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

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2.1 Prototyping methodology

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

The methodology of prototyping is still young, dynamic and developing. However, it can be described as an innovative process in 4 steps: analysis and diagnosis, design, testing and improving and dissemination (Figure 2.1).
The process of prototyping starts with a regionally *based analysis and diagnostic* phase that includes the following aspects: sectorial statistics, farm structure, agro-ecological state-of-the-art, ecological–environmental impact, the socio-economic situation, trends in structural changes and current political conditions.
Based on an analysis of shortcomings in current farming methods and of future perspectives, the *design phase* starts by establishing a hierarchy of objectives for all-round sustainable farming systems.
In the Vegineco prototyping practice, these rather abstract objectives are translated into five directional themes: quality production, clean environment, attractive landscape and diversified nature, the sustainable management of resources, and farm continuity.
In order to quantify the objectives of a theme, each one is fixed within a number of farm-level parameters. Each parameter is given a target value so that a well defined, documented and clear framework can be established to design, test and improve farming systems. The target levels are future oriented and are derived from legislation, scientific evidence or expert knowledge.
The next step is to design a suitable set of farming methods (methods are defined here as coherent strategies on the major aspects of farming). In most cases, these methods need further development if they are to realise their objectives.
To create a basic framework for interpreting the results, the next step in the methodology is to design a theoretical prototype to link the parameters with the methods. It then becomes possible to check the links. The last part of the theoretical exercise ends with detailed cropping programmes, allowing for adjustments that might be necessary for specific crops, weather and soil conditions.

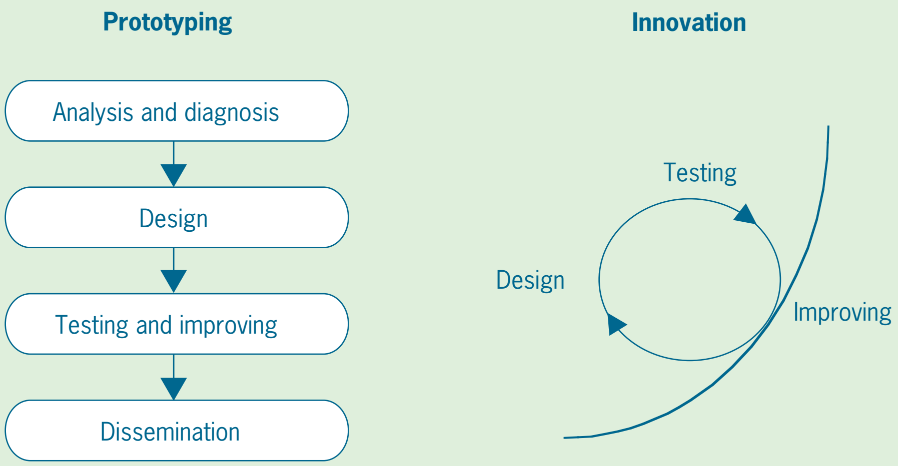

Figure 2.1 Prototyping methodology and the process of testing and improving

The next phase is *testing and improving* the farming system that has been designed. For the test phase to be successful, a farming system has to be laid out in time and space. Important here is the choice, not only of a multi-functional crop rotation, but also of the agro-ecological identity of the farm.
When the prototype shows stable results at the level of the parameter targets, the next logical step is dissemination. The perspectives of a new prototype can only be evaluated in practice. Management is the key factor for the success and feasibility of these new approaches. Therefore a region-specific prototype, developed on experimental farms, is first tested on a small number of pilot farms. This is considered an indispensable step before new prototypes are introduced on a large scale.

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

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

Some statistics

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

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

Farm types

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

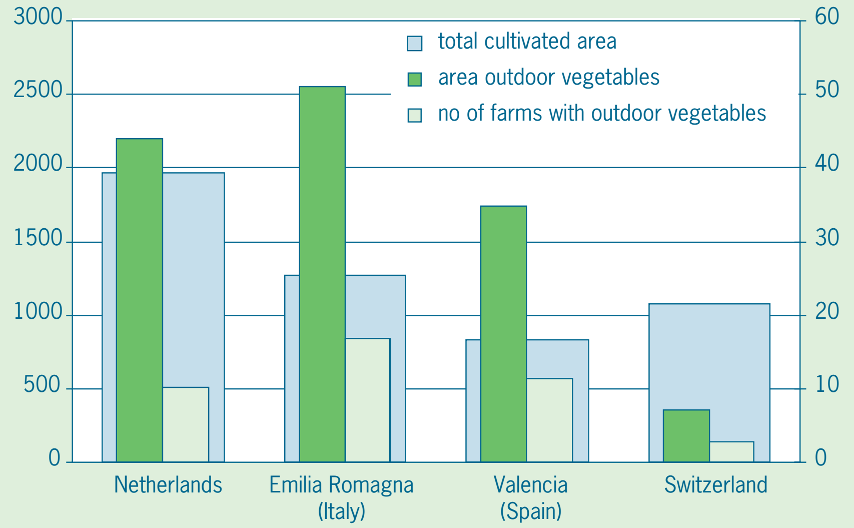

*Figure 2.2 Left axis: Total agricultural area under cultivation (*1000 ha) and area of outdoor vegetables (* 100 ha); Right axis: number of farms involved (*1000)*

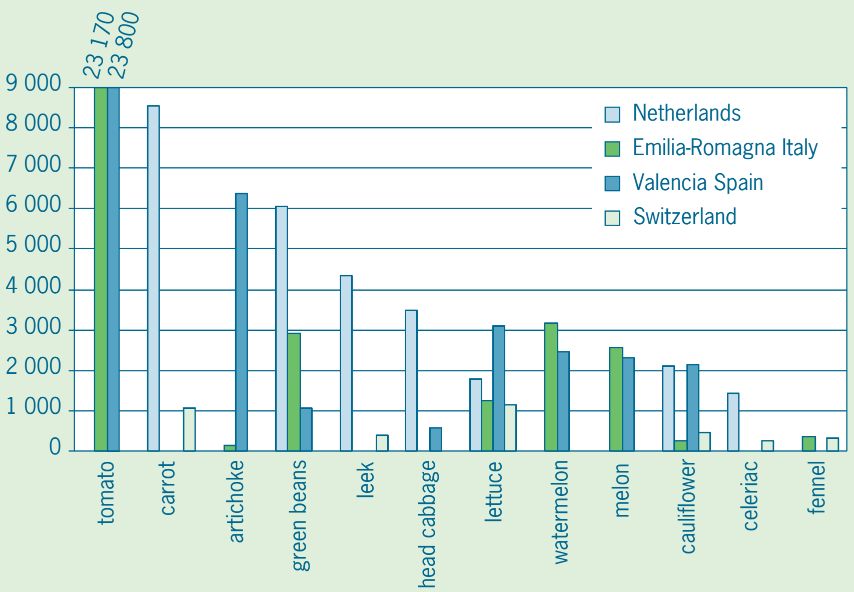

Figure 2.3 The major crops per partner in terms of area (ha), based on national statistics from 1995-1997 (the Dutch sample excluded potato, peas, onions, and chicory roots)

vegetables. These labour-intensive farms grow a wide variety of crops and are oriented towards producing fresh market produce. They are mostly family operated and are very intensive in terms of land use and inputs such as fertilisers and pesticides. A small group specialises in one or two crops, in the Netherlands, for example, Brussels sprouts or leeks.
2. Larger farms (10-50 ha) with either arable or citrus/fruit-tree acreage (Valencia) combined with outdoor vegetables. This is an expanding group. The well-mechanised vegetable crops can be produced without intensive labour.
3. The remaining farms are those that combine indoor and outdoor vegetables (Switzerland and Valencia) or those combining highly mechanised fresh market or industrial vegetable crops with arable farming (Emilia-Romagna and the Netherlands).

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

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

Environmental and agronomic problems
The intensive use of land, overfertilisation and a high input of pesticides are generally considered to be problematic, causing high emissions of nutrients and pesticides into the environment.
Except for Switzerland, problems caused by nitrogen leaching into the ground and surface water are clearly evident and well documented, as is the emission of pesticides in the Netherlands. Although the emission of pesticides is also viewed seriously in Italy and Spain, there is little documentation on its effects there.
There is ongoing concern about the sustainability of production in terms of soil fertility (especially biological and physical soil fertility) and the options for controlling soil-borne pests and diseases in the long term. Of particular concern, due to the one-sided agrochemical approaches, is the growing resistance of pests, diseases and weeds to pesticides.
Efficient large-scale agriculture has decreased bio-diversity in the main growing areas by removing flora and fauna habitats and corridors. The old landscapes formed by small-scale farming are rapidly disappearing. Even where small fields are maintained (as in Valencia, Spain), the hedges that used to separate them have largely been removed.

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

Market and label developments
The governments of Switzerland, the Netherlands, Spain and Italy are encouraging the development of organic farming by introducing subsidies to help farms convert to this style of production. In Switzerland and the Netherlands this development is being stimulated further by large grocery/supermarket chains who are actively incorporating organic production into their product range.
The development of integrated production labels started in the early nineties, stimulated, in the Netherlands and Spain, by either the auctions or co-operatives, in the Netherlands also by other groups in society (e.g. consumer groups), or, in Italy and Spain, by the government. A comparable development began earlier in Switzerland and has led to the present situation whereby almost all vegetable growers produce under the IP label. Parallel government subsidies, available to enterprises whose production processes are more or less the same as the guidelines for IP production, are in place to stimulate this trend further.
Driven by concerns about food health and safety, another important development is market and consumer awareness of the internal quality of produce. Where quality chain approaches are applied, this will lead to controlled and certified quality and the reduction of hazards throughout the chain.

Table 2.1 Themes and common parameters used in the Vegineco project

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

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

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

Summary of trends

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

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

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

2.2.2 Design: Objectives, parameters and methods

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

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

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

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

2.3 New approaches

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

2.3.1 Quality production

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

Quantity of produce

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

Quantifying yield is one thing, but how to interpret its value is another. In the case of integrated/organic farming systems, most of the time there was no zero reference in the experiment — no conventional system to measure the yields against. Therefore a reference had to be devised. The criterion followed in the Vegineco project was the reference: *Regional Good Yields and Quality.*

An estimation of 'regional good yields and quality' was made from available data and expert knowledge. It is important to note that the values obtained were *not year-specific, but indicated the average performance.* A yield and quality reference could also be made more farm- or system-specific by making it a yield quality target based on a combination of factors, such as ambition, what is realistic and what is usually achieved in practice.

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

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

Using this QNP has a number of advantages:

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

Quality of produce

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

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

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

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

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

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

2.3.2 Evaluation of the use and effects of pesticides

Pesticide use

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

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

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

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

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

Pesticide emission

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

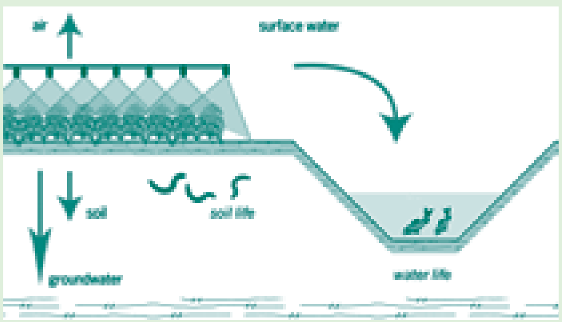

Figure 2.4 The main emission routes and ecological effects of pesticide use

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

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

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

Ecological risks

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

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

Intermezzo: Environments Exposure to Pesticides (EEP)

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

The EEP basic data are:

DT50 = half life time of pesticide in soil, a measure of the persistence in the soil

K_{om} = the partitioning coefficient of the pesticide over the dry matter and water fraction of the soil/organic matter fraction of the soil to organic matter

VP = vapour pressure; a measure for the volatilisation in Pascal

Derived from this basic data is:

F = the F value, a measure of the fraction of the active ingredient that leaches

$F = \exp(-[(A \times f_{om} \times \ln 2 \times K_{om}) / DT50 + (B \times \ln 2) / DT50 + C])$

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

2.3.3 Energy input

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

System bounderies

In order to quantify energy use, the system boundaries have to be clear.

Energy input was quantified according to the following criteria:

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

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

Calculation

To calculate the energy input at either crop-, field- or system level, the following steps were taken:

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

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

Example

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

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

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

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

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

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

2.3.4 Methodology and parameters on ecological infrastructure management

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

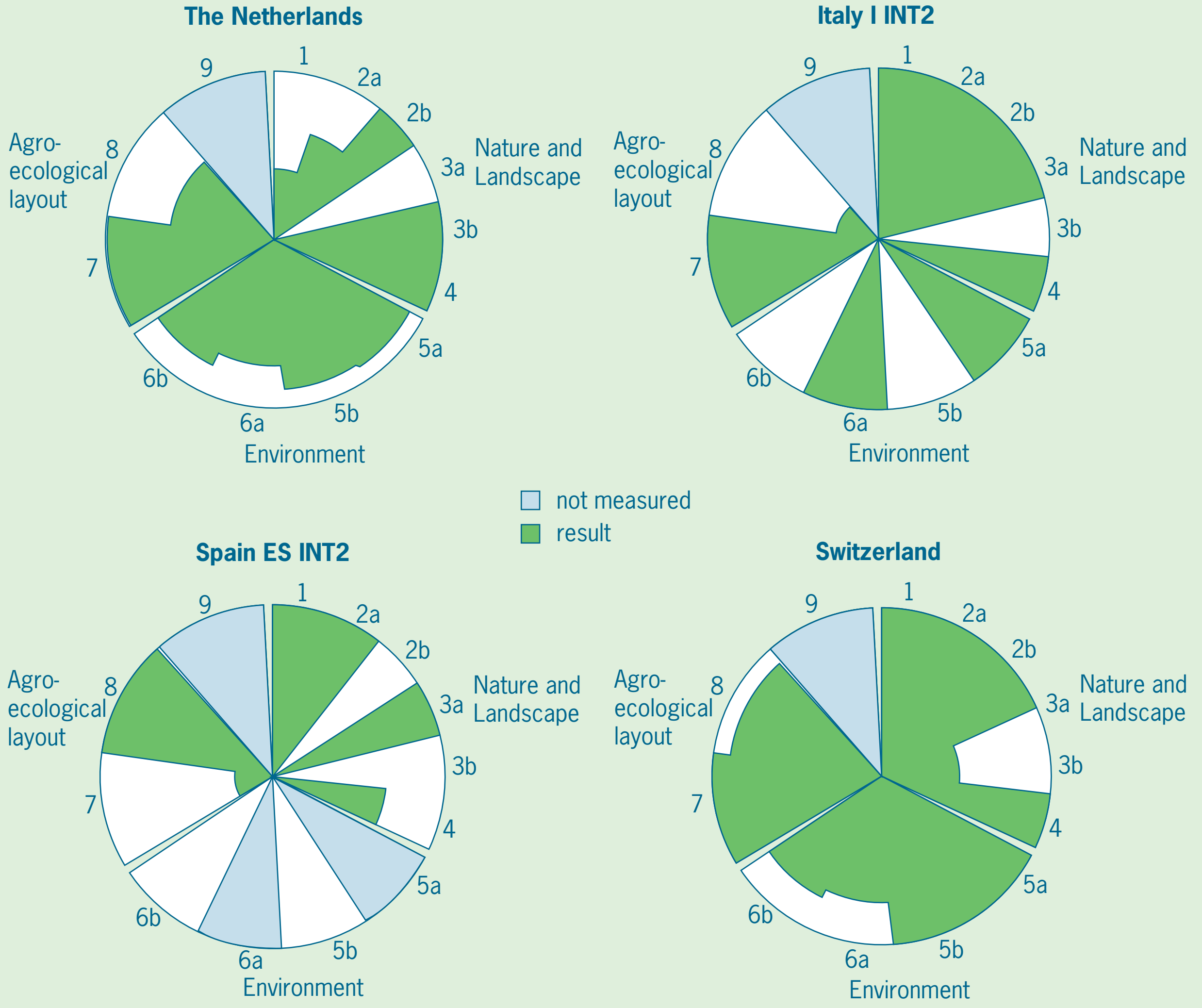

Figure 2.5 Representation of the realisation of on farm nature parameters per country

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

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

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

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

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

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

2.4 Testing and improving

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

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

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

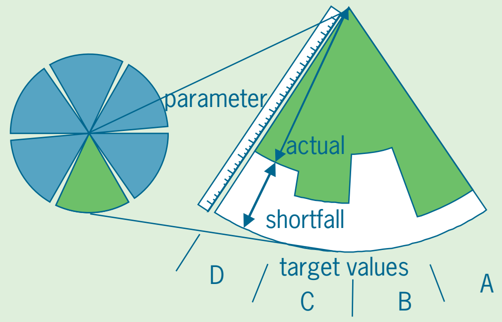

Figure 2.6 Schematic representation of target realisation and shortfall

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