2000. Dreireihiger Anbau auf Folie steigert die Ertragssicherheit von Kopfsalat. Der Gemüsebau 12/2000: 22-23

Lichtenhahn M. 1997. Bioverarbeitungsgemüse – eine Alternative für den Verarbeitungsstandort Schweiz? Der Gemüsebau. 5/1997: 14-15

Lüthi J. 1995. Jahresbericht 1994 der Schweizerischen Zentralstelle Gemüsebau. Oeschberg-Koppigen

Lüthi J. 1996. Jahresbericht 1995 der Schweizerischen Zentralstelle Gemüsebau. Oeschberg-Koppigen

Mäder P. 1996. Interprofession – Ein Modewort kommt in der Gemüsebranche aus der Mode. Der Gemüsebau 15/1996: 3

Pretty J. 2000. Conditions for succesful implementation of sustainable agriculture. In: M. Härdtlein, M. Kaltschmitt, I. Lewandowski & H.N. Wurl (eds). Nachhaltigkeit in der Landwirtschaft, Landwirtschaft im Spannungsfeld zwischen Ökologie, Ökonomie und Sozialwissenschaften. Erich Schmidt Verlag GmbH & Co. Berlin. pag. 323-343

Rossing W.A.H., F.G. Wijnands & A.T. Krikke (1995). Voortgang vernieuwing in de landbouw: het samenspel van prototypering en toekomstverkenning. In: Haverkort, A.J., en P.A. van der Werff (Eds). AB-DLO Thema's 3. Hoe ecologisch kan de landbouw worden? Themadag KLV, AB-DLO en PE gehouden op 21 november 1995 te Wageningen. pag. 115-135

Sprangers J.T.C.M. 1999. Vegetation dynamics and erosion resistance of sea dyke grassland. PhD. thesis, Wageningen Agricultural University. Wageningen. The Netherlands. 167 pp.

Todt W. 1996. Bioproduktion, die Chance der Zukunft. Der Gemüsebau 6/1996: 24-25

Urbano P. & R. Moro. 1992. Sistemas agricolas con rotaciones y alternativas de cultivos. Ediciones Mundiprensa.

van der Zee S.E.A.T.M & J.J.T.I. Boesten. 1991. Effects of soil heterogeneity on pesticide leaching to groundwater. Water resources research. Vol 27, No 12. p 3051-3063

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

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

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

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

Vereijken P., Visser, R.P. & Kloen, H. 1998. Innovatie van de EKO-akkerbouw en groenteteelt met 10 voorhoedebedrijven (1991-1997). In Dutch. Rapport 88. AB-DLO. Wageningen. 110 pp.

Vereijken P. 1999. Manual for prototyping integrated and ecological arable farming systems (I/EAFS) in interaction with pilot farms (concerted action AIR3-CT927705). AB-DLO. Wageningen. 51 pp.

Vereijken P. 1992. A methodic way to more sustainable farming systems. Netherlands Journal of Agricultural Science 40:209-223.

Wijnands F.G. 1992. Evaluation and introduction of integrated arable farming in practice. Netherlands Journal of Agricultural Science. Vol. 40. No. 3. Pag. 239-249.

Wijnands F.G., P. van Asperen & S.R.M. Janssens. 1998. Evaluation and testing of integrated arable farming systems on innovative pilot farms in the Netherlands. In: Conference Proceedings Volume 3, The 1998 Brighton Conference, Pests and Diseases. British Crop Protection Council. Pag. 1115-1125

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

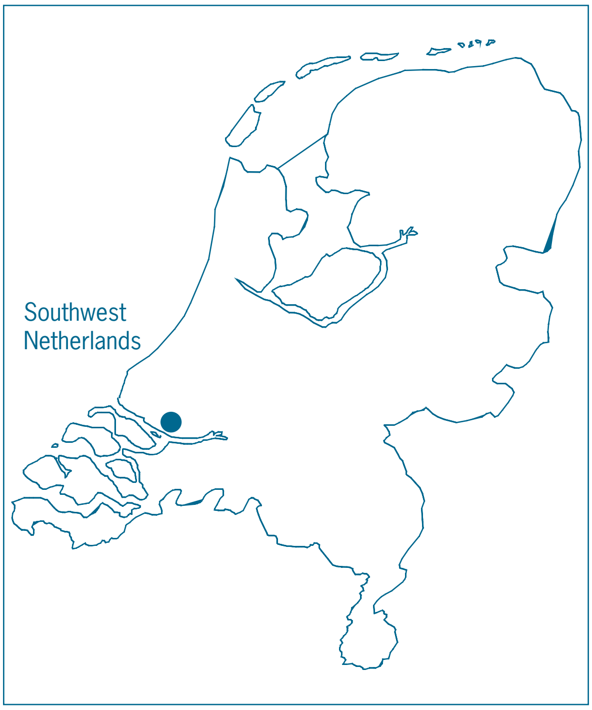
Soil characteristics	Integrated	Organic
main soil type	marine clay	marine clay
clay (%)	33	33
organic matter (%)	2.4	2.2
pH (KCl)	7.5	7.2

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

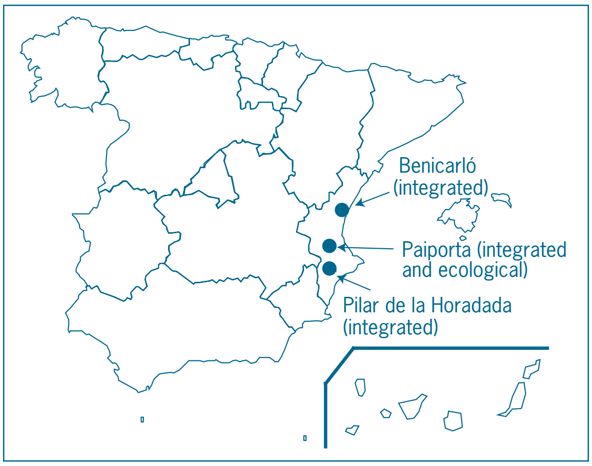
Integrated industry system (I INT1)	Integrated fresh market system (I INT2)	Organic fresh market system (I ORG)
1. spinach tomato	1. lettuce spr./sum./aut. catch crop	1. green beans fennel
2. wheat green beans	2. green beans	2. melon
3. sugar beet catch crop	3. strawberry celery + catch crop	3. catch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

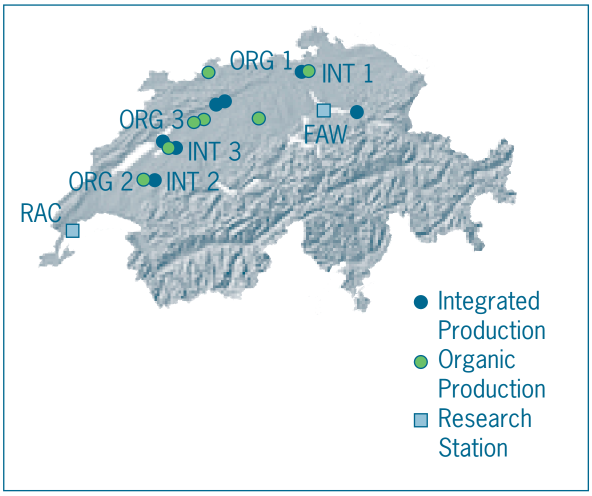
Three integrated and three organic pilot farms were tested:
INT1/ORG1: wholesale distributors, Zurich
INT2/ORG2: direct sale, French-Swiss
INT3/ORG3: retailers / wholesalers, Seeland

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 cm^{-2} (Liebefeld 95)	3 858 MJ cm^{-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. Definition of parameters

QNP, QLP

Full name: Quantity of produce, Quality of produce

Definition:
- Actual marketable production divided by production level according to Good Agricultural Practices (GAP = average of marketable production of the crop in the region/soil type/country under normal circumstances)
- Quality of marketable produce divided by quality according to GAP (= mean percentage of 1st quality produce in the region/soil type/country under normal circumstances)

Dimension: -

Level: Crop, farm

Target: 1

Countries: NL, I, ES, CH

Calculation: Crop level:

$$\text{QNP crop}^{1)} = \frac{\sum 1\text{-n (actual marketable quantity cropping activity}^{2)}\text{ i)/n}}{\text{Marketable GAP quantity}}$$

$$\text{QLP crop}^{1)} = \frac{\sum 1\text{-n (actual quality of marketable produce cropping activity}^{2)}\text{ i)/n}}{\text{Quality of marketable produce according to GAP}}$$

Farm level:

If QNP-crop' > 1 then QNP crop = 1; if QNP-crop' ≤ 1 then QNP-crop' = QNP crop
QNP farm = (∑ 1-n QNP" i)/n

If QLP-crop > 1 then QLP-crop" = 1; if QLP-crop ≤ 1 than QLP-crop" = QLP crop
QLP farm = (∑ 1-n QLP" i)/n

Testing:
- Establish actual QNP, QLP values at farm and crop level
- If QNP and/or QLP < 1, analyse cause of shortfall per crop: method-related or accidental non-systemic shortfall
- Improve methods that caused the shortfall

1) There can be cultivation methods or periods with different marketable GAP qualities/quantities. Every separate cultivation method or period has its own QLP/QNP-crop

2) Within a cultivation method or period, there can be different cropping activities caused by different sowing or planting dates. All cropping activities within a cultivation method or period have the same GAP quality/quantity

NCONT

Full name: Nitrate content in crops

Definition: Nitrate (NO_3^-) content of marketable produce

Dimension: mg kg^{-1} Level Crop (all leafy crops + other crops where relevant)

Target: NCONT < x
EU-standard is maximum of 2 500 mg per kg fresh product (May-October) for leafy vegetables)

Countries: NL, I, CH

Testing: Define desired levels for NCONT taking into account national or regional policy papers or local considerations. Desired levels can be defined per crop or crop group:
- Establish nitrate content per crop or even per crop activity (for example lettuce).
- If nitrate in crop is larger than target value, then analyse cause of shortfall per crop: method-related or accidental non-systemic shortfall.
- Improve methods (nutrient management, crop rotation) that caused the shortfall.

NS	
Full name	Net Surplus
Definition	Gross revenues minus all costs including the costs for all labour hours equal to the costs for comparable labour in other economic sectors
Dimension	Currency $farm^{-1}$
Level	Farm
Targets	$NS \geq 0$
Countries	NL, I, ES, CH
Calculation	*revenues* = $\sum_{1}^{n}$ *(farm quantity Xi * price Xi)*
Testing	• Define a standard farm (area, machinery, buildings, storage) • Registration of all farm inputs in costs (mechanisation, lease, labour, sales costs,) • Registration of all labour input in terms of manual labour hours or in terms of cultivation times • Consider reasons for negative results and the profitability of different crops • Remove crops from rotation if negative results are repeated every year

HHW	
Full name	Hours Hand Weeding
Definition	Hours of manual weeding
Dimension	Crop, Farm
Level	Crop, Farm
Target	HHW < x Countries NL, ES
Testing	• Define desired levels for HHW • Establish HHW per farm or per crop • If shortfall between actual and desired, then improve I/ECP to meet criteria

PAR, KAR	
Full name	Phosphate Available Reserve, Potash Available Reserve
Definition	Soil reserves of Phosphate (P_2O_5) and Potash (K_2O) available for uptake by plants
Dimension	Dependant of analytical technique
Level	Field, farm
Target	Agronomically desired and environmentally acceptable range xN < PAR/KAR < yN;
Countries	NL, I, ES, CH
Testing	• Define a desired range of PAR/KAR for the system: sufficient from an agronomic point of view and acceptable from ecological point of view • Establish mean actual PAR/KAR per field • If actual PAR/KAR < desired range → P_2O_5/K_2O input > P_2O_5/K_2O off take (repair applications) • If actual PAR/KAR = within desired range → P_2O_5/K_2O input = P_2O_5/K_2O off take (excluded unavoidable losses) • If actual PAR/KAR AR > desired range → P_2O_5/K_2O input < P_2O_5/K_2O off take

OMAB

Full name: Organic Matter Annual Balance

Definition: Annual input / annual output of effective organic matter

Dimension: -

Level: Farm, field

Target: Dependent of actual level and desired range of Organic Matter Available Reserves (OMAR):
- If actual level < desired range, then OMAB > 1
- If actual level ≥ desired level, then OMAB = 1

Calculation: Effective organic matter input / organic matter output
- Effective organic matter input consists of effective organic matter in crop residues, green manure, organic manure, paper pots and straw (in kg ha^{-1})
- Organic matter output consists of respiration and erosion (in kg ha^{-1})
- Organic Matter Available Reserves can be calculated by measuring organic matter content

Countries: NL, I, ES, CH

Testing:
- Define desired range for Organic Matter Available Reserves for the system
- Establish mean actual OMAR for every field
- If actual OMAR < desired range; then OMAB > 1
- If actual OMAR ≥ desired range; then OMAB = 1
- If shortfall between actual an desired, then improve nutrient management and crop rotation to reduce shortfall

NAR

Full name: Nitrogen Available Reserve

Definition: Mineral, nitrogen soil reserves (0-100 cm) at start of the leaching period (the period that evapo-transpiration < precipitation).

Dimension: kg ha^{-1} Level Field, farm, crop

Target: Acceptable range in order to minimise leaching to ground and surface water

Countries: NL, I, ES, CH

Testing:
- Define maximum NAR to meet desired maximum level of nitrate leaching from system
- Establish achieved NAR for each field
- Improve nutrient management or crop rotation if there is a shortfall between actual NAR and desired range of NAR

PAB, KAB

Full name: Phosphate Annual Balance, Potash Annual Balance,

Definition: P_2O_5/K_2O input / P_2O_5/K_2O off take (farm, field, crop)

Dimension: -

Level: Farm, field, crop

Targets: Dependent of actual level and desired range of PAR/KAR:
- If actual level < desired range than PAB/KAB > 1
- Iif actual level > desired level than PAB/KAB < 1

Countries: NL, I, ES, CH

Calculation: P_2O_5/K_2O input / P_2O_5/K_2O off take
- P_2O_5/K_2O -input consists of P_2O_5/K_2O in plant material or seeds, organic and mineral fertilisers and deposition in kg P_2O_5/K_2O ha^{-1}.
- P_2O_5/K_2Ooff take consists of P_2O_5/K_2O in off take of produce and removed from crop residues in kg P_2O_5/K_2O ha^{-1}.

Testing:
- Define desired range of PAR/KAR for the system
- Establish mean actual PAR/KAR per field
- Test PAB/KAB per field:
  - If actual PAR/KAR < desired range; then PAB/KAB > 1 (repair gifts)
  - If actual PAR/KAR = within desired range; then PAB/KAB = 1 (excluded unavoidable losses)
  - If actual PAR/KAR > desired range, then PAB/KAB < 1
- Average fields to calculate PAB/KAB on farm level

PESTAS-Synth and PESTAS-Cu

Full name	Pesticides input active ingredients
Definition	Annual input of active ingredients of synhethic pesticides or copper
Dimension	kg ha^{-1}
Level	Crop, farm, pesticide group
Target	PESTAS < x
Countries	NL, I, ES, CH
Testing	• Define levels for PESTAS • Establish inputs in kg ha^{-1} • If shortfall between actual and desired, then improve MCR and/or I/ECP to meet defined criteria

EEP-air, groundwater, soil

Full name	Environment Exposure to Pesticides to air, groundwater and soil
Definition	Extent to which air, groundwater and soil are maximally exposed to pesticides
Dimension	EEP-air =kg ha^{-1} , EEP-groundwater = ppb, EEP-soil = kg day ha^{-1}
Level	Application, Crop, Farm
Target	EEP-air, EEP-soil: 70% reduction to average practice EEP-groundwater per application: 0.1 ppb, on farm: 0.5 ppb
Countries	NL, I, ES
Testing	• Define desired levels for EEP at farm level • Establish actual EEP values at application, crop and farm level • If shortfall between actual an desired, then search for applications/products with the highest contribution to the EEP-value • Reduce EEP by replacing these applications/products. First review non-chemical alternatives, next look at alternative chemicals, dosage or application techniques

EI

Full name	Ecological Infrastructure
Definition	Percentage of farm production area managed as nature habitat and/or corridor
Dimension	%
Level	Farm
Target	EI < x%
Countries	NL, I, ES, CH
Testing	• Define target value or range for EI • Establish EI per farm • If shortfall between actual and desired, then improve Ecological Infrastructure Management to meet defined area

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.

VEGINECO

EU. FAIR PROGRAM