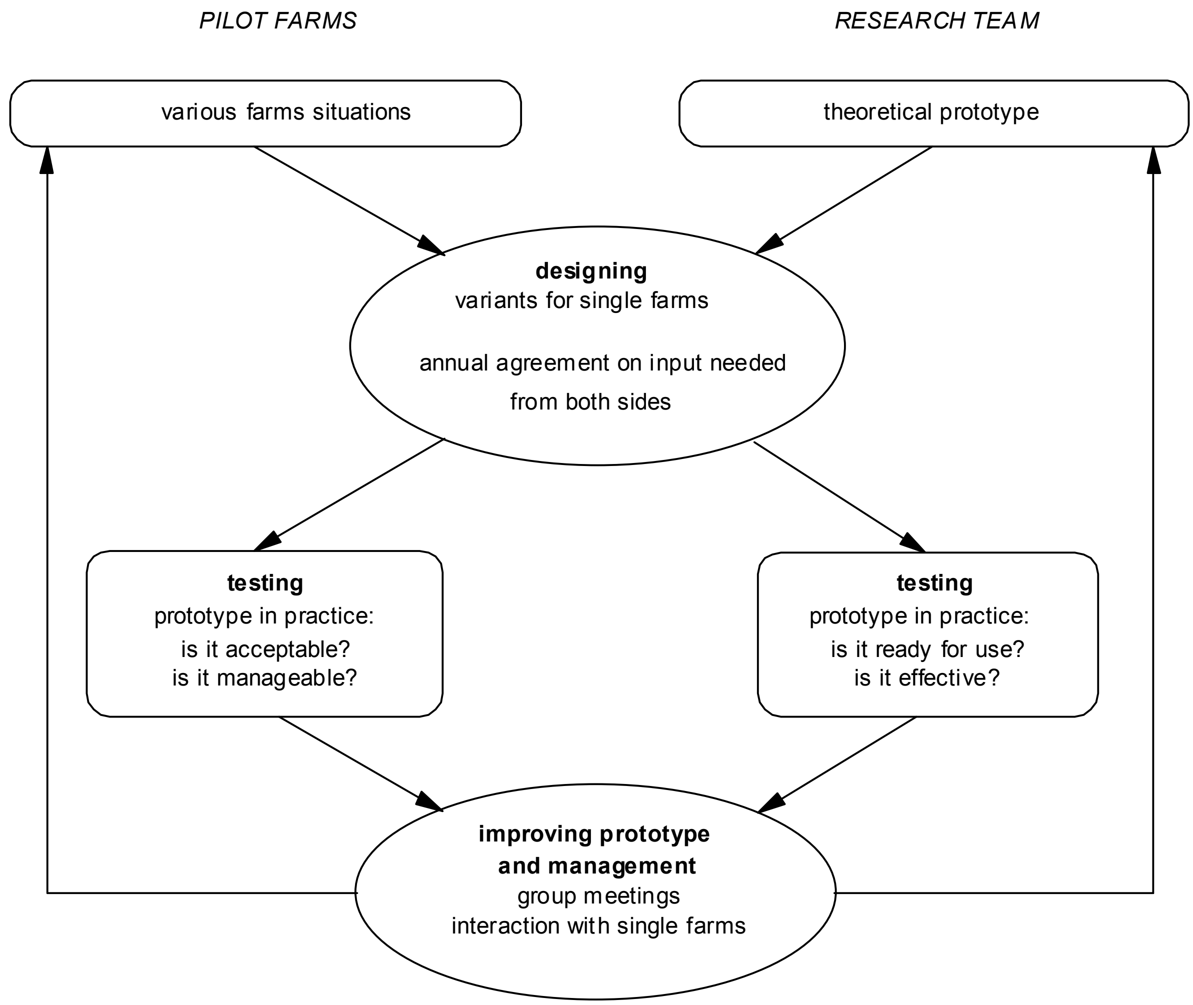
Manual for prototyping integrated and ecological arable farming systems (I/EAFS) in interaction with pilot farms

P. Vereijken



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Abstract

A manual for prototyping Integrated and Ecological Arable Farming Systems (I/EAFS) in interaction with pilot farms is presented. It concerns a comprehensive and consistent approach of 5 steps. Step 1 is establishing a hierarchy of objectives considering the shortcomings of current farming systems in the region. Step 2 is transforming the objectives in a set of multi-objective parameters, to quantify them and establishing a set of multi-objective farming methods to achieve them. Step 3 is designing a theoretical prototype by linking parameters to farming methods and designing the methods in this context until they are ready for initial testing. Step 4 is laying out the prototype on at least 10 pilot farms in appropriate variants and testing and improving the prototype (variants) until the objectives, as quantified in the set of parameters, have been achieved (after repeated lay-out). Step 5 is disseminating the prototype (variants) to other farms with gradual shift in supervision from researchers to extensionists. This 5 steps method of prototyping has been elaborated and tested by a European network of more than 20 research teams, sponsored by the European Union (AIR-concerted action). The teams express their achievements in a consistent set of 6 parts of an identity card of their prototype. The 6 parts of the EAFS-prototype of the author's team are presented to illustrate the method of prototyping. Part 6 presents the state of the art. It shows that the results desired have progressively been achieved, which may be considered as the best proof of the effectiveness of prototyping.

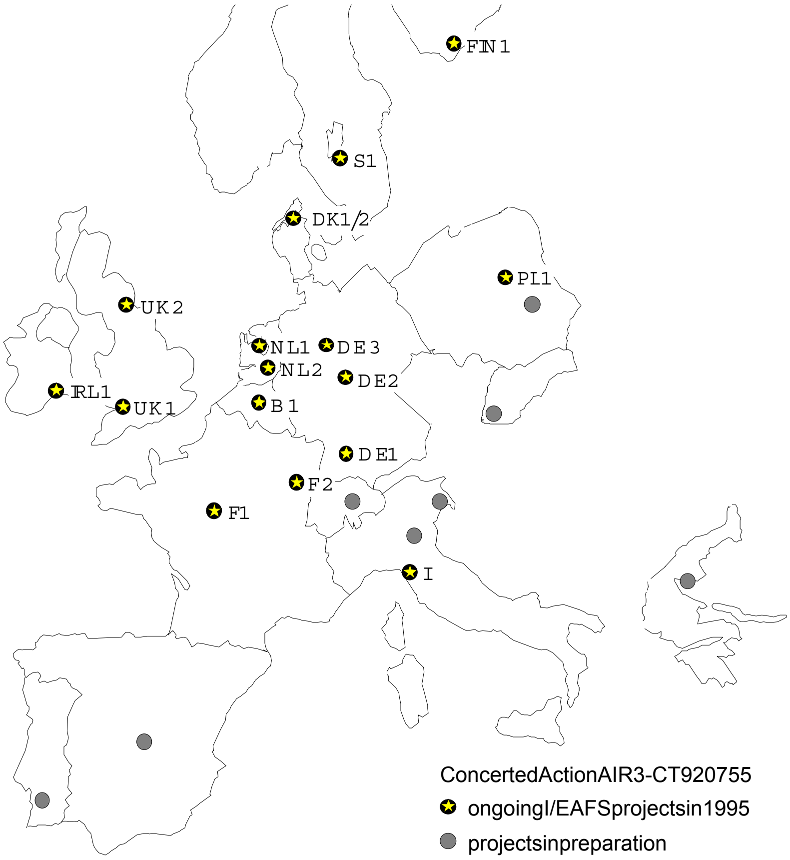

Figure 1 European network of research teams prototyping I/EAFS

Outline 1 Five steps to design, test, improve and disseminate prototypes of Integrated and Ecological (Arable) Farming Systems (I/EAFS).

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(1) Hierarchy of objectives:
drawing up a hierarchy in 6 general objectives, subdivided into 20 specific objectives as a base for a prototype in which the strategic shortcomings of current farming systems are replenished (Part 1 of the identity card of a prototype).

(2) Parameters and methods:
transforming the major specific objectives (10) into multi-objective parameters to quantify them, establishing the multi-objective farming methods needed to achieve the quantified objectives (Part 2 of the identity card).

(3) Design of theoretical prototype and methods:
designing a theoretical prototype by linking parameters to farming methods (Part 3 of the identity card), designing methods in this context until they are ready for initial testing (Multifunctional Crop Rotation as major method and Part 4 of the identity card).

(4) Layout of prototype to test and improve:
laying the prototype out on an experimental farm or on pilot farms in an agro-ecologically appropriate way (Part 5 of the identity card),
testing and improving the prototype in general and the method in particular until (after repeated laying out) the objectives, as quantified in the set of parameters, have been achieved. (Part 6 of the identity card).

(5) Dissemination:
disseminating the prototype by pilot groups (< 15 farmers), regional networks (15 - 50 farmers) and eventually by national networks (regional networks interlinked) with gradual shift in supervision from researchers to extensionists.

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1. Introduction

The European Union (EU) is facing an agricultural crisis with two major symptoms: deterioration of rural income and employment and deterioration of environment, nature and landscape. The basic mechanism is a continuous intensification causing surplus production and price fall on the one hand and ecological deterioration on the other hand. Therefore, a crucial question for the Common Agricultural Policy (CAP) is to alleviate the symptoms of intensification on the short term and to find a sustainable solution on the long term. In the early 1990s, various EU-countries started promoting Integrated Farming Systems to alleviate the agricultural crisis, when drastic reductions in inputs of pesticides and fertilisers were achieved with initial prototypes on experimental farms. Subsequently, in 1993 the EU decided to sponsor a network of research teams on prototyping Integrated Arable Farming Systems (IAFS). The setting up of the network should be combined with development and standardisation of the methods of prototyping in a concerted action within the third EU framework programme for agricultural research. The main deliverable is this manual is to explain and illustrate the methods of prototyping as developed by the research network.

Most research teams joined the network to develop IAFS prototypes feasible for the main group of farms. This group must try to be competitive on the world market, based on high and efficient production, and this gives only limited scope for pursuing non-marketable objectives such as environment, and nature/landscape. Therefore, a more consistent integration is needed for such long term objectives. Consequently, many research teams also or exclusively develop an IAFS for the long term, albeit that this IAFS is as yet only feasible for pilot groups of farms. Contrary to short-term IAFS, these long-term IAFS place income/profit subordinate to environment, and rely on ecologically-aware consumers willing to pay premium prices for food products with high added value and a credible label.
In the short-term IAFS, Chemical Crop Protection is minimised to the benefit of the environment (Integrated Crop Protection). In the long-term IAFS, Chemical Crop Protection is fully replaced by a package of non-chemical measures, to achieve ambitious objectives in environment, nature/landscape and quality and sustainability of food supply. So, long-term IAFS are based more on ecological awareness and knowledge than short-term IAFS. Therefore, our prototypes of long-term IAFS are simply called EAFS (Ecological Arable Farming Systems), and short-term IAFS are referred to as IAFS.

Organic systems can be considered to be a forerunner of EAFS, but they have no quantified objectives in environment and nature/landscape and as a result, they need to be considerably improved to become acceptable to the majority of consumers. Nevertheless, organic farming has a strategic significance to Europe because it is the first example of a market model of shared responsibility of consumers and producers for the rural areas. Therefore, many research teams are collaborating with a pilot group of organic farms which have primarily been selected for their willingness to achieve more than is required by current minimal guidelines of the EU organic label.

Selected on a set of general and specific criteria (Annex 1), 22 research teams from 14 EU and 3 associated countries have been brought together into the network, since the start in 1993 (Fig. 1). Together they invest more than 30 scientist years per annum in prototyping. This manual focusses on 5 steps for prototyping I/EAFS developed within the network as a common frame of reference. The consecutive steps are presented and illustrated by the state of the art of the author's own project on EAFS with a group of pilot farms (NL 2), started in 1991.

Building on initial experience with an experimental farm at Nagele (Vereijken, 1992) and the input of the research leaders from the network, prototyping of I/EAFS has been elaborated in 5 formal steps (Vereijken, 1994, 1995, 1996, 1997,1998). (Outline 1). The outcome of these 5 steps is expressed in parts of an identity card for the prototype to facilitate the cooperation within the team and the exchange with the other teams in the network. In the following sections the 5 steps are explained in more detail and illustrated by the various parts of the identity card of our prototype EAFS for the central clay region in The Netherlands (NL 2).

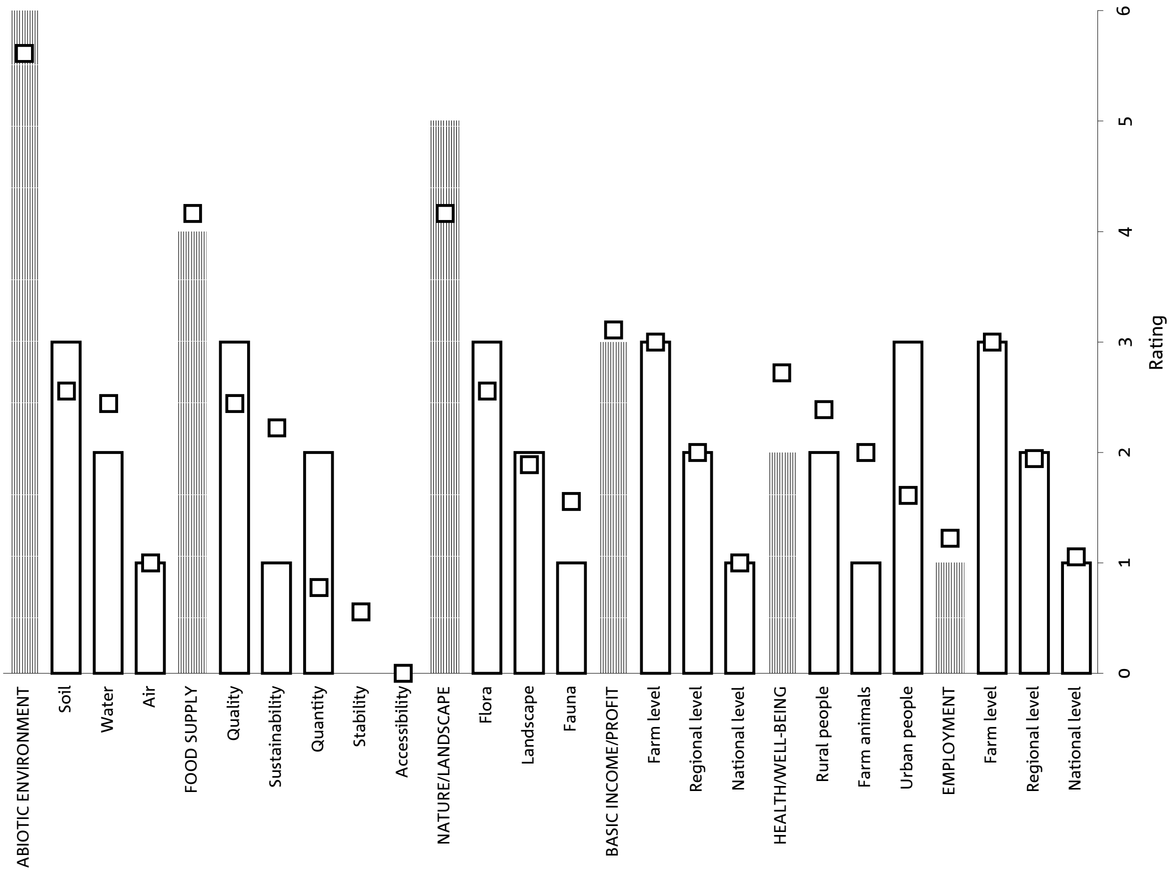

Figure 2 Hierarchy of objectives in EAFS prototyping in Flevoland (NL 2) as an example of Part 1 of a prototype's identity card in the I/EAFS-Network
(squares - average of 9 European EAFS prototypes, rating explained in text).

In Flevoland (NL 2) abiotic environment is the main objective, ahead of nature/ landscape and food supply.
Although pesticides have been abandoned, abiotic environment remains of primary concern since soil fertility in EAFS is chiefly maintained by recycling organic waste, especially manure. Because organic fertilisers generally contain nutrients in ratios which do not correspond with the crop needs, accumulation and eventually leaching of certain nutrients can only be avoided by sophisticated nutrient management focusing on agronomically desired and ecologically acceptable nutrient reserves in the soil.
Nature/landscape is the second main objective, since current organic farming has no explicit guide-lines and technology for this increasingly scarce commodity. An Infrastructure for Nature and Recreation will overcome this shortcoming and stimulate ecologically-aware consumers to switch to ecological products. In Flevoland, development of an Infrastructure for Nature and Recreation will focus on vegetation of the ditch sides, attractive to man and animals.
Food supply is the third main objective, with the focus on an optimum balance of quantity and quality, as an indispensable basis for basic income/profit and health/well-being. This balance, called quality production, requires new and sophisticated technology, including a multifunctional crop rotation as a major substitute for external inputs, notably pesticides.

2. Hierarchy of objectives (step 1)

Table 1 presents 6 general values or interests involved in agriculture, each subdivided into 3 or 5 specific values or interests. The first step for prototypists of farming systems is to establish a hierarchy of objectives within this framework, taking into account the shortcomings of farming systems in the region and the targeted contribution the prototype should deliver to improve the situation in the short term (IAFS) or the long term (EAFS).

The procedure is simple: in the first round the general objectives are rated from 6 to 1 in descending order of importance. In the second round the specific objectives within each general objective are rated from 3 to 1 in descending order of importance (in food supply by 3, 2, 1, 0, 0 because there are 5 specific objectives, not 3).

Table 1 General and specific social values and interests involved in agriculture*

Values and interests (not in order of importance)			
general	specific	general	specific
Food supply		Abiotic environment	
	quantity		soil
	quality		water
	stability		air
	sustainability		
	accessibility	Nature/Landscape	
Employment			flora
	farm level		fauna
	regional level		landscape
	national level	Health/Well-being	
Basic income/Profit			farm animals
	farm level		rural people
	regional level		urban people
	national level		

* Simplified from (Vereijken, 1992)

By this procedure the author's team has drawn up the hierarchy of objectives as step 1 in pilot project NL 2 (Fig. 2). It clearly shows we want to prototype an EAFS, building forth on organic farming as a forerunner and improving it on 3 strategic shortcomings: nutrient management, care of nature and landscape and quality production.

This hierarchy of objectives should not be considered as just the vision of our prototyping team. Though we proposed it, the group of pilot farms has taken it over after ample discussions during several study meetings. In our experience, the hierarchy of objectives is a simple and effective instrument to achieve consensus between researchers and farmers on the agenda for innovative research. It could also be a good instrument to achieve consensus on the research agenda if more parties would be involved, such as organisations of consumers or environmental groups. In that case a useful procedure would be to first let the various parties draw up their own hierarchy of objectives. Secondly, the various hierarchies should be highlighted and critically examined. Thirdly, a common hierarchy of objectives should be negotiated, based on a thorough weighting of the various arguments and sealed by a memorandum of mutual understanding or rather an agreement of cooperation and mutual support.

Table 2 Parameters and methods in EAFS prototyping in Flevoland (NL 2) as an example of Part 2 of a prototype's identity card in the I/EAFS-Network

Top 10 of objectives	Top 10 objectives quantified in multi-objective parameters (defined in outline 2)	Top 10 objectives achieved by multi-objective farming methods (defined in outline 2)
1. Abiotic environment-Soil	1.1 EEP-soil = 0 1.2 20 < PAR < 30 * PAB > 1 if PAR < 20 PAB < 1 if PAR > 30 ** 1.3 x < KAR < y * KAB > 1 if KAR < x KAB < 1 if KAR > y ** 1.4 PNL (0-100 cm) < 70 kg ha^{-1}	1.1 - 1.4 MCR 1.2 - 1.4 ENM
2. Nature/Landscape - Flora	2.1 INRI > 5% farm area 2.2 PSD > 50 INR^{-1} of a farm 2.3 PSDN> 20 INR $section^{-1}$ (100 m)	2. INR (target species sowing included)
3. Food supply - Quality	3.1 QPI > 0.9 $crop^{-1}$	see 1
4. Abiotic environment - Water	4.1 EEP-water = 0 4.2 ANL < 11.2 mg l^{-1} (EU-norm) see 1	see 1
5. Nature/Landscape - Landscape	5.1 FDI > 10 flowers m^{-1} (Apr-Oct) 5.2 SED> 7 per farm see 2	see 2 (bird habitats included)
6. Basic income/Profit - Farm level	6.1 NS > 0 6.2 HHW < 25 hours ha^{-1} see 3	6.1 FSO see 1 and 2
7. Food supply - Quantity	see 3	see 1 and 2
8. Health/Well-being - Urban people	see 1-6	see 1 and 2
9. Basic income/Profit - Reg. level	see 1-6	see 1, 2 and 6
10. Abiotic environment-Air	10.1 EEP-air = 0(see 1)	see 1
	Total parameters: 12 EU, 4 local	Total methods: 4 EU, 0 local

Outline 2 *Brief definitions of the 16 parameters and 4 methods used to quantify and achieve the top 10 of specific objectives for the prototype EAFS in NL 2 (as listed in Table 2).*

A. Parameters

1.1. Environment Exposure to Pesticides-soil (EEP-soil) = active ingredients (kg ha^{-1}) * 50% degradation time (days).

1.2. P Available Reserves (PAR) = Pw count in NL = mg l-1 P2O5 in the cultivated soil layer, 1:60 extracted with water. P Annual Balance (PAB) = P input / P output.

1.3. K Available Reserves (KAR) = K-count in NL = mg K2O in 100 gram air-dry soil from the cultivated layer, 1:10 extracted with 0.1 n HCl. K Annual Balance (KAB) = K input / K output.

1.4. Potential N Leaching (PNL) = kg ha-1 Nmin in the soil layer 0 - 100 cm at the start of the period of precipitation surplus, e.g., N leaching.

2.1. Infrastructure for Nature and Recreation Index (INRI) =share of farm area managed as a network of linear and non-linear habitats and corridors for wild flora and fauna, including buffer strips.

2.2. Plant (target) Species Diversity (PSD) = number of species/INR of a farm, with conspicuous flowers by colour and/or shape, attractive for fauna and recreationists.

2.3. Plant (target) Species Distribution (PSDN) = mean number of target species/100 m of INR.

3.1. Quality Production Index (QPI) crop $product^{-1}$ = Quality Index (QI) * Production Index (PI) crop $product^{-1}$ = (achieved price kg^{-1}/top quality kg^{-1}) * (on market kg ha^{-1}/on field kg ha^{-1}) crop $product^{-1}$. ($0 \leq QPI \leq 1$)

4.1. Environment Exposure to Pesticides-water (EEP-water) = EEP-soil * mobility. (Mobility = Kom-1 and Kom = partition coefficient of the pesticide over dry matter and water fractions of the organic matter fraction of the soil).
4.2. Actual N Leaching (ANL) = mg l^{-1} Nmin in drainage water, mean for period of precipitation surplus.
5.1. Flower Density Index (FDI) = mean number of flowers/m/month of Infrastructure Nature/ Recreation.
5.2. Side-Elements Diversity (SED) = number of small landscape elements diversifying the INR.
6.1. Net Surplus (NS) = total returns minus all costs, including an equal payment of all labour hours.
6.2. Hours Hand Weeding (HHW) = mean number of hours ha^{-1} in hand weeding.
10.1. Environment Exposure to Pesticides-air (EEP-air) = active ingredients (kg ha^{-1}) * vapour pressure (Pa at 20 - 25°C).

B. Methods

1.1.-1.4. Multifunctional Crop Rotation (MCR) = a farming method with such alternation of crops (in time and space) that their vitality and quality production can be put safe with a minimum of remaining measures or inputs.
1.2.-1.4. Ecological Nutrient Management (ENM) = a farming method with such tuning of input to output of nutrients, that soil reserves fit in ranges, which are agronomically desired and ecologically acceptable.
2. Infrastructure for Nature and Recreation (INR) = such layout and management of a network of landscape elements, that it is accessible and livable to wild flora and fauna and attractive to urban and rural recreationists.
6.1. Farm Structure Optimisation (FSO) = a mostly indispensable method to render an agro-ecologically optimal prototype also economically optimal, by establishing the amounts of land, labour and capital goods, which are minimally needed to achieve the desired Net Surplus.

3. Parameters and methods (step 2)

Having put the objectives in a hierarchy prototypists need to transform them into a suitable set of parameters to quantify them. Subsequently, the quantified objectives are used as the desired results at the evaluation of the prototypes. Prototypes are tested and improved until the results achieved match the desired results.

Given the overwhelming number of parameters available, there are two major reasons for not using a large set. Firstly, using a large set is time-consuming and expensive. Secondly, doing so does not assure that the objectives are integrated which is crucial because the objectives may conflict in many ways. Consequently, prototypists must first identify a limited set of multi-objective parameters, to ensure that the objectives are integrated sufficiently. Additionally, they must establish a set of specific parameters for those objectives that are not or only insufficiently integrated by the set of multi-objective parameters.

To develop I/EAFS prototypes in which potentially conflicting objectives are sufficiently integrated, prototypists need a suitable set of farming methods and techniques. Current methods and techniques mostly serve one or two of the set of objectives and harm the others. Chemical crop protection is a clear example. Therefore, it should first be looked for integrating methods and techniques which bridge the gaps between conflicting objectives and are not harmful to the others. Additionally, specific methods may be established aimed at major specific objectives that are insufficiently covered by the set of integrating methods.

In this way the authors's team has quantified the objectives and established the methods as step 2 in pilot project NL 2 (Table 2). In the first column of Table 2 the top 10 of specific objectives is listed, drawn up from the hierarchy of objectives (Fig. 2) by multiplying the ratings of the specific objectives by the ratings of the general objectives which they belong to. In the second column of Table 2, the top 10 of specific objectives has been transformed into and quantified by a set of 16 parameters, of which 12 are on a shortlist of the I/EAFS network and 4 have a local status. In the third column of Table 2 the 4 farming methods are listed, needed to achieve the top 10 of specific objectives, as transformed into the set of 16 parameters. The 16 parameters and 4 methods are briefly defined in Outline 2.

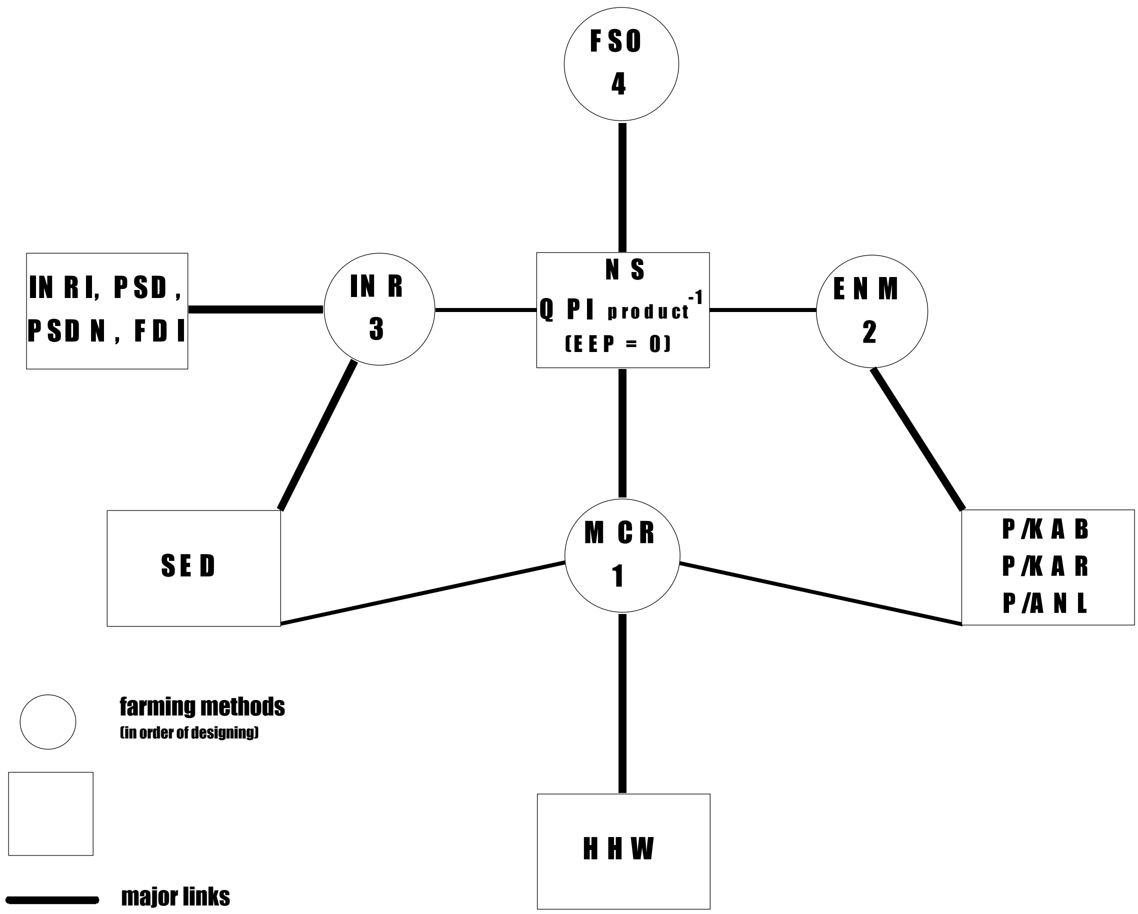

Figure 3 Theoretical prototype for EAFS in Flevoland (NL 2) as an example of Part 3 of a prototype's identity card in the I/EAFS-Network (see Outline 2 for explanation of parameters and methods).

In Flevoland, the major 10 objectives as quantified in 16 parameters are achieved by 4 multi-objective methods and made ready for use in the order that follows.

(1) Multifunctional Crop Rotation (MCR) is the major method to achieve desired results in Quality Production Indices (QPI product^{-1}) without using pesticides (EEP=0), Net Surplus (NS) and Hours of Hand Weeding (HHW). It is also a method supporting P and K Annual Balance (P/KAB), P and K Available Reserves (P/KAR), Potential and Actual N Leaching (P/ANL) and Side Elements Diversity (SED).

(2) Ecological Nutrient Management (ENM) is the major method to achieve desired results in P and K Annual Balances, P and K Available Reserves, Potential and Actual N Leaching. It is also a method supporting Quality Production Indices (without using pesticides) and Net Surplus.

(3) Infrastructure for Nature and Recreation (INR) is the major method to achieve desired results in Infrastructure for Nature and Recreation Index (INRI), Side- Elements Diversity and local parameters of flora: Plant Species Diversity (PSD), Plant Species Distribution (PSDN) and Flower Density Index (FDI). It is also a method supporting Quality Production Indices and Net Surplus.

(4) Farm Structure Optimisation is the finalising method to achieve the desired result in Net Surplus, if the current amounts of land, labour or capital goods of a pilot farm fail to do so with the agronomically and ecologically optimised prototype EAFS. Currently, it is not clear if FSO is needed. Therefore, it is not developed yet.

4. Design of theoretical prototype and methods (step 3)

Most of the methods of the European shortlist have to be designed or redesigned, because they are non-existent or not ready for use. However, they cannot be designed independently from each other and in arbitrary order, because they should be multi-objective and should achieve the set of objectives quantified by the set of parameters within a consistent farming system and by mutual support. Consequently, in step (3) we first establish major and minor links between the methods and the parameters they should help to achieve in a theoretical prototype before proceeding with designing the methods in their appropriate context.

In this way we have designed a theoretical prototype and the methods in this context as step 3 in pilot project NL 2 (Fig. 3). This theoretical prototype shows the major and minor methods needed to achieve the desired results for each objective, e.g., for each parameter. Vice versa, it also shows which parameters are supported by a method and thus indicates the potential impact of a method. Consequently, the theoretical prototype defines the context and the order of designing the methods. In the next sections the design of the methods of the European shortlist is highlighted.

4.1 Designing a Multifunctional Crop Rotation (MCR)

In all theoretical prototypes of the I/EAFS-Network, Multifunctional Crop Rotation (MCR) plays a central role as a major method to achieve desired results in the multi-objective parameters of soil fertility and environment (P/KAR, EEP etc.), as well as in the Quality Production Indices (QPIs product^{-1}) and the major parameters of economic and labour efficiency (NS and HHW). Consequently, MCR should be designed primarily to provide for a well-balanced 'team' of crops requiring a minimum of inputs that are polluting and/or based on fossil-energy (nutrients, pesticides, machinery, fuel) to maintain soil fertility and crop vitality as a basis for quality production (Outline 3).

Outline 3 Procedure of designing a Multifunctional Crop Rotation (MCR) for I/EAFS.

(A) *Identifying and characterising potential crops for your region or farm:*
- making a list of crops (set-aside included) in diminishing order of marketability and profitability (≥ 6 crops for IAFS and ≥ 8 crops for EAFS);
- characterising the crops in their potential role in the MCR in biological, physical and chemical terms, as is done in Table 3A.

(B) *Drawing up an MCR based on (1) and simultaneously fulfilling a multi-functional set of demands:*
- filling the first rotation block with crop no. 1.;
- filling subsequent blocks while preserving biological soil fertility by limiting the share per crop species to ≤ 0.25 in IAFS and ≤ 0.167 in EAFS and the share per crop group to ≤ 0.50 in IAFS and ≤ 0.33 in EAFS;
- filling subsequent blocks, while preserving physical soil fertility by consistently scheduling a crop with a high rating of soil cover (erosion-susceptible soils) or effect on soil structure (compaction-susceptible soils) after a crop with a low rating, overall the MCR resulting in a soil cover ≥ -1 in IAFS and = 0 in EAFS and a soil structure ≥ -1 in IAFS and ≥ 0 in EAFS (ratings explained below Table 3);
- filling subsequent blocks while conserving chemical soil fertility by consistently scheduling a crop with a high rating of N transfer before a crop with a high rating of N need and a crop with a low N transfer before a crop with a low N need, overall the MCR resulting in an N need ≤ 3 in IAFS and ≤ 2 in EAFS;
- filling single blocks by 2 or 3 crops with corresponding characteristics, if needed for reasons of limited labour capacity or limited market demand;
- ensuring crop successions are feasible in terms of harvest time, crop residues and volunteers from preceding crops.

The resulting MCR may be considered as superior to any other crop rotation, because short-time interests of marketing and profit are optimally blended with long-term interests of preserving soil fertility with minimum need for external inputs. However, an MCR can only achieve the desired results if it is laid out in an agro-ecological way (Section 5.1).

Table 3 Multifunctional Crop Rotation for EAFS in Flevoland (NL 2) as an example of Part 4 of a prototype's identity card in the I/EAFS-Network

A. Selection of crops by pilot farm 6 (crops in order of profitability).

crop	biological		physical (ratings)				chemical (N ratings)	
no.	species	group[1]	cover[2]	rooting[3]	compaction[4]	structure[3+4]	uptake[5]	transfer[6]
1	carrot	umbel.	-2	1	-4	-3	4	1
2	potato	solan.	-2	1	-2	-1	5	2
3	onion	lil.	-4	1	-2	-1	4	1
4	celeriac	umbel.	-2	1	-4	-3	4	1
5	sugar beet	chen.	-2	1	-4	-3	5	1
6	pea, bean	leg.	-2	2	-1	1	0	2
7	wheat	cer.	-2	3	-1	2	4	1
8	oats	oats	-2	3	-1	2	3	1
9	barley	cer.	-2	3	-1	2	3	2
10	grassclover	leg.	0	3	-1	2	2	2
mean of crop selection			-2.0	1.9	-2.1	-0.2	3.4	1.4

B. Multifunctional Crop Rotation of pilot farm 6.

block	crop	biological		physical (ratings)		chemical (N ratings)		
no.	no.	species	group[1]	cover[2]	structure[3+4]	uptake[5]	transfer[6]	need[7]
I	1/5	carrot/sugar beet	umbel./chen.	-2/-2	-3/-3	4/5	1/1	3/4
II	6	pea, bean	leg.	-2	1	0	2	-1
III	2	potato	solan.	-2	-1	4	2	2
IV	10	grassclover	grass/leg.	0	2	2	2	0
V	3/4	onion/celeriac	lil./umbel.	-4/-2	-1/-3	4/4	1/1	2/2
VI	7	wheat	cer.	-2	2	4	1	3
mean of crop rotation		share species^{-1} ≤ 0.167	share group^{-1} ≤ 0.25	-1.8	-0.2	3.2	1.5	1.6

1) Genetically and phytopathologically related groups, such as cereals, legumes, crucifers and chenopodes, composites, umbellifers, liliaceae. All subsequent blocks of perennial crops are counted as 1 block.
2) No cover in autumn and winter = -4, no cover in autumn or winter = -2, all others = 0 (green manure crops included).
3) Cereals, grasses and lucerne = 3, root, bulb and tuber crops = 1, all others = 2 (green manure crops included).
4) Compaction by mowing in summer = -1 and autumn = -2, lifting in summer = -2 and in autumn = -4.
5) N uptake by crop from soil reserves: legumes = 0. All other crops: 25-50 kg ha-1 = 1, 50-100 kg ha-1 = 2, 100-150 kg ha-1 = 3, 150-200 kg ha-1 = 4, etc.. (N uptake = N product + N crop residues).
6) N transfer is the expected net contribution of N to subsequent crop, based on N residues in the soil after harvest, N mineralisation from crop residues and N losses by leaching and denitrification. In this rating, the effect of green manure crops should be included. N transfer < 50 kg ha-1 = 1, 50-100 kg ha-1 = 2, 100-150 kg ha-1 = 3.
7) N need (block *x*) = N uptake (block *x*) minus N transfer (block *x*-1). N need is net N input to be provided by manure or N fertiliser.

Being the central method, and also the first to be designed, MCR is an appropriate Part 4 of the identity card, after theoretical prototype as Part 3. Table 3 presents the MCR of one of the 10 pilot farms in NL 2 as an example of Part 4 of the identity card of an EAFS prototype. Format A first presents the selection of the most profitable crops eligible for the MCR of the pilot farm in question, with their major characteristics concerning biological, physical and chemical soil fertility. Subsequently, format B presents the MCR which optimally complies with the multifunctional set of demands. This MCR has been designed for a sandy clay area dominated by lifted crops. The shares of single crop species and related crop species are within the demand (≤ 0.167 and ≤ 0.33). However, demands to soil cover (= 0) and soil structure (≥ 0) are not met. N-need fulfils the demand (≤ 1).

4.2 Designing Integrated or Ecological Nutrient Management (I/ENM)

Brief definition:
I/ENM is a method additional to MCR to sustain Quality Production by preserving chemical soil fertility by tuning inputs of nutrients to outputs, to achieve and maintain agronomically desired and ecologically acceptable soil reserves. Inputs of inorganic fertilisers are minimised in INM and are fully replaced in ENM by recycling nutrients from organic residues and by fixing N biologically.

General design of ENM:

		appraisal available soil reserves of P and K		
agronomically undesirable	<	desired range	<	ecologically undesirable
input > output		input = output		input < output
		nutrient management to be followed		

(1) *Estimating the PK need of the farm in next year, to be covered by organic fertilisers :*
- estimating available soil reserves of PK (soil analysis of the fields to be fertilised);
- estimating PK output in next year (yields related to crop plan, PK contents of produce);
- estimating PK need of the farm, based on output and available reserves (see outline above);
- choosing the most appropriate kind of organic fertiliser, based on its PK content and the PK need of the farm;
- estimating the quantity of organic fertiliser (and additional K fertiliser) to be applied (and to be purchased).

(2) *Estimating the N need of the farm in next year:*
- estimating N output (as for PK);
- estimating net N input (= N output) based on organic fertiliser to be applied, aerial deposition and biological N fixation;
- Tuning N input to N output by growing more or less legumes in current or next year and/or adjusting the incorporation or grazing of legumes.

(3) *Applying the organic fertiliser:*
- partitioning organic fertiliser to the most demanding crops, based on a recent analysis of the organic fertiliser and estimating N supply by crop residues;
- aiming technique, dosage and timing at maximum N utilisation by crops.

Detailed formats for the various steps in between are available from NL 2.
INM can be designed analogously, by combining inorganic and organic fertilisers or biological N fixation instead of organic fertiliser and biological N fixation.

4.3 Designing Minimal Soil Cultivation (MSC)

Brief definition:
MSC is a method additional to MCR and I/ENM 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 quantified in EE and in SCI and OMAB too, the latter two being crucial for sustainability of food supply on erosion-susceptible soils.

(1) *Establishing if non-inversion tillage or even zero tillage (direct drilling) is needed:*
  - avoiding erosion by water or wind on slopes or on sandy soils;
  - saving labour and energy and thus enabling a large-scale farm with good prospects of a Net Surplus.

(2) *Establishing if non-inversion tillage or even direct drilling is feasible:*
  - avoiding physical soil fertility being insufficiently restored because of compaction by late harvested crops, especially in the case of root, tuber and bulb crops on heavy soils;
  - avoiding regeneration of crops from residues threatening quality production of subsequent crops;
  - avoiding gradual increase of perennial weeds that require increasing mechanical or chemical control.

(3) *Establishing if minimal inversion tillage on a rotation basis is a good compromise:*
  - establishing which crops could or should be grown with non-inversion tillage or even zero tillage and which crops could or should not.

(4) *Designing MSC complementary to MCR and I/ENM:*
  - considering all parameters involved in your theoretical prototype;
  - considering short-term and long-term effects on individual crops and the whole rotation.

4.4 Designing Infrastructure for Nature and Recreation (INR)

Brief definition:
INR is a method for rendering single farms and entire production areas habitable for wild flora and fauna and enjoyable for people. In addtion to MCR, it may sustain Quality Production by providing habitats and corridors for predators and parasites needed to control harmful organisms not sensitive to MCR (airborne and polyphagous soilborne or semi-soilborne).

(1) *Establishing a minimum area of the farm to be devoted to INR:*
  - establishing the area of linear elements (hedges, ditches, stone walls etc.) and non-linear elements (groups of trees or single trees, ponds, haystacks etc.) present and to be added in order to obtain spatial and temporal continuity as a prerequisite for INR;
  - establishing the area of buffer strips along or around these elements needed for appropriate INR.

(2) *Establishing a plan of INR aimed at long-term objectives for the flora, fauna and landscape:*
  - establishing which target species of flora and fauna should be enhanced;
  - establishing how INR should be to render a farm habitable for the target species and enjoyable for people, if necessary by including more special non-linear landscape elements such as strips of flowers, ponds, observation huts, plantations etc.

4.5 Designing Integrated Crop Protection (ICP) and Environment Exposure-based Pesticide Selection (EEPS)

Brief definition:
ICP is a method additional to MCR, I/ENM, MSC and INR to sustain Quality Production by efficient control of remaining harmful species, with minimal use of well selected pesticides, sparing all other species and meeting EEP norms.
EEPS is a method additional to ICP to reduce the overall exposure of the environment to pesticides in order to prevent short-term and long-term adverse effects on all species throughout the biosphere.

(1) *Establishing which harmful species need additional control:*
- pests (nematodes, insects, slugs, rodents, birds), diseases (viruses, bacteria, fungi) and weeds (annuals, perennials)
- by non-chemical measures (resistant varieties, cultural measures such as adapted sowing date and row spacing, mechanical weed control, genetic and biological control)
- by pesticides (insecticides, fungicides, herbicides);

(2) *Establishing which pesticides are available and effective (in order of preference):*
- as a seed treatment (least environmental exposure)
- as a row application (moderate environmental exposure)
- as a full field application (greatest environmental exposure)

(3) *Establishing which pesticides should be selected:*
- EEP air = active ingredients (kg ha^{-1}) * vapour pressure (Pa at 20-25 °C) of the pesticide application should be $\leq x_1$;
- EEP soil = active ingredients (kg ha^{-1}) * 50% degradation time (days) of the pesticide application should be $\leq x_2$;
- EEP groundwater = EEP soil (kg days ha^{-1}) * mobility of the pesticide application should be $\leq x_3$;
  (mobility = ($K_{om}{}^{-1}$, and K_{om}= partition coefficient of the pesticide over dry matter and water fractions of the soil / organic matter fraction of the soil).
- norms of EEP (x_1, x_2, x_3) should be gradually lowered to minimise overall exposure of the environment to pesticides.

4.6 Designing Farm Structure Optimisation (FSO)

Brief definition:
FSO is a mostly indispensable final method to render an agronomically and ecologically optimised prototype economically optimal too, by determining the minimum amounts of land, labour and capital goods needed to achieve the required Net Surplus (NS) and Energy Efficiency (EE).

(1) *Establishing a model of a farm structure to quantify the required land, labour and capital goods by linear programming, assuming:*
- a family farm with 1 full labour force of the entrepeneur and additional hired labour;
- labour capacity limited by weather conditions;
- methods of the prototype, notably MCR, can be fine-tuned.
- Net Surplus should be sufficient to appropriately pay for invested labour, at least (NS $\geq$ 0).

(2) *Establishing a representative and reliable database on the inputs and outputs of the agronomically and ecologically optimised prototypes, comprising:*
- as inputs: mechanisation (various combinations of machines and equipment, including timetables and labour inputs), fertilisers, pesticides and support energy;
- as outputs: marketed kg ha^{-1} of main products and by-products and expected prices;
- ranges of inputs and outputs, prices included, based on optimistic and pessimistic prospects.

(3) *Running the FSO model in interaction with designers and farmers. This comprises:*
- initial run of the model based on the unchanged prototype, to establish the required amounts of land, labour, machinery and other capital goods;
- if the desired NS cannot be achieved, new runs are made, with major variants of MCR, whilst maintaining the character of the rotation blocks;
- finalising runs are made to minimise the land required or to optimise NS by trade off between labour, machinery and herbicides;
- establishing ranges in the prospects of the prototype,
  based on ranges in inputs and outputs.

(4) *Using FSO to disseminate the prototype:*
- this should be elaborated at a later stage.

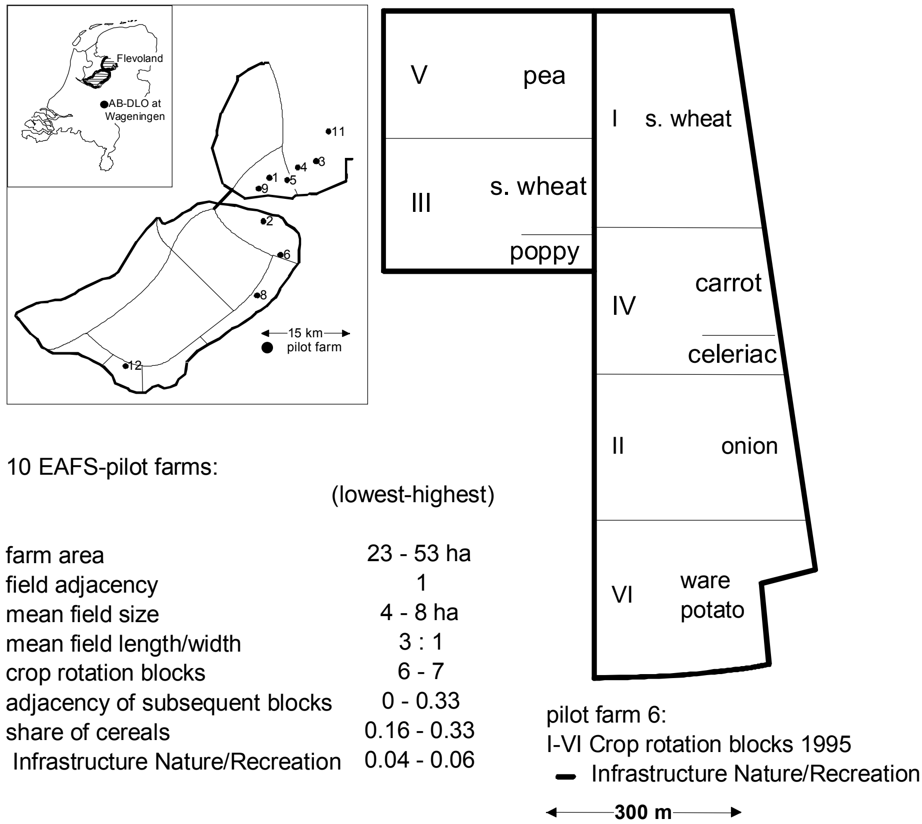

Figure 4 Layout of EAFS pilot farms in Flevoland (NL 2) as an example of Part 5 of a prototype's identity card in the I/EAFS-network.

Outline 5 Criteria for an agro-ecological layout of I/EAFS.

(1) *Field adjacency = 1*
All fields of a farming system should be adjacent to each other, to obtain an agro-ecological whole as a prerequisite for an agro-ecological identity.

(2) *Field size ≥ 1 ha*
To obtain a prototype farming system with sufficient agro-ecological identity, the fields as sub-units have to be of a minimum size.

(3) *Field length/width ≤ 4*
Round or square fields contribute optimally to the agro-ecological identity of a farming system. Therefore, a maximum is to be set to the length/width ratio of fields, to limit the loss in identity.

(4) *Crop rotation blocks ≥ 4 (IAFS) or ≥ 6 (EAFS)*
The shorter the crop rotation, the greater the biotic stress on the crops and the need for external inputs to control that stress. Therefore, crop rotation is required based on 4 (IAFS) or 6 (EAFS) rotation blocks, at least (crop rotation in time).

(5) *Adjacency of subsequent blocks = 0*
Harmful semi-soilborne species are to be prevented from following their host crop by a crop rotation without any adjacency of subsequent blocks to ensure crops are not just moved to an adjacent field from year to year (crop rotation in space).

(6) *Share of cereals ≤ 0.5 (IAFS) or ≤ 0.3 (EAFS)*
The larger the share of cereals in rotation, the greater the biotic stress and the need for external inputs for this crop group, the largest in European arable farming. Therefore, the crop rotation should have a maximum of 0.5 (IAFS) or 0.3 (EAFS) of cereals.

(7) *Infrastructure for Nature and Recreation ≥ 0.05 of I/EAFS area*
To bridge the gap between 2 growing seasons, airborne and semi-soilborne beneficials need an appropriate Infrastructure for Nature and Recreation of at least 5% of the farm area.

5. Layout of prototype to test and improve (step 4)

Step (4) implies testing and improving the prototype until the objectives as quantified in the set of parameters have been achieved. Because it is the most laborious and expensive step, requiring at least a full rotation of the prototype on each field (4-6 years for IAFS-EAFS), it is crucial that all preceding steps have been followed with the greatest accuracy. Therefore, it is useful to take a critical retrospective view before proceeding to step (4):

- does the hierarchy of objectives really cover the shortcomings of conventional arable farming (IAFS) or organic farming (EAFS) in the target region (not too low ratings for 'new' objectives such as nature and too high ratings for 'old' objectives such as basic income/ profit to ensure that one is really innovating and not just slightly ahead of the main group of farmers) (step 1)?
- have the objectives really been transformed in the appropriate set of multi-objective parameters (not too few but certainly not too many parameters!) and has each objective been quantified appropriately (not more but certainly not less ambitious than needed) and has the appropriate set of methods been established (not too many single-objective and too few multi-objective methods) (step 2)?
- should the theoretical prototype be redesigned to link up with possible changes in the first two steps (step 3)?

5.1 Layout

Testing a prototype means laying it out on an experimental farm or on a group of pilot farms and ascertaining if the results achieved correspond with the desired results.
If all the methods of the theoretical prototype have been designed, an initial layout is not very complicated in the case of an experimental farm, providing a possible supervising committee and the farm manager think it acceptable and manageable. However, much more time is generally needed to come to a first layout for pilot farms (Outline 4).

Outline 4 Preparations to come to a first layout of a theoretical prototype on pilot farms.

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(1) *Forming a pilot group*:
   - generating interest by articles in agricultural periodicals or by public meetings;
   - inviting potential pilot farmers to attend study meetings;
   - selecting pilot farmers according to general criteria such as being full-timers on farms of sufficient size, having appropriate production activities, being located in the region, having a particular soil type etc., but also according to agro-ecological criteria such as field adjacency and field size.

(2) *Making a variant of the prototype for each pilot farm, in interaction with the farmer*:
   - variant of Multifunctional Crop Rotation (in time and space);
   - variant of Integrated or Ecological Nutrient Management;
   - variant of Infrastructure for Nature and Recreation;
   - etc.

The basic task of I/EAFS designers, to replace physico-chemical methods by biological methods and techniques, requires an appropriate concept:
I/EAFS is an agro-ecological whole consisting of a 'team' of steadily interacting and rotating crops, plus their accompanying (beneficial or harmful) flora and fauna.
The designer's task can thus be specified: design a rotation with a maximum of positive interactions and a minimum of negative interactions between the crops. These interactions strongly influence physical, chemical and biological fertility of the soil and consequently vitality and quality production of the crops. However, a Multifunctional Crop Rotation (MCR) cannot cope with semi-soilborne and airborne harmful species. Therefore, an agro-ecologically optimum layout of I/EAFS should meet additional criteria (Outline 5). In line with these criteria, we have designed an appropriate agro-ecological layout for any EAFS variant on the 10 pilot farms in NL 2 (Fig. 4).

Table 4 Improving I/EAFS prototypes by carrying out 4 tasks [1]

(1) Establishing parameters with short-falls				(2) Establishing the main cause of any shortfall			(3) Establishing the first criterion not yet fulfilled by any method listed under (2)				(4) Establishing improvements of any method listed under (2), to fulfil the criterion under (3)
para-meters	desired results	achieved results	relative shortfalls	slow response	major methods	minor methods	ready for use	man-age-ability	accept-ability	effect-iveness	

1 Tasks 1 – 4 are explained in Sections 3.1 – 3.4

5.2 Testing and improving in general

By laying out a prototype it can be tested. By testing it will appear to what extent the desired results for any parameter have been achieved. If a shortfall appears between achieved and desired results, the prototype should be improved in the parameter in question, by adjusting the major or minor methods involved according to the theoretical prototype. Such shortfalls between achieved and desired results may arise from one or more of the following 4 causes: the method(s) in question is not ready for use, or not manageable by the farmer, or not acceptable to the farmer or not effective. In positive terms, step 4 (testing and improving) has been finalised if the prototype in general and the methods in particular fulfil these 4 consecutive criteria.
Consequently, improving the prototype implies the following procedure (Outline 6).

Outline 6 Procedure to improve prototypes of I/EAFS

(1) Establishing which parameters have shortfalls between achieved and desired results
(2) Establishing from the theoretical prototype which methods are involved
(3) Establishing which criteria are not yet fulfilled by these methods:
- ready for use;
- manageable by the farmers;
- acceptable to the farmers;
- effective.

(4) Establishing targeted improvements of methods to meet the successive criteria

After improving according to Outline 6, the prototype is laid out and tested for another year. Subsequently, the prototype is improved again, based on the remaining shortfalls, and laid out again, and so on. Consequently, Step 4 is a matter of testing and improving the prototype for several years until all shortfalls between achieved and desired results in the set of parameters have been made good. The final outcome of Step 4 is that the prototype is all-round, i.e. all objectives as quantified in the set of parameters have been achieved by a set of methods that are manageable, acceptable and effective!

To facilitate a coherent and transparent carrying out of the Tasks 1 – 4 in Outline 6, a format is proposed (Table 4). The tasks are elaborated and the format is explained in Sections 5.2.1 – 5.2.4.

5.2.1 Establishing parameters with shortfalls between achieved and desired results

Task 1 entails:
- listing in the first column of the format all parameters from your (updated) theoretical prototype (Part 3 of your prototype's identity card);
- listing in the second column the desired results for any parameter (quantified objectives of your Part 2);
- listing in the third column the result achieved at the latest testing for any parameter;
- calculating and listing in the fourth column, the relative shortfall of the achieved to the desired result for any parameter.

The shortfall between achieved and desired results should be calculated in relative terms to be able to present the state of the art in testing and improving (Step 4) by a simple and clear circle diagram (Part 6 of your prototype's identity card (Chapter 8)). The relative shortfall = 0, at minimum, if the achieved result is equal to or better than the desired result of a parameter.
The relative shortfall = 1, at maximum, if the absolute difference between achieved and desired result, divided by desired result, ≥ 1. In other words, the relative shortfall = 1 if either achieved result ≥ 2 *x* desired result, when the desired result concerns a maximum norm (for example PNL ≤ 70 kg/ha); or if achieved result = 0, when the desired result concerns a minimum norm (for example PSD ≥ 50 species).
So the range of the relative shortfall is 0 ≤ relative shortfall ≤ 1 (assuming desired result > 0).

5.2.2 Establishing the main cause of any shortfall

Task 2 entails establishing if the main cause for any shortfall is:
- either the major method indicated in the theoretical prototype (which is likely in initial years of testing);
- or a minor method indicated in the theoretical prototype (which may occur in later years of testing);
- or a slow response of the parameter in question (which may occur in initial years of testing and is likely in later years of testing in inert parameters such as PAR, KAR and PSD).

For any shortfall, the main cause should be specified in the format by a mark in the fifth column, for slow response, or by an acronym of a method in the sixth or seventh column, for major or minor method.

5.2.3 Establishing the first criterion not yet fulfilled by a farming method

Task 3 entails establishing for any major or minor method identified as the main cause of a shortfall between achieved and desired results which is the first criterion that has not been fulfilled:
- either not ready for use;
- or not manageable by the farmers;
- or not acceptable for the farmers;
- or not effective.

For any method as a main cause of a shortfall, the first criterion not yet fulfilled should be specified in the format by a mark in one of the four columns, as indicated.
Task 3 is rather complicated. Therefore it is elaborated in Subsections 5.2.3.1 - 5.2.3.4.

5.2.3.1 When is a farming method not ready for use?

One main reason why a method may not appear ready for use is the unexpected occurrence of factors that interfere to such an extent that the method needs to be revised to take these factors and their effects into account. As a result, methods will gradually evolve from those that are simple and subjective to those that are comprehensive and objective.
Examples:
- management factors, such as choice of crops and varieties, machines, fertilisers, pesticides;
- agro-ecological factors, such as pests, diseases, weeds, and physical and chemical soil status.

5.2.3.2 When is a farming method not manageable?

Even if ready for use, a method may still not appear to be manageable to the farmers.
Examples:
- planning or operations too complicated;
- too laborious to fit into the labour film;
- too specific to be carried out with the usual machinery.

5.2.3.3 When is a farming method not acceptable?

Even if ready for use and manageable, a method may still not appear to be acceptable to the farmers.
Examples:
- costs too high and/ or too few benefits, at least in the short term;
- too little confidence in utility and/or effectiveness.

5.2.3.4 When is a method not effective?

Even if ready for use, manageable and acceptable, a method may still not appear to be effective for achieving the desired result for a certain parameter. This conclusion may be premature, as in case of parameters with a slow response. Apart from this, the main reason why a method may, indeed, not be effective is that the theoretical prototype is too simple or distorted for the method and parameter in question.

Examples:
- the method needs the support of another method;
- the method has only a minor influence, so another method should be established as the major method.

Because most parameters are under the control of more than one method, and because many parameters have a slow response, effectiveness is the most difficult and also the most time-consuming of all the 4 criteria to establish. Generally, testing and improving a prototype will take at least 4 years for I/EAFS and 6 years for EAFS (corresponding with one run of the prototype as a complete crop rotation on each field) before reliable responses of abiotic parameters (soil, groundwater) and biotic parameters (crops, flora and fauna) are obtained. The effectiveness of the methods and the overall prototype can only be established on the basis of these reliable responses of the multi-objective parameters.

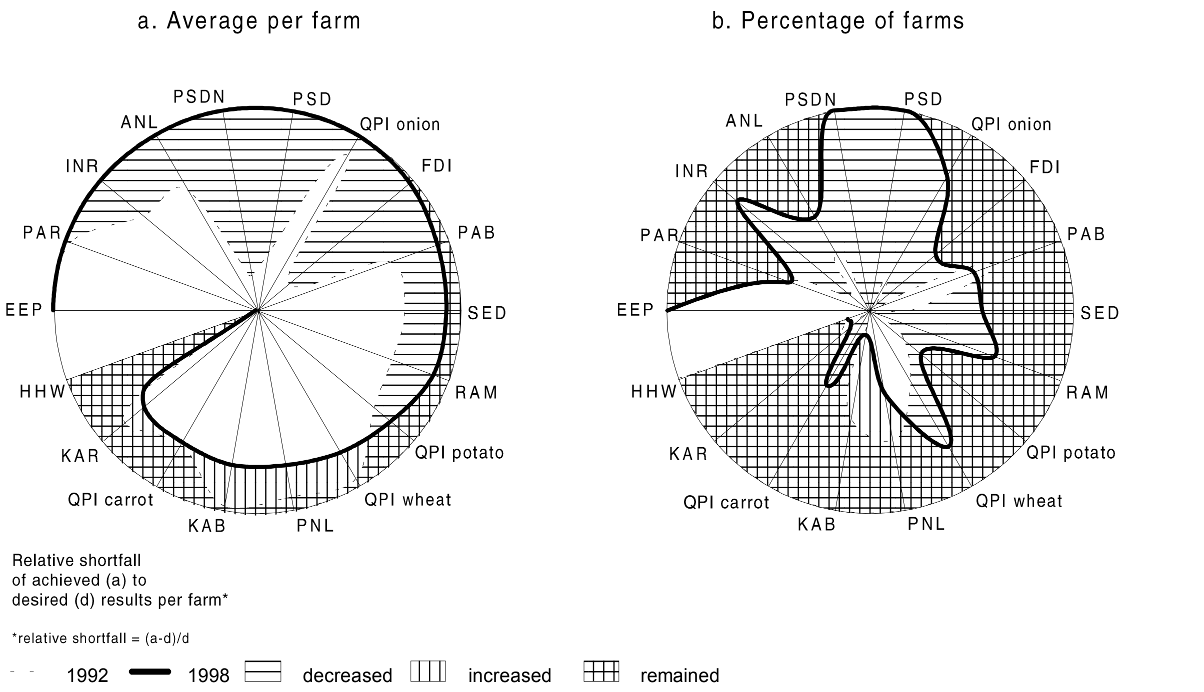
Theoretically the number of years needed for Step 4 would be the sum of the years needed to fulfil the first 3 criteria and the years, needed to fulfil the 4th criterion. In practice, however, biotic and abiotic parameters begin to respond from the very first year the prototype is laid out, provided the prototype is well designed and does not change dramatically in subsequent years. As a result, the adaptation of these parameters mostly occurs simultaneously with testing and improving by farmers and researchers, so Step 4 could be completed in a minimum of 4-6 years. This does not imply, however, that all parameters will have achieved a steady state by then. For example, it may take decades before possible excessive reserves of soil P diminish or depleted organic matter reserves are replenished to desired ranges. Nevertheless, if the shortfalls between achieved and desired results incontrovertably decrease from year to year, you may speak about reliable responses proving the effectiveness of the prototype. As a result, the final step 5 of dissemination can be envisaged with confidence.

5.2.4 Establishing improvements of methods to fulfil the consecutive criteria

Task 4 of the improving part of Step 4 entails establishing for any method those improvements that are needed for it to fulfil the first criterion not yet fulfilled in the latest testing year. Depending on the first criterion not yet fulfilled, one of the Subsections 5.2.3.1 – 5.2.3.4 should be studied to establish targeted improvements. These improvements should be specified in short lines or keywords in the last column of the format.

The state of the art in step 4 for EAFS in NL 2 clearly shows, which of the parameters still have to be improved before the prototype is 'all round' (Fig. 5.1). It also proves that our prototyping is effective, considering the clear progress from 1992 to 1997. In 1992, the EAFS prototype was laidout and tested for the first time. Since then, the EAFS prototype has been through another 5 cycles of testing and improving. As a result, average shortfalls per farm between achieved and desired results have been made good in INRI, ANL, PSDN, PSD, QPI of onion, and almost in PAB, SED, RAM (Fig.5.1, left-hand circle). However, average shortfalls in QPI of potato and carrot and HHW have largely remained and shortfalls have even increased in QPI of wheat, PNL, KAB and KAR.

In most parameters there is a large variation in performance per farm, which is hidden by the average presented in the left-hand circle. It can be seen, however, in the right-hand circle, which presents shortfalls if in any parameter less than 9 out of 10 farms have achieved the desired result. The left-hand circle presents the state of the art for those interested in the average performance of the prototype at the regional level, accepting underperforming farms are compensated by overperforming farms. The right-hand circle presents the state of the art for those interested in the performance of the prototype at the farm level, considering its variation in manageability, acceptability and effectiveness in the context of the region. How the state of the art can be improved, both for the region and for single farms, will be highlighted in subsequent chapters for each of the 4 methods, as established in the theoretical prototype.



Parameters (in ascending order of relative shortfall)	Desired results per farm	% farms	Achieved results per farm	% farms	Main causes of shortfall in 1998	Methods first of all to be improved in: Read-iness for use	Accept-ability	Manage-ability	Effect-iveness
EEP = Exposure Environment to Pesticides	0 (air, water, soil)	90	0	100					
PAR = P Available Reserves	20 < Pw-count < 30	90	29	40	slow response				
INR = Infrastructure for Nature and Recreation	> 0.05	90	0.06	80					
ANL = Actual N Leaching	< 11.2 NO3-N mg/l	90	11.1	50					
PSDN= Plant Species Distribution	> 25 species/INR-section (100 m)	90	26	100					
PSD = Plant Species Diversity	> 50 species/INR	90	57	90					
QPI = Quality Production Index (onion)	> 0.9	90	0.9	70					
FDI = Flower Density Index (apr.-sept.)	> 10 flowers/m INR/month	90	10	40	slow response				
PAB = P Annual Balance	0.8 < PAB < 1.2	90	1.25	50	ENM			ENM	
SED = Side Element Diversity	7	90	7	50	INR		INR		
RAM = Relative Area according to MVM	0.95	90	0.9	60					
QPI = Quality Production Index (potato)	> 0.9	90	0.8	30	MCR	MCR*1			
QPI = Quality Production Index (wheat)	> 0.9	90	0.7	70					
PNL = Potential N Leaching	< 70 kg/ha (0-100 cm)	90	85	40	ENM	ENM			
KAB = K Annual Balance	0.6 < KAB < 1.0	90	1.2	10	ENM			ENM	
QPI = Quality Production Index (carrot)	> 0.9	90	0.7	40	MCR	MCR*1			
KAR = K Available Reserves	14 < K-count < 20	90	25	10	ENM			ENM	
HHW = Hours Hand Weeding	< 500 h/farm (own labour capacity)	90	137	10	MCR	MCR*2			

*1 Biological control of non MCR sensitive diseases
*2 Various measures against non MCR sensitive weeds

Figure 5.1 State of the art in prototyping EAFS in Flevoland (NL 2), 1992 - 1997
(Part 6 of the prototype's identity card). The prototype is all-round if achieved results match the desired results.

6. Testing and improving a Multifunctional Crop Rotation

In all theoretical prototypes of the I/EAFS-Network, Multifunctional Crop Rotation (MCR) plays a central role as a major method to achieve desired results in the Quality Production Indices (QPI crop^{-1}), the major parameters of economic and labour efficiency (NS and HHW) and the major parameters for soil fertility on the long term (SCI and OMAB) . In this chapter, testing and improving MCR for QPI crop^{-1} and HHW will be highlighted, based on the results in pilot project NL 2 (NS will be discussed in Chapter 10). In addition, testing and improving MCR for SCI and OMAB will be highlighted, based on the results in various European projects on experimental farms.

6.1 for QPI crop^{-1}

Brief definition:
QPI is a comprehensive parameter of quality and quantity of production of single crops = Quality Index * Production Index = (achieved price kg $^{-1}$/top-quality price kg^{-1}) * (marketed kg ha^{-1}/field produced kg ha^{-1}).

Range of QPI:

QPI = 1 at maximum, if a crop product has been marketed for a top quality price (QI = 1) without any losses before, during or after harvest (PI = 1). This may only occur if the crop is vital, with optimal growth and minimal stress physically (soil structure, water and air supply), chemically (nutrients supply) and biologically (weeds, pests and diseases).

QPI = 0 at minimum, if a crop product has completely gone to waste before or after the harvest because of lodging, weeds, pests or disease, regardless of conditions of weather, soil or preservation (PI = 0), or whether the product has not been marketed because of unacceptable low quality or there is a surplus on the market (QI = 0).

(a) Testing with QPIs of single crops

(a.1) Quantifying losses in quality (prices kg $^{-1}$):

- dividing achieved price by the top-quality price achievable at the moment of marketing a product (Quality Index);
- assigning possible price losses to assessed causes (any cause ≥ 5% of top-quality price).

(a.2) Quantifying losses in production (kg ha^{-1}):

- assessing losses before (ripening stage), during or after harvest;
- calculating on-field yield (kg ha^{-1}) = pre-harvest losses + post-harvest losses + on-market yield (kg ha^{-1});
- dividing on-market yield (kg ha^{-1}) by on-field yield kg ha^{-1} (Production Index).
- assigning possible production losses to assessed or probable causes (any cause ≥ 5% of on-field yield);

(a.3) Quantifying QPIs and QPI corrected yields:

- calculating crop-wise QPI = Quality Index * Production Index
- calculating crop-wise QPI corrected yield = marketable yield at top-quality price = on-field yield * QPI.

***(b) Improving with QPIs of single crops*:**

- assessing crop-wise a desired QI, PI and QPI estimating the chances of overcoming the causes of current losses;
- establishing which crops have shortfalls between achieved and desired results in QPI;
- assessing from the theoretical prototype which methods are involved (MCR, ICP, I/ENM etc.) with the major causes of losses;
- establishing which criteria have not yet been fulfilled by these methods (ready for use, manageable by the farmers, acceptable to the farmers, effective);
- establishing targeted improvements of the methods to meet the successive criteria.

Figure 6.1 presents the testing results for the QPIs of the main crops of NL 2. At current quality demands, the QPIs of 6 out of 9 major crops, averaged over the 10 pilot farms, fall short of the desired (innovation norm) QPI (Figure 6.1a). Besides, in most crops the QPI- corrected yields do not tend to increase through the years (Figure 6.1b-c), which would be desirable because the 30-50%

lower yields compared to conventional farms bring considerably higher prices for consumers (less accessible food supply!). However, there are large differences between farms, as is illustrated in carrot, the crop performing least (Figure 6.2). In 1995 and 1996 some farms lost a large part of the yield, and even their entire yield because of infestation by *Alternaria caricina*, a seed-borne and airborne fungus insensitive to MCR. Consequently, this fungus is the main cause of the insufficient average OPI in carrot (Figure 6.2b). Similarly, the seed- and soil-borne, polyphagous fungus *Rhizoctonia solani* is a major cause of insufficient QPI in seed and ware potato. In ware potato, the airborne fungus *Phytophtora infestans* is the major cause of the low on-field yield, due to premature defoliation of the crop.

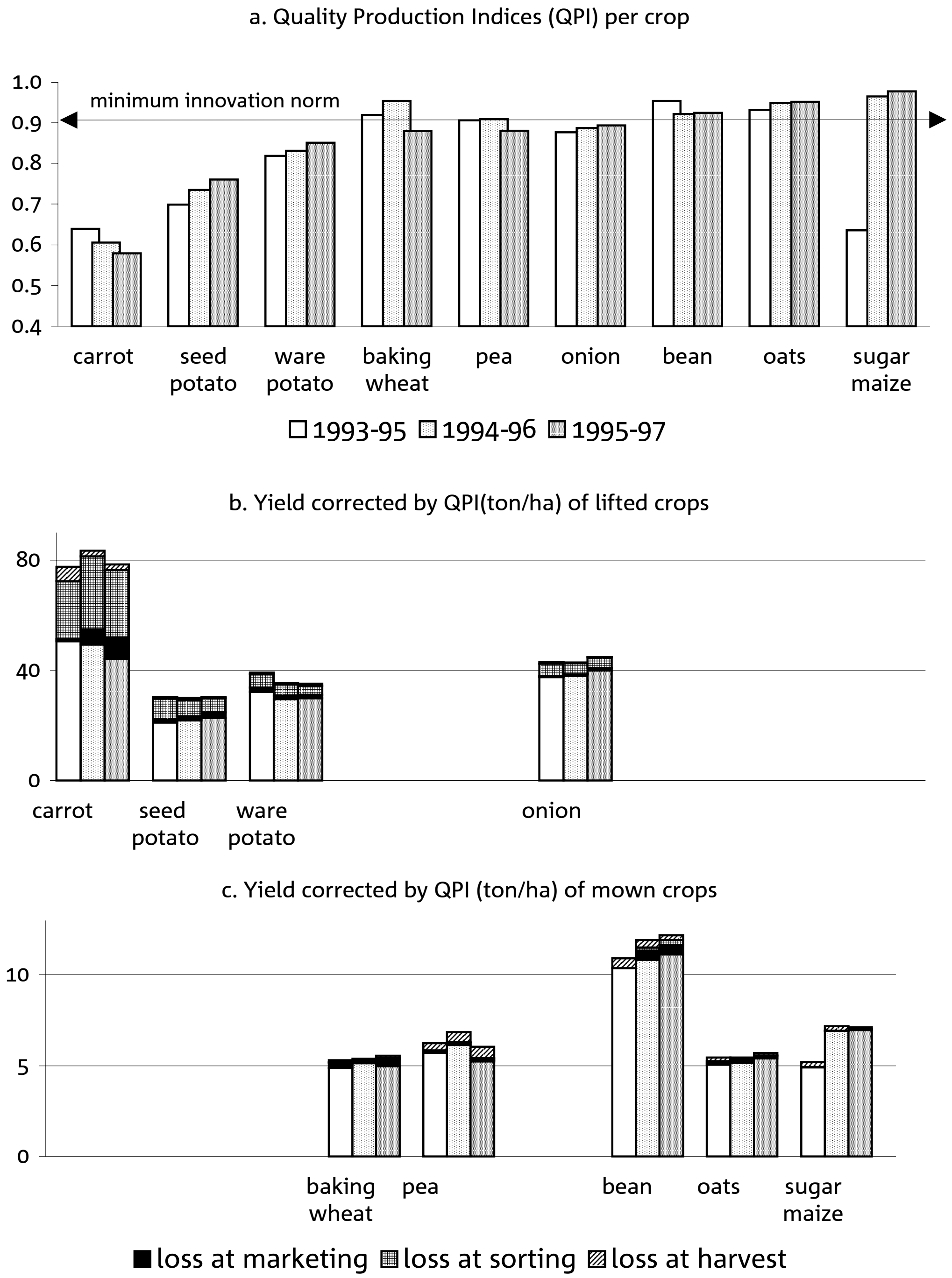


Figure 6.1 Progress in quality production on the 10 pilot farms based on progressive means of QPI and QPI- corrected yield per crop (1993 - 1997).

How can QPI of various crops be improved? From the foregoing, it must be concluded that for more effective quality production MCR needs support through better cropping systems and better management. In carrot, *Alternaria caricina* could be controlled by coating the seed and possibly spraying the crop with antagonists. In addition, farmers could improve their soil management to reduce rejection of carrots malformed by soil degradation, the second cause of the low QPI of carrot (Figure 6.2c). In potato, *Rhizoctonia solani* is insufficiently controlled by the use of clean seed tubers. This fungus is polyphagous and can as sclerotia survive longer than the 6 years of the rotation. To control the sclerotia, the harvest residues of the crop could be sprayed with the antagonist *Verticillium biguttatum*. The most noxious fungus, *Phytophtora infestans,* could be controlled by better management, thus improving the vitality of the crop by more care for soil structure and N dosage and by intensively monitoring the crop to remove the first plants infested in order to slow down the spread of the disease. In addition, natural fungicides could help suppress the fungus; such as etheric oils from citrus pits. Nevertheless, more resistant varieties should be bred too, since current varieties are highly vulnerable.

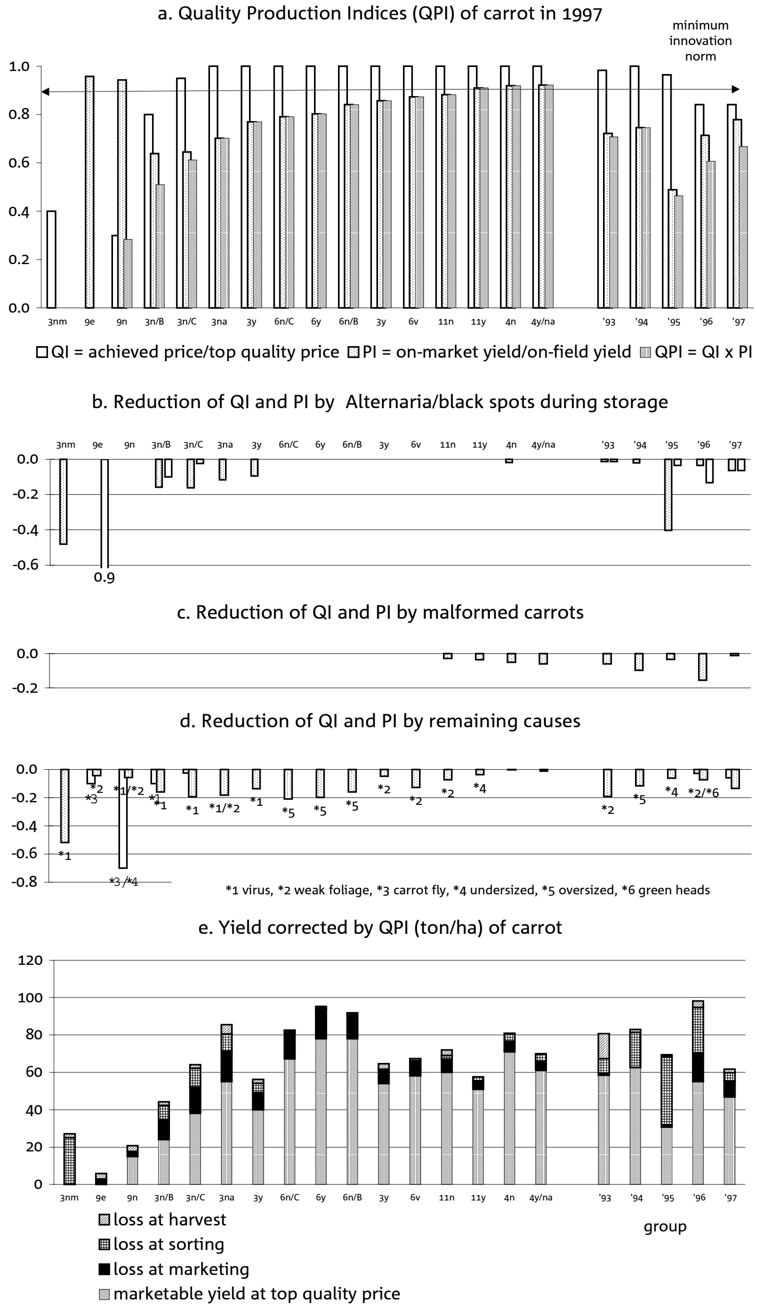


Figure 6.2 Quality production of winter carrot per farm in 1996 based on QPI, causes of losses and QPI-corrected yield (varieties: be=bergen, e=ebro, ka=kamaran, ne=nerac, val=valor, y=yukon).

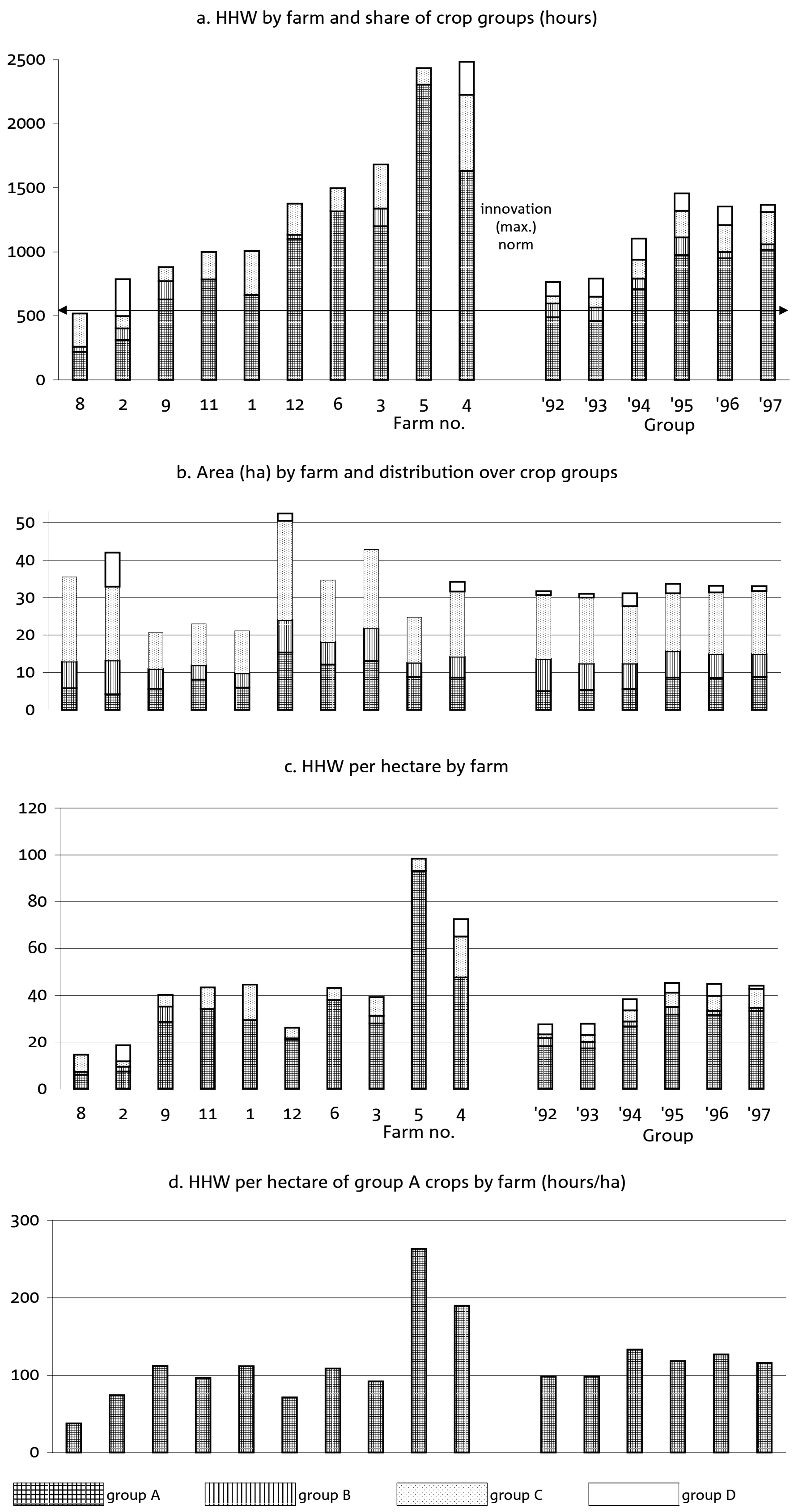


Figure 6.4 Hours of Hand Weeding (HHW) in weed control at the 10 pilot farms in 1997 including averages 1992-1997 (more details on crop groups A-D in Figure 6.5).

6.2 for Hours of Hand Weeding (HHW)

The strict alternation of mown and lifted crops in MCR has also been designed to combine optimally competition of crops (for light, nutrients and water) and mechanical weed control (Figure 6.3). Thus MCR can reduce the large amount of manual labour needed from within and outside the farm, which is typically a major impedement for the dissemination of EAFS. Therefore the effectiveness of MCR is also tested by the need for weeding by hand, as expressed in Hours of Hand Weeding (HHW).

In 1997, HHW varied from 500-2400 per farm (Figure 6.4a). So to date, only 1 of the 10 pilot farms has achieved the desired result HHW < 500, i.e. no dependency on manual labour from outside the farm. The large variation in HHW per farm remains, after correction for the variation in farm size (Figure 6.4b-c). HHW requires 1 – 4.8 manual labourers at least (500 HHW per weeder during the weeding period of 4 months). The need for weeding by hand may increase up to double these amounts because of wet weather and soil. It means that farmers who also weed themselves need at least 0 - 3.8 manual weeders from outside, and at a maximum 1 – 7.6 from outside. Most of HHW (75% on average) is accounted for by scarcely competitive crops (onion, carrot, beet and chicory).

HHW per ha in these crops (Group A) varies strongly between farms (Figure 6.4d) and seems to be the main cause of variation in HHW per farm. This variation can be caused by variation in weed pressure and/or the persistence and capability of the farmer and his weeders. Weed pressure depends on soil type and soil history. But if MCR is effective, weed pressure should, on average, be decreasing and so be reflected in decreasing HHW. Figure 6.4 shows, to the contrary, that from 1992 to 1997 HHW per farm increased, because of increase in the area of Crop Group A. However, HHW per ha of Crop Group A has hardly changed (Figure 6.4d). As a result, the organisation and implementation of hand weeding remains a serious problem.

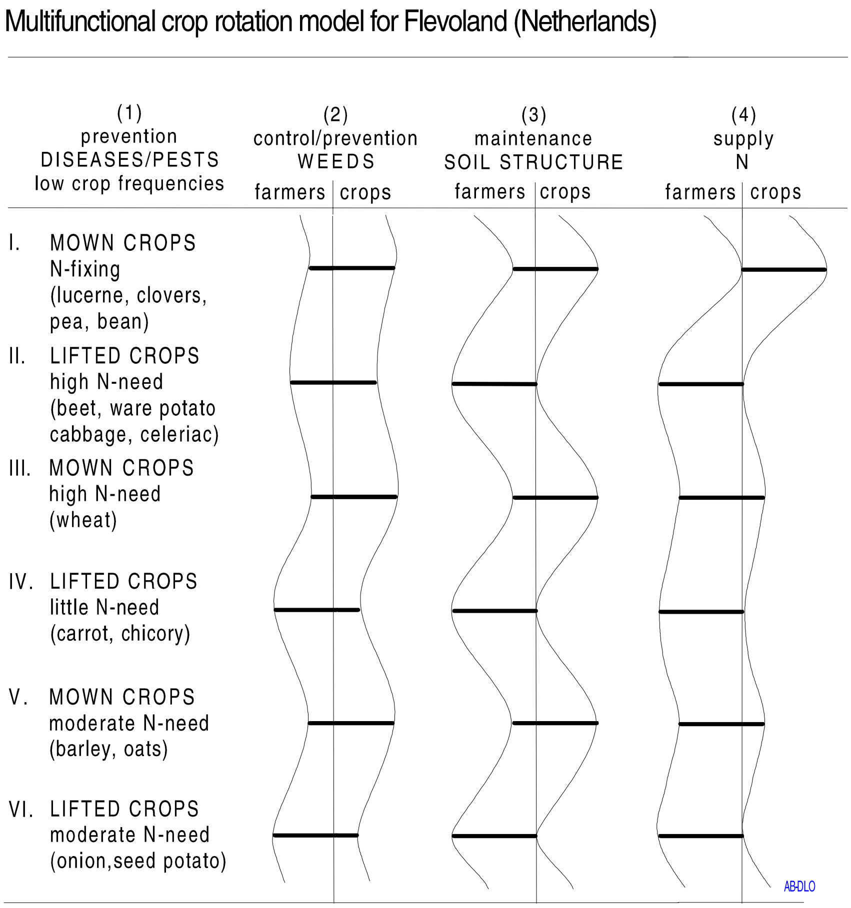


Figure 6.3 Multifunctional Crop Rotation for the sandy clay soils in NL2, showing alternation of mown and lifted crops may simultaneously fulfil 4 major functions to maintain soil fertility.

How can high HHW be reduced? From the foregoing it must be concluded that to be more effective MCR needs support through better cropping systems and better management, similary to the case of quality production. A radical improvement would be to replace crops with a weak combination of competitiveness and mechanical weed control by crops with a strong combination. From Figure 6.5 it appears that the following replacements would help to reduce HHW considerably:

- bean (for canning) instead of pea (for canning);
- maize instead of wheat;
- white cabbage (or celeriac) instead of potato.

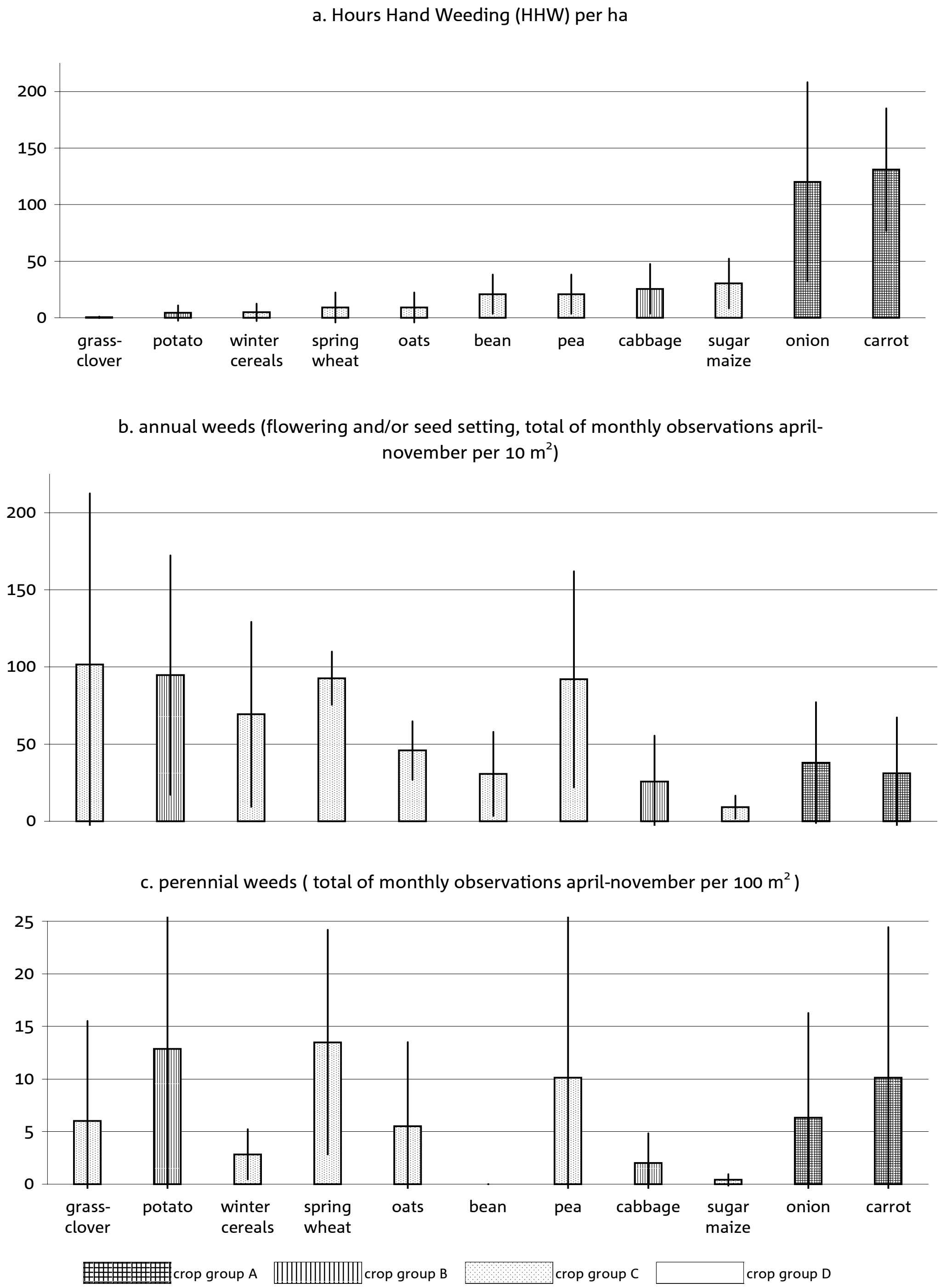


Figure 6.5 Hours of Hand Weeding (HHW) and multiplication of annual and perennial weeds per crop (standard deviation based on 4 farms, at least) in 1995.

Less radical steps would be to improve cropping systems and management by stale seed beds, greater distance between rows to enable better mechanical weed control, etc. The management of Farm 8 is a good example. On this farm weeds have been monitored intensively for more than 10 years to minimise weed pressure by picking any weed before seed setting and thus exhausting the seed bank. The fact that this farm is the only one that has achieved the desired result in HHW to date proves such a management strategy, requiring large labour inputs in initial years, can be successful in the long term (Figure 6.4). Finally, biological control of the dominant weed species *Stellaria media* (chick weed) will be studied. From Figure 6.6 it appears that this weed is by far the most successful in achieving the stage of seed production, because it can germinate at almost any time of the year and produce seeds after a few weeks. As a result its control requires almost half of the average HHW of the 10 pilot farms (Figure 6.7).

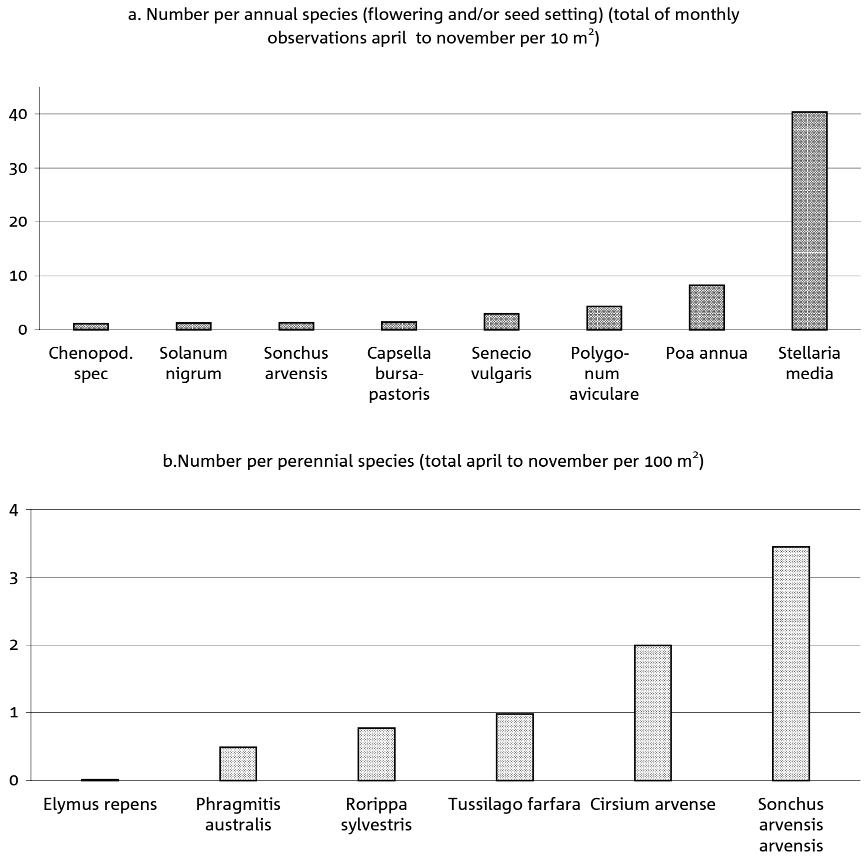


Figure 6.6 Most frequent annual and perennial weed species in 1995 (average of the 10 pilot farms).

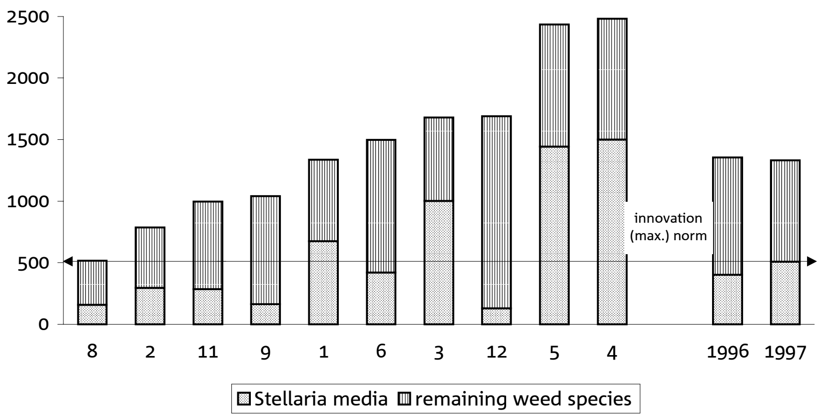


Figure 6.7 Hours of Hand Weeding (HHW) per pilot farm in 1997 spent on *Stellaria media* and remaining weed species.

6.3 for Organic Matter Annual Balance (OMAB)

Brief definition:
OMAB is annual input/output of effective organic matter. Inputs are crop residues (green manures included) and organic waste, such as manure (kg ha^{-1}) * humification coefficients.
Output is estimated loss of soil organic matter by respiration and possibly erosion.

Desired ranges of OMAB:
By analogy with PK Balances and PK Available Reserves, a desired range of OMAB can only be established after a desired range of organic matter content (or, by analogy, Organic Matter Available Reserves = OMAR) has been established.

(a) Testing with OMAB:
- establishing desired ranges of OMAR for your I/EAFS, by system (or farm) or by field;
- establishing mean actual OMAR of the fields of each system;
- establishing desired ranges of OMAB (>1 or=1 if actual OMAR < or ≥ desired range).

(b) Improving with OMAB:
- establishing which fields/crops achieve an OMAB falling short of the desired range;
- establishing from the theoretical prototype which methods are involved (mostly I/ENM, MSC and MCR);
- establishing which criteria have not yet been fulfilled by these methods (ready for use, manageable by the farmers, acceptable to the farmers, effective);
- establishing targeted improvements of the methods to meet above criteria.

Figure 6.8 presents the testing results with OMAB of I 1, the only I/EAFS project having data available from at least 3 consecutive years (1993 - 1995). For both prototypes, OMAB = 1 has been established as the desired result. Apparently, the actual OMAR is in the desired range. In both systems the desired OMAB was achieved in 1994 and 1995.

Besides I 1, DK 1 and S 1 have OMAB in their theoretical prototypes. The fact that only one of 3 teams is able to present data may indicate falling interest in OMAB. This would be a mistake in the case of heavy soils vulnerable for compaction and water logging, or light soils vulnerable for erosion and drought. As well as for physical soil fertility (balance between solid matter, air and water), OMAB accounts for chemical soil fertility (N mineralisation) and biological soil fertility (feed for soil life, buffering against pests and diseases, and restoring soil structure). Though less directly and specifically, SCI also covers these objectives. Therefore each team should consider the value OMAB may add to SCI in their regional circumstances.

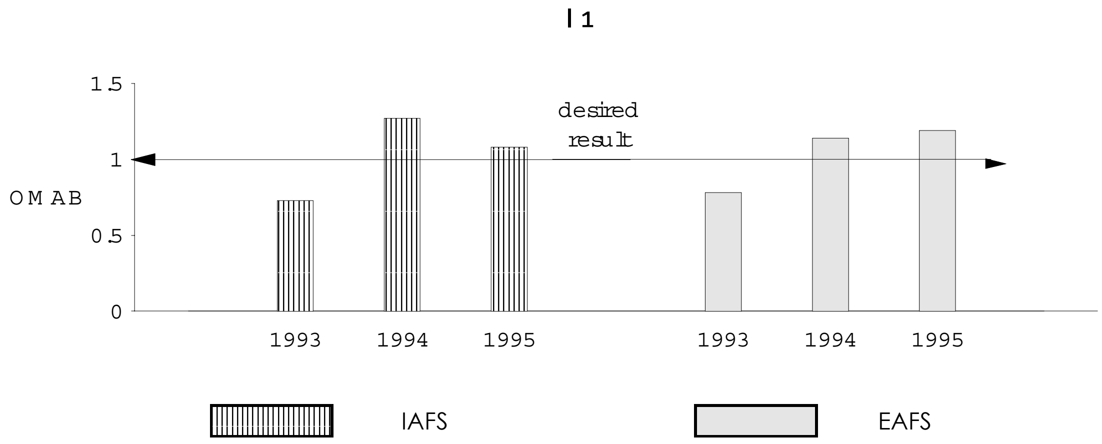


Figure 6.8 Testing and improving Organic Matter Annual Balances (OMAB) of I/EAFS prototypes on Montepaldi (I 1), 1993 – 1995

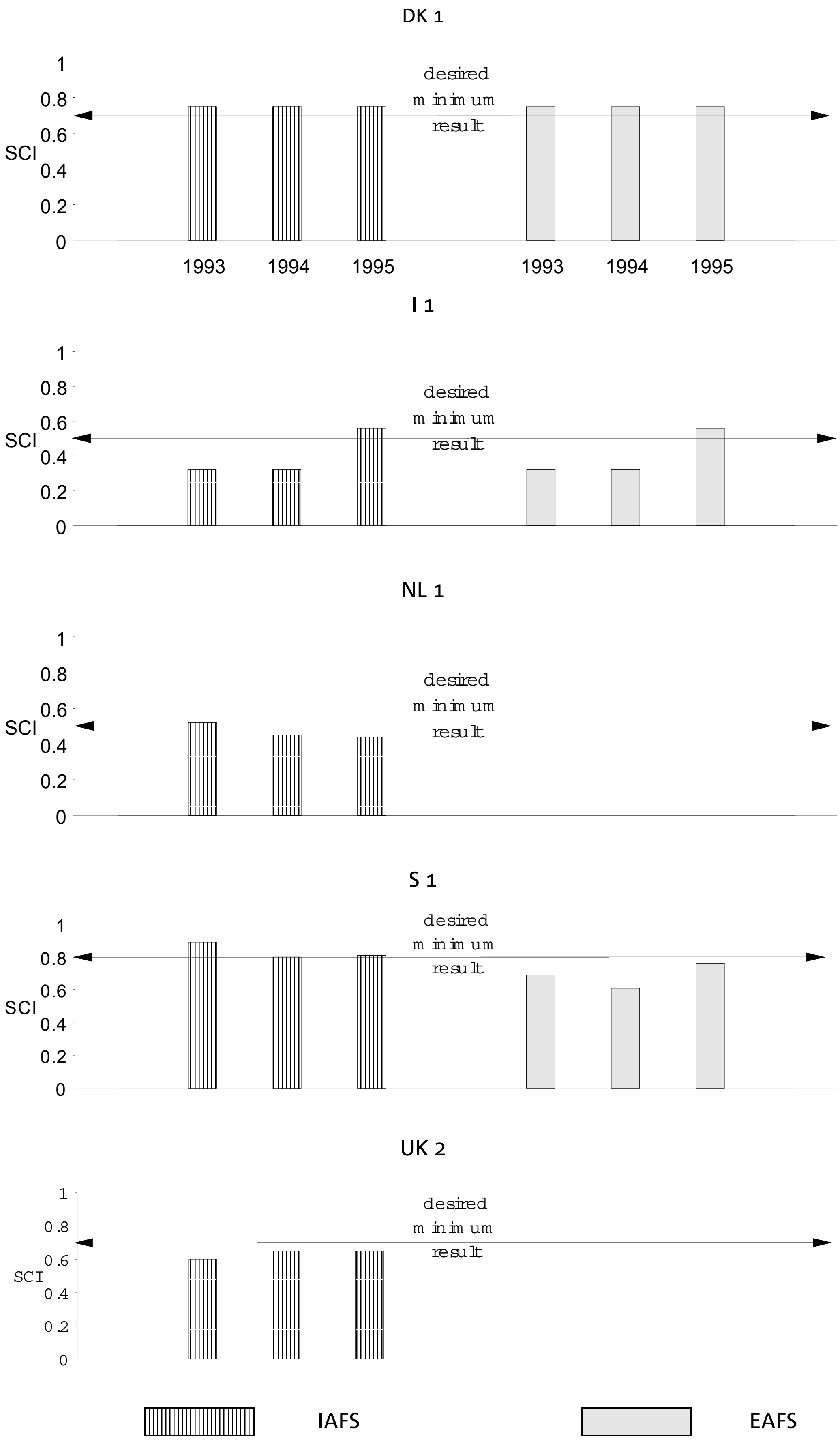


Figure 6.9 Testing and improving Soil Cover Indices (SCI, for the whole year) of I/EAFS prototypes on 5 experimental farms, 1993 – 1995

6.4 for Soil Cover Index (SCI)

Brief definition:
SCI expresses the extent to which the soil of a field or a farm is covered by crops or crop residues, during a crucial period or throughout the year. It is assessed at monthly intervals:

$$\text{SCI month}^{-1} = \frac{\text{SCI (at start)} + \text{SCI (at end)}}{2} \qquad \text{SCI period}^{-1} = \frac{\text{sum SCIs month}^{-1}}{\text{number of months}}$$

Range of SCI:

SCI = 1 at maximum, if soil is fully covered by a crop or crop residues.
SCI = 0 at minimum, if soil is entirely fallow throughout the crucial period of the year.

(a) *Establishing desired ranges of SCI month^{-1} or period^{-1}:*
- in view of the need for soil cover on the entire farm, or on individual, steeply sloping or sandy fields, to control erosion and nutrient losses by runoff or leaching;
- in view of the need for soil cover on the entire farm, or on individual fields, to benefit fauna and landscape.

(b) *Testing with SCI month^{-1} or period^{-1}:*
- establishing actual SCI month^{-1}, field by field ($0 \leq \text{SCI} \leq 1$);
- calculating SCI period^{-1} by field or by farm. The latter is a weighted average of all fields (including Ecological Infrastucture and land permanently set aside) on the farm, taking into account the area of the fields (ha).

(c) *Improving with SCI month*$^{-1}$ or period^{-1}:
- establishing whether there is a shortfall between achieved and desired SCI;
- establishing from the theoretical prototype which farming methods are involved (mostly MCR and MSC);
- establishing which criteria have not yet been fulfilled by these methods (ready for use, manageable by farmers, acceptable to farmers, effective);
- establishing targeted improvements of the methods to meet the above criteria.

Figure 6.9 presents the testing results with SCI of the 5 I/EAFS projects on experimental farms that have data available from at least 3 consecutive years (1993 - 1995). The 5 teams (DK 1, I 1, NL 1, S 1 and UK 2) have established desired results for mean SCI year^{-1} that vary between SCI > 0.5 and SCI > 0.8. Probably these desired results are based on a best guess. However, to ascertain the underlying methods (MCR, MSC) are both effective in control of erosion and nutrient runoff, and in providing cover for fauna and landscape, the desired result in SCI should correspond with the desired result for the most demanding underlying parameter!

In the follow-up, it would be worthwhile to quantify the desired result in SCI for the separate underlying parameters and, subsequently, to assess the overall desired result in SCI. This would help targeted improvements based on shortfalls between achieved and desired results to be made.

From Figure 6.9 it can be concluded that all 5 teams have achieved the desired result, more or less. But the question is, whether all desired results of underlying parameters are now covered, so that MCR and MSC are generally effective in terms of erosion control, control of nutrient runoff and leaching, provision of food and shelter for fauna and provision of an attractive landscape for recreationists.

7. Testing and improving Ecological Nutrient Management

In all theoretical prototypes of the I/EAFS-Network, Integrated or Ecological Nutrient Management (I/ENM) is the major method to achieve desired results in various multi-objective parameters for chemical soil fertility and environment. ENM has been designed to tune input of nutrients to their output in such a way that soil reserves fit in a range which is agronomically desired and ecologically acceptable. ENM is much more complicated than INM, i.e. the nutrient management for IAFS, in which single nutrients can be applied (inorganic fertilizers). In ENM nutrients are applied in combinations (organic fertilizers) that rarely meet the need of single crops. Consequently, it may easily lead to shortage of some nutrients and excess of others, to the detriment of production and the environment. To prevent this, we have designed an ENM comprising 5 steps (details in Outline 7, end of Chapter 7):

1) Estimating P and K need per field, based on the average output by harvest products and on remaining soil reserves (assuming crops do not need a specific dosage of P and K);
2) Estimating the N need per crop based on the foreseen uptake and remaining soil reserves at harvest (assuming crops do need a specific dosage of N);
3) Estimating the part of the N need to be covered by manure (i.e. estimating the N input by crop residues, green manure and organic matter);
4) Estimating the need of manure or a combination of manures, covering both P, K and N needs;
5) Partitioning the manure to fields based on the N need per crop whilst ensuring :
   - P need per field is also sufficiently covered by planning at Step 1 the proportion of legumes in the cropping plan according to P reserves in such a way that at high P reserves there is little need of manure for both P and N, and that at low P reserves there is a great need of manure for both P and N;
   - K need per field is also covered by supplying K as a single fertilizer (as natural salt or vinasse), if needed.

In this chapter, testing and improving ENM with P/KAB, P/KAR and P/ANL will be highlighted, based on the results in pilot project NL 2.

7.1 for P/K Available Reserves (P/KAR) and P/K Annual Balances (P/KAB)

Brief definitions and ranges
Phosphorus and Kalium Available Reserves (P/KAR) is the agronomically desired and environmentally acceptable range of PK soil reserves (x_p < PAR< y_p, x_k < KAR < y_k).
Phosphorus and Kalium Annual Balances (P/KAB) is PK inputs / product PK outputs (over all fields). The balances are the help parameters to manage slowly responding reserves. Consequently, desired P/KAB > 1, = 1 or < 1, if P/KAR is below, in or beyond the desired range.

(a) *Testing with P/KAR and P/KAB:*
- establishing desired ranges of PAR and KAR for your IAFS or EAFS;
- establishing mean actual PAR and KAR of fields to be fertilised this year;
- establishing desired ranges of PAB and KAB for your IAFS or EAFS
  (PAB > 1, = 1 or < 1, if actual PAR <, = or > desired PAR) (similarly for KAB);
- establishing actual PAB and KAB after fertilisation and harvest of crops.

(b) *Improving with P/KAR and P/KAB:*
- establishing parameters for which there is a shortfall between achieved and desired testing results;
- establishing from the theoretical prototype which methods are involved
  (mostly INM or ENM);
- establishing which criteria have not yet been fulfilled by these methods
  (ready for use, manageable by the farmers, acceptable to the farmers, effective);
- establishing targeted improvements of the methods to meet these consecutive criteria.

The great challenge is, of course, to get and keep P/KAR in their desired ranges by tuning PK inputs from organic or inorganic fertilisers to PK outputs in harvest products, i.e. to manage P/KAR by a well established P/KAB. The performances of the 10 pilot farms of NL 2 will now be briefly discussed in the light of this challenge.

7.1.1 P and K Annual Balances (P/KAB)

P and K Annual Balances (P/KAB) are the parameters to test acceptability and manageability of ENM. The pilot farms differ in innovation norms (desired results) for P/KAB (Figure 7.1a). Farms 12 and 9 have high PAB as a norm, since their P Available Reserves (PAR) are below the desired range. Farms 4, 5 and 1 have low PAB as a norm, since their PARs exceed the desired range. However, Farms 5 and 1 exceed the norm amply as they do not restrict manure application, because they want to cover their N need. ENM is difficult to manage for these farms, because the fields with excessive PAR cannot be cropped with legumes to cover the N need after abandoning manure. The complication is that these very fields are infested by polyphagous eelworms which would be favoured by legumes. The alternative is application of liquid manure in spring, with a high fraction of available N, though Farms 5 and 1 do not accept liquid manure as main N source. Figure 7.1a shows that Farms 11 and 6 also exceed the innovation norm of PAB. If this remains an incident, it will not influence PAR on the long term.
The pilot farms differ little in KAB (Figure 7.1b). Most farms have low KAB as a norm, because their KAR exceeds the norm, usually considerably. The average KABs show a trend of excessive K input, which could lead to increasing K content of soil and shallow waters, thus reducing the prospects for drinking water production. However, most farms can prevent this by reducing K input as cattle manure, because they already apply too much P. Farms 12 and 9 should rather replace cattle manure with its low P/K rate by chicken or pig manure, which has a high P/K rate.

In the Netherlands, the 10 pilot farms are quite unique since their means P/KABs are nearly 1. Nevertheless, the overall tendency to exceed the norms indicates limited acceptance by farmers, based on their fear of N shortage. The N parameters show whether this fear is justified or not.

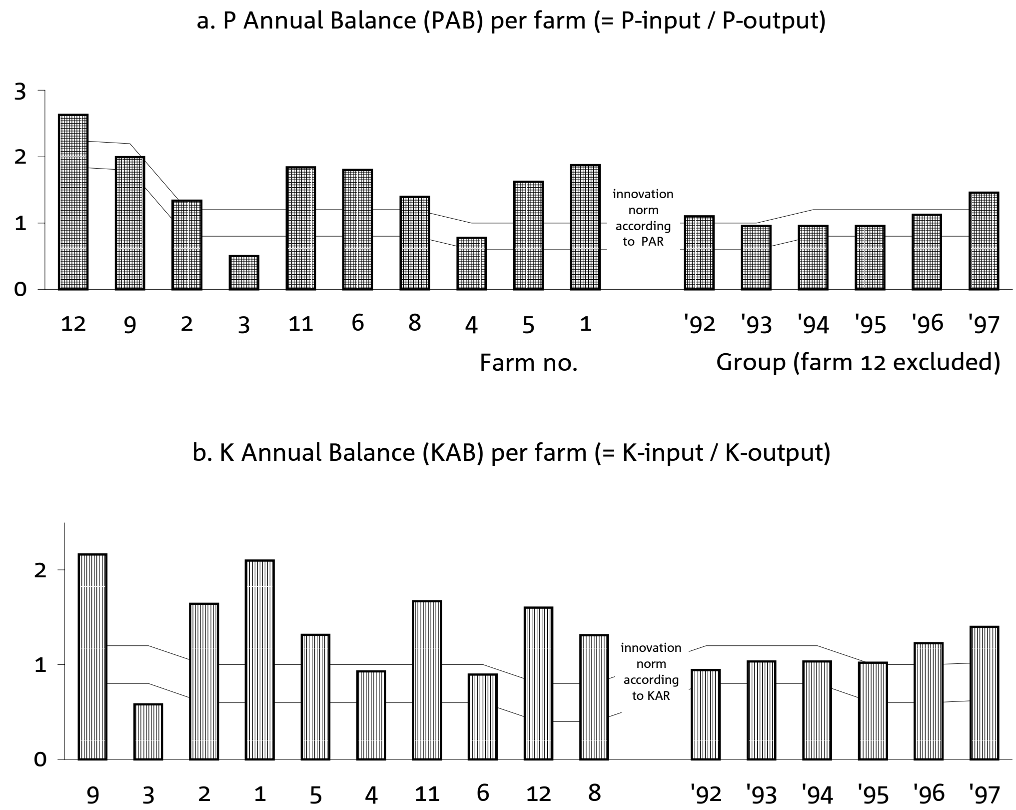
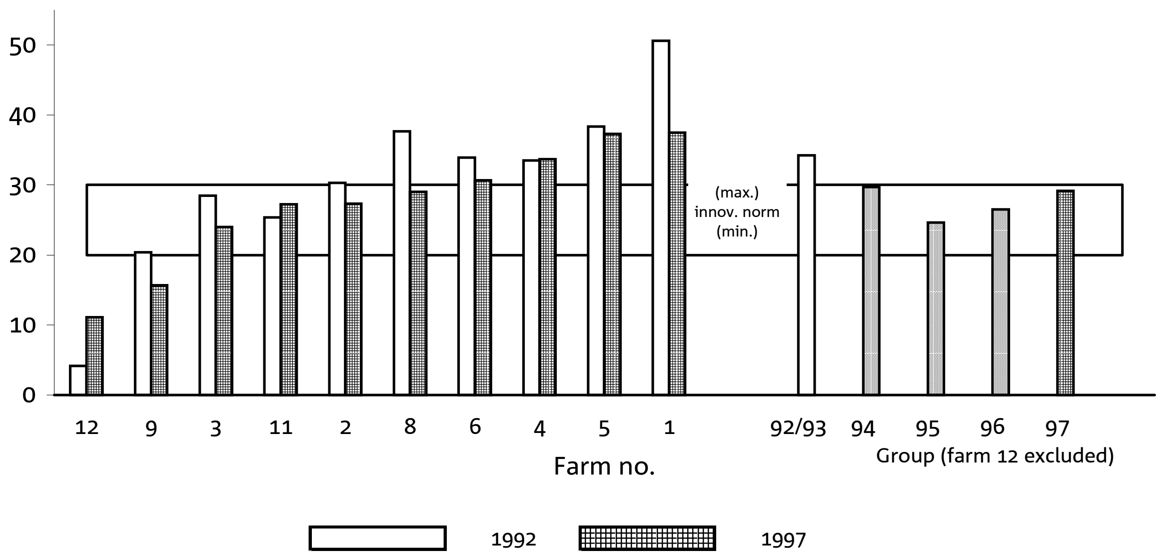


Figure 7.1 P and K Annual Balances (P/KAB) of the 10 pilot farms in 1997.
Farms are ranked according to increasing P and K Available Reserves (P/KAR) (established spring 1996), i.e. decreasing innovation norms for P/KAB.

7.1.2 P/K Available Reserves (P/KAR)

Since 1992-1997 mean PAR of the pilot farms has decreased 5 units, though PAB was 1.1 in that period (Figure 7.2a). So, notwithstanding some net input, available P has been immobilised. In the same period, mean KAR increased 6 units. Normally, it takes 100 kg/ha K_2O to increase KAR by 1 unit. Since mean KAB was 1.1 during this period, equivalent to 15 kg/ha K_2O net input per annum, increase in KAR can only be explained by mobilisation of K from the solid reserves. As a result, the pilot farms should greatly reduce their KAB to control KAR. The best solution would be to change from applying cattle manure, with a low P/K rate, to applying poultry or pig manure, which has a high P/K rate. However, such manure is not available from acceptable husbandry systems that conform EU guidelines for the organic label. Consequently, the pilot farms should just await the evolution of KAR, while in the meantime we will carefully monitor K leaching, which up until now has not been related to KAR. The latter suggests that it would be ecologically acceptable to raise the upper limit of the desired range of KAR.

a. P Available Reserves (PAR = Pw-count)



b. K Available Reserves (KAR = K-count)

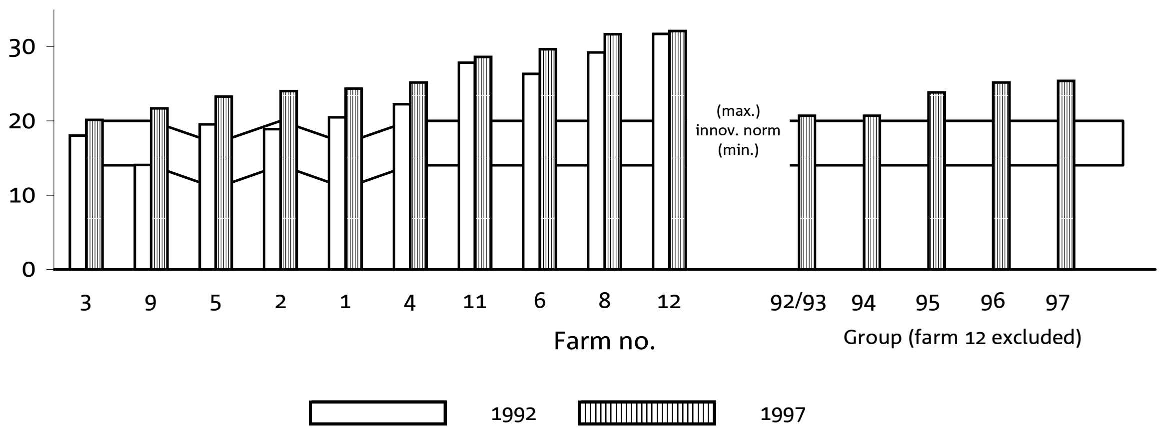


Figure 7.2 P and K Available Reserves (P/KAR) of the 10 pilot farms in 1992 and 1997 (farms ranked according to increasing reserves). Farm 12 is quite different from the rest and has only been participating since 1995, therefore it is excluded from the averages.

7.2 for Potential/Actual N-Leaching P/ANL

Brief definitions and ranges:
Potential N Leaching (PNL) is N_{min} soil reserves (0-100 cm) at start of leaching period. PNL < 45 kg ha^{-1} on sand and PNL < 70 kg ha^{-1} on clay is derived from the EU norm for drinking and shallow ground water, (< 50 mg nitrate l^{-1}). Actual N Leaching(ANL) is the nitrate content of drainage water or shallow groundwater (mg/l), weighted for the precipitation surplus per month or entire leaching period. ANL < 50 mg nitrate l^{-1}, (EU norm) is an appropriate desired result. By testing crops and farms for both parameters, the definitive PNL norm can be established. Then it would suffice to test on PNL, saving a lot of time and money.

(a) Testing with PNL:
- establishing desired range of PNL to meet desired ANL for your IAFS or EAFS (EU norm or EU guideline, which is < 25 mg nitrate l^{-1});
- establishing achieved PNL of each field.

(b) Improving with PNL:
- establishing which fields/crops have a PNL exceeding the desired range;
- establishing from the theoretical prototype which methods are involved (mostly I/ENM);
- establishing which criteria have not yet been fulfilled by these methods (ready for use, manageable by the farmers, acceptable to the farmers, effective);
- establishing targeted improvements of the methods to meet these consecutive criteria.

On average, ANL achieves the norm in NL 2, as in 1994 and 1995 (Fig. 7.3a). (In 1995 there was hardly a precipitation surplus, so no drainage water could be tapped). The crops exceeding the norm (maize, onion, pulses and potato) account for 70% of ANL, though their share in the rotation is only 35%. ANL varies greatly among the farms, generally following variation in PNL (Figure 7.3b). However, the lutum content of the soil is important. Farm 8 with 40-50% lutum has a PNL that far exceeds the norm, though its ANL is amply within the norm! In contrast, Farms 5 and 1, with 5-30% lutum, have PNLs slightly below the norm, though an ANL beyond the norm! Farms 2, 11 and 3 with intermediate lutum contents remain within the ANL norm, though they exceed the PNL norm. So, the innovation norm in PNL needs to be determined in relation to the lutum content.

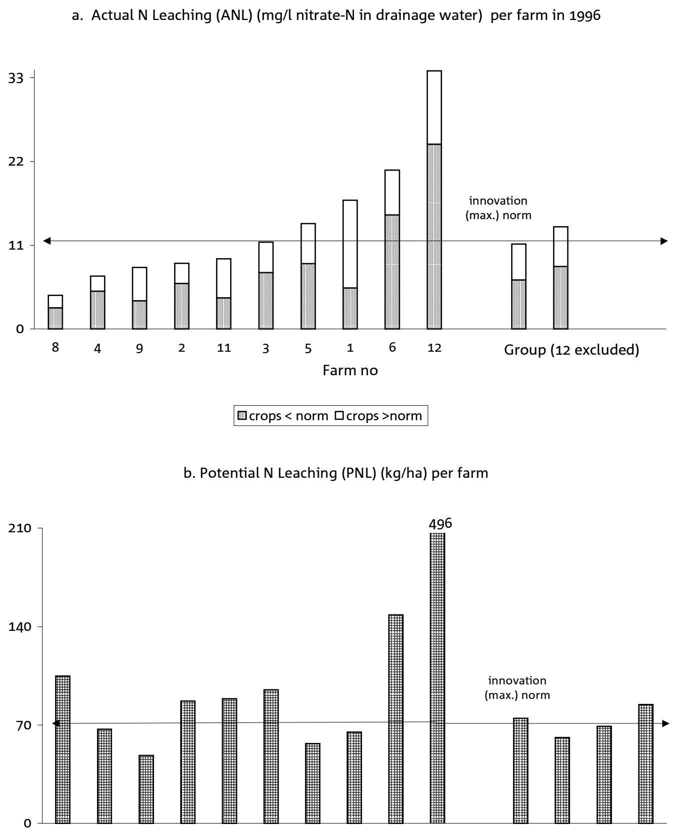


Figure 7.3 Actual N Leaching (ANL) of the 10 pilot farms in 1996 related to Potential N Leaching (PNL) (kg/ha N_{min} in 0-100 cm soil layer at the start of leaching period).

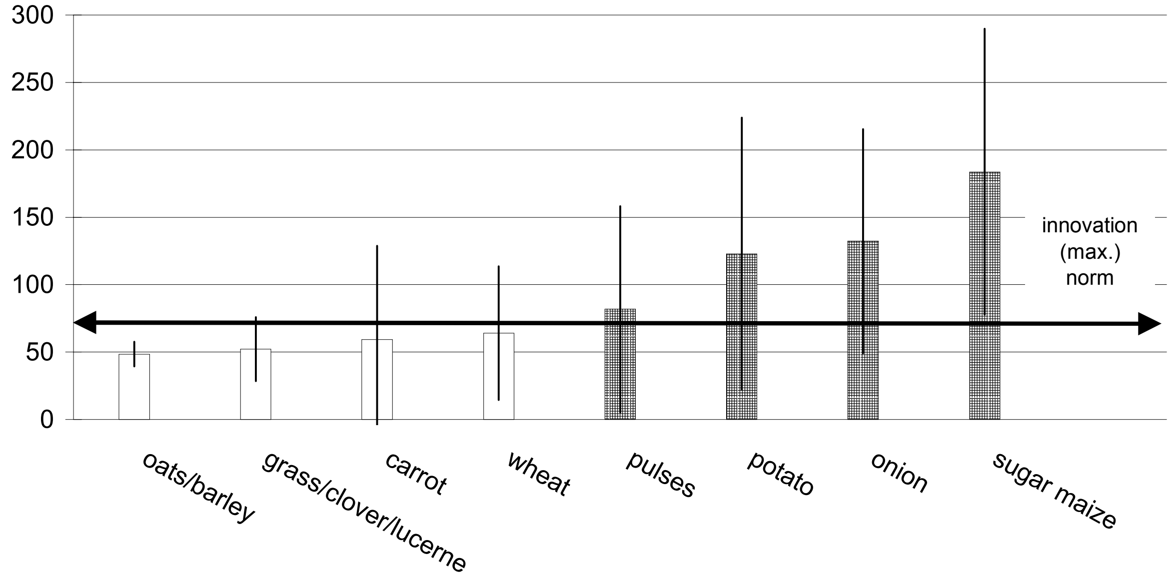


Figure 7.4 Potential N Leaching (PNL) of the main crops on the 10 pilot farms in 1997 (kg/ha N_{min} in 0-100 cm soil layer at the start of leaching period).

As shown by Fig. 7.3, farms exceeding the innovation norms for PNL and ANL, may improve by targetly reducing PNL and ANL of the crops exceeding the innovation norms. The main N critical crops are potato, onion and sugar maize, though the high standard deviations indicate large differences between farms (Fig. 7.4). To offer the pilot farms a key to this issue, we have established a range in N need per crop, based on the top 5 fields in quality production with a PNL within the innovation norm. In case of onion, it appeared that top quality production may well go along with a PNL within the norm (Fig. 7.5). The farmers with more or less overfertilised fields may learn from this figure, that high N supply may rather lead to leaching than to top quality production! For the other crops ranges of N need have been established in a similar way. These ranges can be used by the farmers at the Ecological Nutrient Management in step 2 (Outline 7).

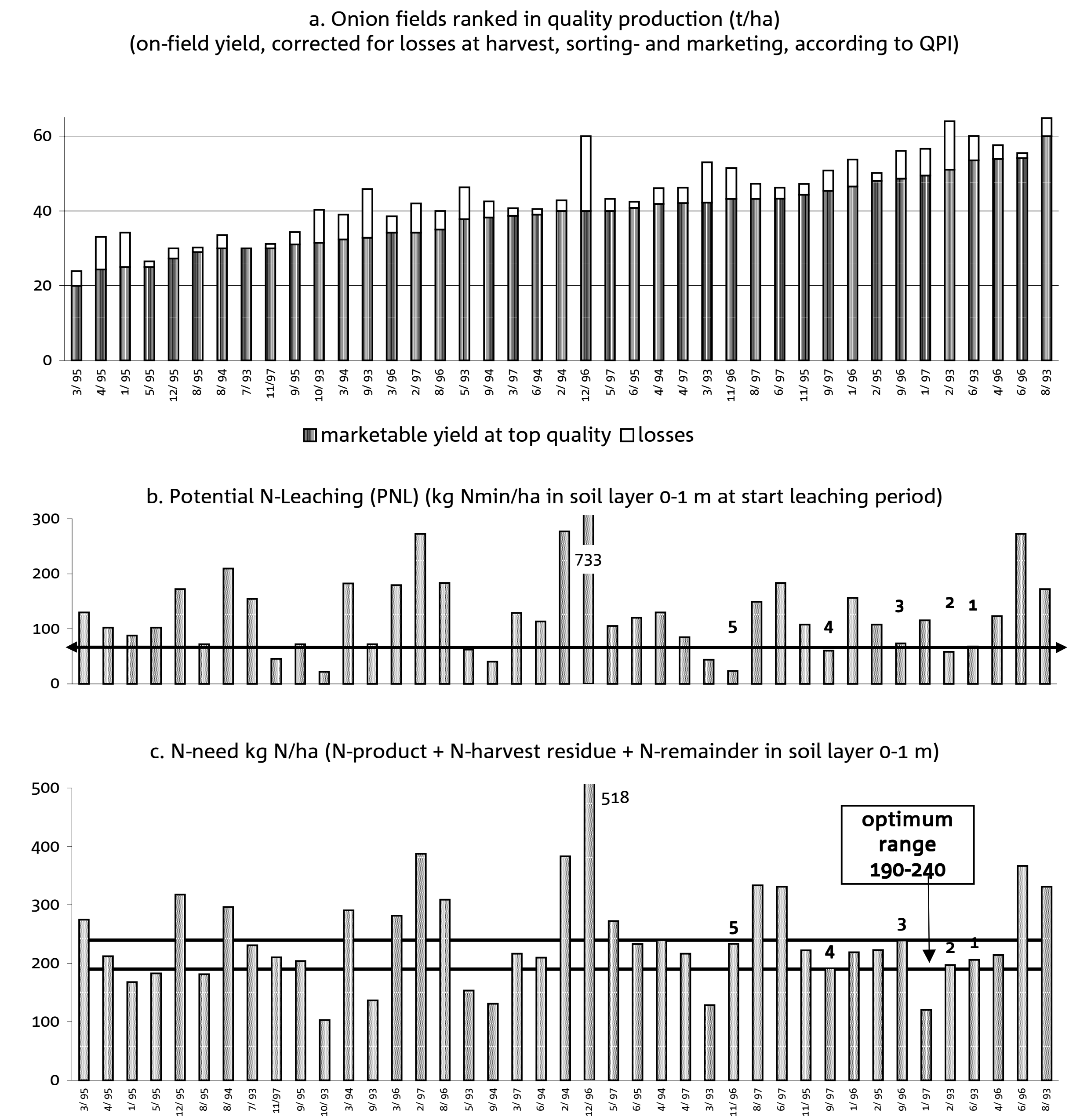


Figure 7.5 Onion fields in 1993-1997 with top 5 in quality production (a) keeping Potential N leaching within the innovation norm (b) thus providing a base for a range of N need to be used in ENM

Estimating PKN-NEEDS (preceding spring)

step 1

Need of P-, $N_{legumes}$- and K per field

(based on actual soil reserve and foreseen offtake by the harvest product)

if soil reserve (P_w - count):		
agronomically too low	within desired range	ecologically too high
then need of P- input with manure is:		
80 -120% offtake + correction	80 -120% offtake	< 100% of offtake
and need of N- input by legumes is:		
0 to 6 (min.)	1 to 6	2 to 6 (max.)

K- need based on K- count and K-offtake *(like P)*

(drafting a crop plan according to MCR and need of legumes)

P- resp. K- offtake per field (kg) = area(ha) * product(t/ha) * P- resp.K- content(kg/t)

step 2

N-need per crop based on foreseen offtake and remaining soil reserve at harvest

N-uptake/crop(kg) = area(ha) * (product+harvest residue)(t/ha) * content(kg/t)

N-need/crop(kg) = N-uptake+area(ha) * ($N_{min\ at\ harvest}$)(kg/ha)

step 3

Part of N-need per crop, to be covered by manure

= N-need minus net input by remaining soil reserve and harvest residue of preceding crop, possible green manure crop, organic matter and aerial deposition

step 4

Crop plan need of best fitting kind(s) of manure (then purchase of manure)

covering all P-, K- and N-needs (steps 2 and 3) according to mean P-, K- and N- contents of the manure (N-content * net available fraction) (possibly supplementary K)

APPLYING PKN AS MANURE (preceding autumn)

step 5

Analysing and partitioning available manure according to N-need per crop

updating steps 1, 2 and 3 (crop plan, N from preceding crop and green manure)

C-rich (rough) lots of manure on early and/or N-rich stubbles

P- or K-rich lots of manure on P- or K-needing fields

(possibly supplementary K)

Outline 7 Ecological Nutrient management for the clay soils of Flevoland, as tested and improved by the 10 pilot farms of NL 2.

8. Testing and improving an Infrastructure for Nature and Recreation

In all theoretical prototypes of the I/EAFS-Network, Infrastructure for Nature and Recreation (INR) is the major method to achieve desired results in multi-objective parameters for Nature/Landscape and Health/Wellbeing. So, INR is a farming method with a double objective. The first is to make a farm accessible and livable again to wild flora and fauna, whose biotope would historically have included the farm. The second is to make the farm accessible and attractive for recreationists from rural and urban areas. In this chapter, testing and improving INR for INRI and 3 flora parameters will be highlighted, based on the results in pilot project NL 2.

8.1 For Infrastructure for Nature and Recreation Index (INRI)

Brief definition and range:
Infrastructure for Nature and Recreation Index (INRI) refers to 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 (0 ≤ INRI ≤ 1).

(1) Testing with INRI:
- establishing the desired range of INRI, based on the desired layout, management and size of INR, and expressed as INR including bufferstrips (ha) / production area of the farm (ha);
- establishing achieved INRI.

(2) Improving with INRI:
- establishing which INR elements are involved in a possible shortfall of achieved results;
- establishing which criteria have not yet been fulfilled by the responsible method INR (ready for use, manageable by the farmers, acceptable to the farmers, effective);
- establishing targeted improvements of INR to meet these consecutive criteria.

In NL 2, INR has been designed and laid out as a network of ditches, the following requirements (Fig. 8.1):

– the network offers variation and continuity to plants through periodic mowing and removal of hay to prevent suffocation and eutrofication, and by maintaining permanent grass strips alongside the ditches, as a buffer against erosion and eutrofication from fields;
– the network offers variation and continuity to animals for feeding, hiding and nesting, supported by various side-elements in the banks of ditches and in the yard (shrubs and trees, haystacks, wood piles, etc.);
– the network offers variation and continuity to recreationists through a variety of images, colours, smells and sounds, from early spring through to late autumn;
– the network comprises at least 5% of the farm area (2.5% ditch banks and 2.5% production area), that meets these criteria.

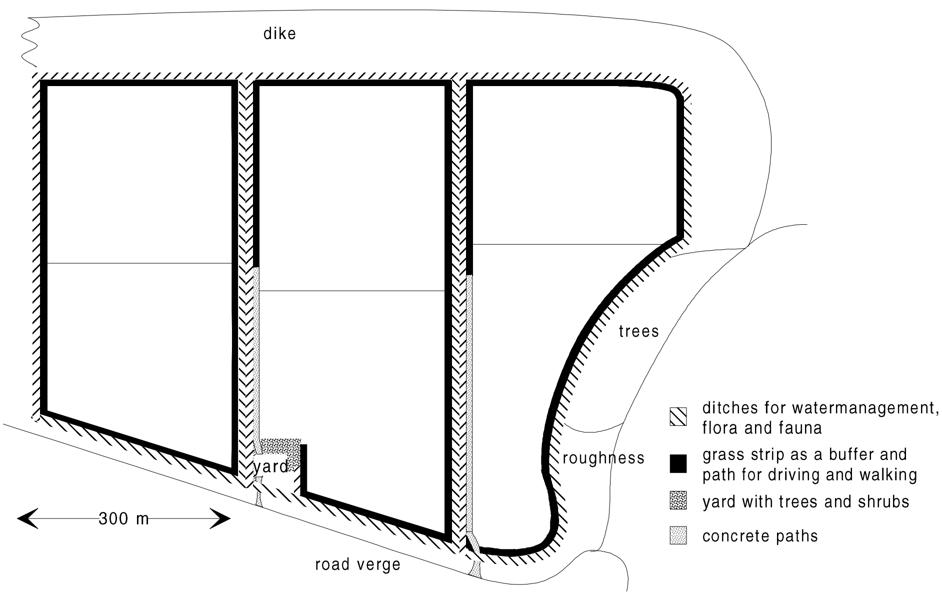


Figure 8.1 Infrastructure for Nature and Recreation of pilot farm 2 in NL 2.

Acceptability and manageability of INR

INR is manageable and acceptable considering that all farms but one have achieved the innovation norm of 5% of farm area devoted to INR, although it took 4 years to achieve this (Figure 8.2). The major cause of this slow response was the reluctance of some farmers, to reduce their production area in favour of permanent grass strips to protect and manage the ditches, for which, currently, there is no financial compensation in terms of direct payment or a better market for products because of their added ecological value. At the start of the project in 1991, the banks of ditches, targeted as the main element of INR, were highly eroded and covered with weeds, such as *Elymis repens* (cough grass). It took 2 years to create banks covered with various non-weedy grass species. In 1991 less than 10 wild plant species with conspicuous flowers grew there spontaneously. So we decided to collect and spread seeds of conspiciously flowering plant species that can thrive on the sandy clay soil, rich in lime. Of the 90 species sown amongst the existing grassy vegetation so far, some 40 have gradually succeeded in establishing themselves there. This success has been achieved by continual ditch management through mowing and removing the hay twice a year, which hinders fast growing grasses by depletion of nutrients in the soil. With the increase in flowers growing on the banks of ditches, the farmers and their families' appreciation of INR rose. To make it still more attractive for man and animal, farms have started to lay out various side-elements,
such as willow shrubs, ribbons of reed, haystacks, wood piles and nesting boxes for kestrels and barn owls. The current innovation norm, i.e. at least 7 out of a list of 12 side elements, has been met by most farms.

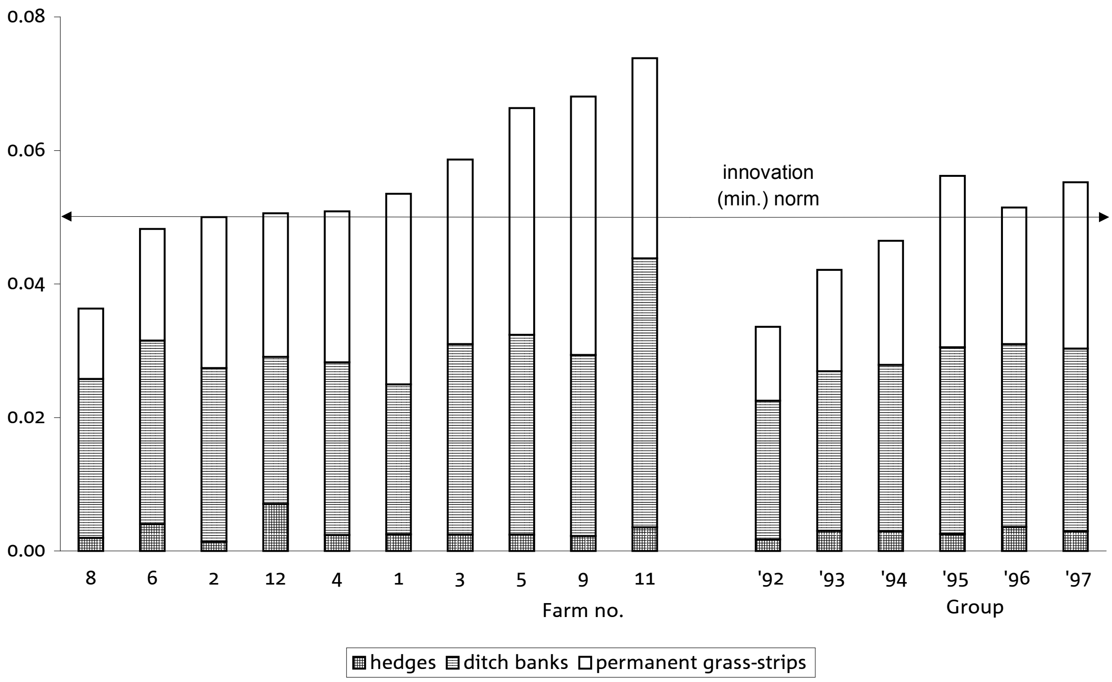


Figure 8.2 Infrastructure for Nature and Recreation Index (INRI) of the 10 pilot farms of NL 2 in 1997.

8.2 For flora/landscape parameters (FDI, PSD and PSDN)

Brief definitions and ranges:
Plant Species Diversity (PSD) is the number of target plant species in the INR. A target plant species is one with conspicuous flowers by color or shape, that is both attractive for recreational use by people and for animals to feed on or shelter in.
Plant Species Distribution (PSDN) is the mean number of target species/100m of INR.
Flower Density Index (FDI) is the mean number of flowers/m/month of INR.

(a) Testing with flora/landscape parameters:
- establishing a desired PSD,PSDN and FDI considering the desired function of the INR as a habitat and corridor for flora and fauna, and as part of a recreational network.

(b) Improving with flora/landscape parameters:
- establishing which INR elements are involved in a possible shortfall of achieved results;
- establishing which criteria have not yet been fulfilled by the responsible method INR (ready for use, manageable by the farmers, acceptable to the farmers, effective);
- establishing targeted improvements of INR to meet these consecutive criteria.

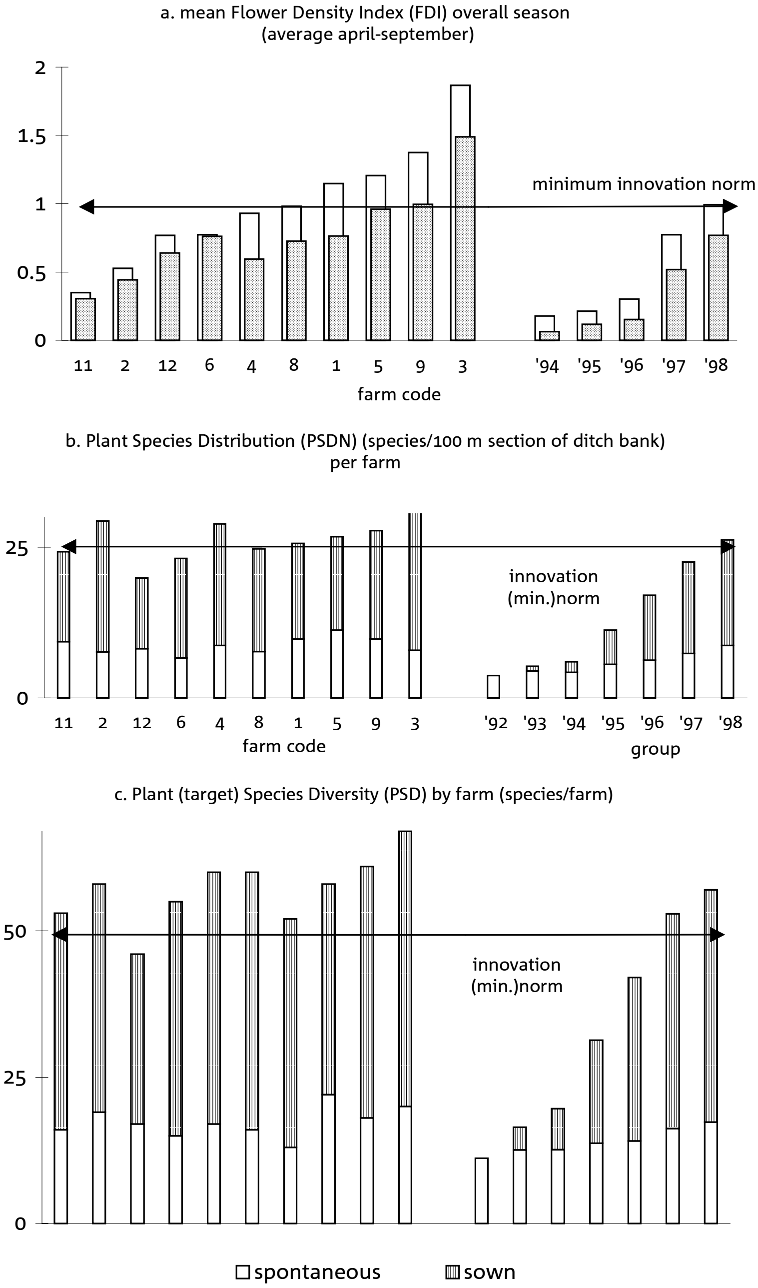


Figure 8.3 The three parameters for flora (in order of importance) in the INR of the 10 pilot farms in 1998.

Figure 8.3 presents the progress of NL 2 for the norms to be achieved in the 3 flora/landscape parameters. The most important norms to be met are those for the flora. Flora should make the INR and the farm viable for animals and enjoyable for people, due to a varying bouquet of flowers that blossom from spring to autumn, well spread throughout the farm. Therefore, the first norm to be met is more then 10 flowers per m (ditch bank + grass strip) from April to September (Flower Density

Index (FDI) = 1 if 12.5-25 flowers per m; = 2 if 25-50 flowers per m; = 3 if 50-100 flowers per m and = 4 if > 100 flowers per m). In 1998, 6 years after sowing the first target species, 5 farms have achieved the innovation norm in FDI (Figure 8.3a). The second norm, 25 target species per 100 m section INR and the third norm, 50 target species over the entire INR, have been achieved by 7 and 9 farms, respectively (Figure 8.3b-c). The growing potential of flowering this represents will enable a further increase of FDI. A short list of 50 target species that were able to settle on the grassy banks of ditches on most farms is important for the dissemination of INR to other farms in the region (Figure 8.4). By collecting and sowing seeds of these species, farms could reduce the time needed to achieve FDI = 1 from 6 to 3 years. In a follow-up project, norms for quality and quantity of fauna could be considered.

MAIN TARGET SPECIES* IN 1998 (incidence > 5) *Latin name*	*not sown*	FLOWERING PARADE *march*	*april*	*may*	*june*	*july*	*august*	*september*	INCIDENCE *(number of farms)*
Ranunculus ficaria		———	———						7
Bellis perennis		———	———	———	———	———	———	———	7
Cardamine			———	———					10
Taraxacum	-		———	———					10
Alliaria petiolata			———	———	———				10
Barbarea vulgaris			———	———	———				7
Primula			———	———	———				7
Anthriscus				———	———				10
Crepis biennis				———	———				10
Lychnis flos-				———	———				8
Plantago lanceolata				———	———				10
Ranunculus acris				———	———				10
Ranunculus repens	-			———	———				8
Rhinanthus minor				———	———				6
Rumex acetosa				———	———				9
Sanguisorba minor				———	———				8
Silene dioca				———	———				10
Myosotis	-			———	———	———			8
Trifolium pratense	-			———	———	———	———	———	10
Silene latifolia				———	———	———	———	———	9
Geranium pratense					———	———			10
Leucanthemum					———	———			9
Phalaris	-				———	———			6
Rhinanthus angustifolius					———	———			6
Tragopogon					———	———			8
Tragopogon pratensis					———	———			10
Galium mollugo					———	———	———		9
Lapsana communis	-				———	———	———		6
Lathyrus pratensis					———	———	———		9
Lotus corniculatus					———	———	———		8
Thalictrum					———	———	———		6
Urtica dioica	-				———	———	———		10
Vicia cracca					———	———	———		8
Achillea					———	———	———	———	10
Campanula					———	———	———	———	10
Centaurea jacea					———	———	———	———	10
Heracleum					———	———	———	———	10
Knautia arvensis					———	———	———	———	10
Malva alcea					———	———	———	———	10
Malva					———	———	———	———	6
Medicago sativa					———	———	———	———	10
Senecio jacobaea					———	———	———	———	10
Trifolium repens	-				———	———	———	———	10
Verbascum nigrum					———	———	———	———	8
Cirsium	-					———	———		7
Dipsacus fullonum						———	———		9
Angelica						———	———	———	10
Arctium tomentosum						———	———	———	8
Epilobium	-					———	———	———	9
Lythrum						———	———	———	6
Origanum						———	———	———	7
Pastinaca sativa						———	———	———	10
Tanacetum vulgare						———	———	———	9
Phragmites	-						———	———	10

*All target species have attractive flowers to insects and/or recreationists, except for Urtica dioica, which is important for feeding cattterpillars of various attractive butterfly species and providing cover to birds, mammals and insects

Figure 8.4 Most frequent target species on the ditch banks of the 10 pilot farms of NL 2.

9. Testing and improving Integrated Crop Protection methods

In theoretical IAFS prototypes, Integrated Crop Protection (ICP) is an indispensable method to support MCR, I/ENM, MSC and INR in sustaining Quality Production by efficient control of remaining harmful species, with minimal use of well selected pesticides (Pesticide Index < x), sparing all other species and meeting norms for Environment Exposure to Pesticides (EEP). To achieve the latter, ICP needs Environment Exposure based Pesticides Selection (EEPS) as an additional method to reduce the overall exposure of the environment to pesticides in order to prevent short-term and long-term adverse effects on all species throughout the biosphere. EEP is of universal use and therefore more appropriate than the Pesticide Index (PI), which relates the pesticide input of the IAFS to the input in conventional systems in the region. In this chapter, testing and improving ICP and EEPS for PI and EEP will be highlighted, based on the results in various EU projects.

9.1 Integrated Crop Protection (ICP) for Pesticide Index (PI)

Brief definition and range:
Pesticide Index (PI) is pesticide inputs in the IAFS in kg active ingredients (a.i.)$ha^{-1}yr^{-1}$ /the same as for a conventional reference system in the region($0 \leq PI \leq 1$).

(a) *Establishing a desired range of PI:*
- taking into account national or regional policy papers, or local considerations;
- by farming system or by crop.

(b) *Testing with PI:*
- establishing total inputs in kg a.i. $ha^{-1}yr^{-1}$ by IAFS-system and by crop;
- establishing PI by system and by crop, based on records of a conventional reference system or on regional or national records.

(c) *Improving with PI:*
- establishing fields/crops for which PI falls short of the desired range;
- establishing from the theoretical prototype which methods are involved (mostly ICP and MCR);
- establishing which criteria have not yet been fulfilled by these methods (ready for use etc.);
- establishing targeted improvements of the methods to meet consecutive criteria.

Figure 9.1 presents the testing results with PI of the 3 IAFS projects on experimental farms that have data from at least 3 consecutive years (1993 - 1995). Though they are prototyping in quite different regions, all 3 teams are aiming to achieve the same PI < 0.7. Having achieved a PI < 0.4 in the last 3 years, I 1 could have set a more ambitious desired PI. The teams of UK 1 and UK 2 have shown little progress towards achieving the rather modest desired PI. Both could benefit from accepting the challenge of trying to meet a more ambitious desired result.

9.2 Environment Exposure based Pesticide Selection (EEPS) for Environment Exposure to Pesticides (EEP)

Brief definition:
EEP is specified as EEPair, EEPsoil and EEPgroundwater by pesticide, crop or farm.
EEPair = active ingredients (kg ha^{-1}) * vapour pressure (Pa at 20-25 °C);
EEPsoil = active ingredients (kg ha^{-1}) * 50% degradation time (days);
EEPgroundwater = EEPsoil (kg days ha^{-1}) * mobility (mobility = K_{om}^{-1} and K_{om} = partition coefficient of the pesticide over dry matter and water fractions of the soil-organic matter fraction of the soil).

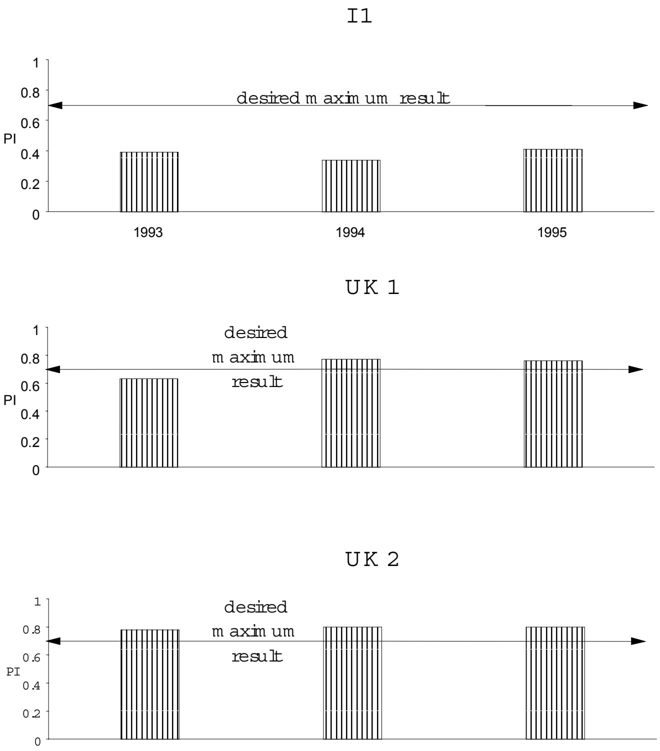


Figure 9.1 Testing and improving Pesticides Indices (PI) of IAFS prototypes on 3 experimental farms, 1993 - 1995

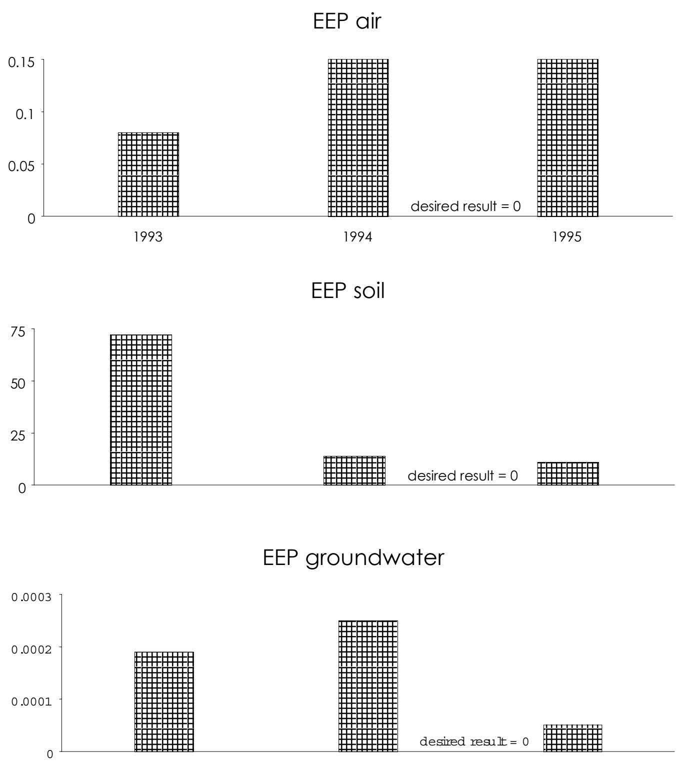


Figure 9.2 Testing and improving Environment Exposure to Pesticides (EEP) of IAFS prototype in Nagele (NL 1), 1993 - 1995, specified for air (kg Pa/ha), soil (kg days/ha) and groundwater (kg days/ha)(mobility).

(a) *Testing with EEPs air, soil and groundwater:*
- establishing achieved EEPs by pesticide (ha^{-1}), by crop (sum of pesticides ha^{-1} $crop^{-1}$) and by farming system (weighted average of pesticides ha^{-1} $crop^{-1}$);
- establishing desired EEPs at the farming system level;
- ranking EEPs at the farm level by pesticide * area treated (ha).

(b) *Improving with EEPs air, soil and groundwater:*
- establishing shortfalls between achieved and desired EEPs at the farming system level;
- establishing how these shortfalls can be made good by replacing the highest ranking pesticide treatments with non-chemical protective measures or less ranking pesticide treatments based on the same or other pesticides, and including band spraying, spot-wise treatment or low-dose treatment;
- establishing whether the needed improvements in ICP, and possibly MCR, INM or another method, are manageable by and acceptable to the farmers.

Figure 9.2 presents the testing results for EEP of NL 1, the only project having data available from at least 3 consecutive years (1993 - 1995). In line with the preventive character of EEP, the NL 1 team has established desired EEPs of air, soil and groundwater = 0! In this way, they have maximised the challenge of achieving sustainable crop protection. The results of the last 3 years show great progress in EEPs soil and groundwater, but stagnation in EEP air. Whether intended or not, the exposure of the local environment to pesticides is more reduced than that of the wider environment. For more information on EEP including latest results, see Wijnands (1997).

10. Testing and improving Farm Structure Optimisation

FSO is a mostly indispensable final method to render an agronomically and ecologically optimised prototype economically optimal too, by determining the minimum amounts of land, labour and capital goods needed to achieve the required Net Surplus (NS) and Energy Efficiency (EE). Since there are no projects yet in the I/EAFS Network with 3 consecutive years of data for these parameters, only the format for testing and improving with NS is presented.

10.1 For Net Surplus (NS)

Brief definition:
NS is gross revenues minus all costs, including a payment for all labour hours, equal to payment for comparable labour in other economic sectors.
Range of NS:

NS < 0 implies labour has not equally been paid and the farm has made no profit.
NS = 0 implies equal payment of labour, though no profit.
NS > 0 implies both equal payment and profit.

(a) *Establishing if testing is reliable and useful:*
- establishing if the prototype can achieve all other desired results as quantified in the various multi-objective parameters;
- continuing with testing and improving if major objectives have not yet been achieved, before testing NS.

(b) *Quantifying and interpreting NS;*
- proceeding with disseminating the prototype (step 5) if the desired NS has been achieved.
- proceeding with FSO if desired NS cannot be achieved with current farm structure (FSO is always advisable to do before proceeding with step 5, to establish a range of optimum farm structures based on optimistic and pessimistic assumptions on future yields and prices).

Some farms have hardly achieved a Net Surplus > 0, which is the desired result for our theoretical prototype (Figure 3). The main cause is chronic yield reduction in the main crops, carrot and potato, by airborne and/or seedborne diseases such as *Alternaria* and *Phytophtora*. Consequently, quality production remains below the desired result. In this situation, FSO is considered premature. Therefore, in a follow-up project the first aim will be to improve QPI of carrot and potato (Section 6.1).

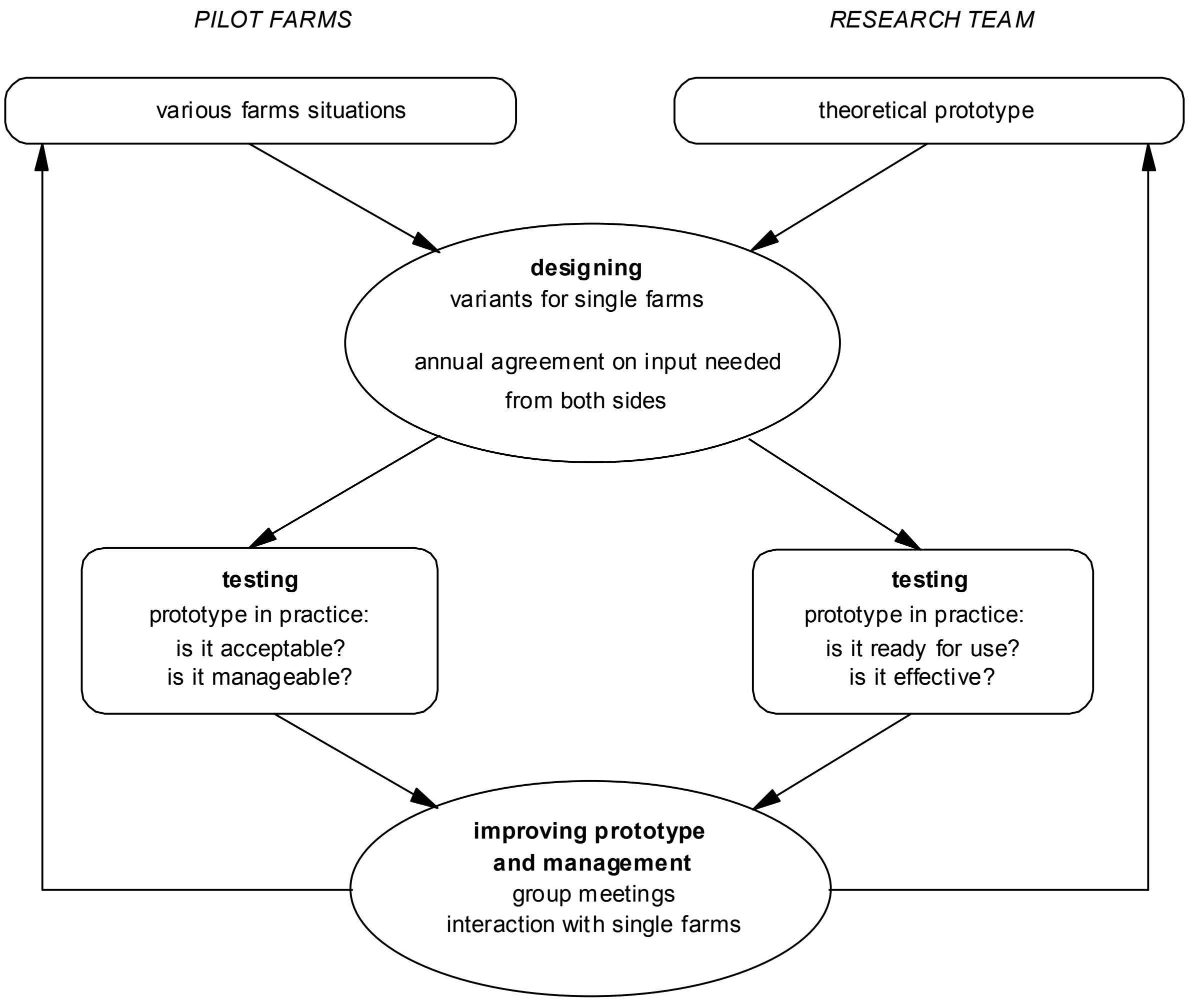


Figure 11 Interactive prototyping: designing, testing and improving a prototype through interaction of pilot farms and the research team

11. Disseminating prototypes (Step 5)

Generally, 'dissemination' refers to the spreading of new information and technology. If the information and technology has been produced by members of the target group or by outsiders in close interaction with members, it could be called *bottom-up dissemination*. If, however, the new information and technology has been produced by outsiders without or with only little interaction with group members, it should be called *top-down dissemination*.

Traditionally, agricultural researchers are outsiders in the farming community, because they produce information and technology without or with only little interaction with farmers. Up till now, this was not considered to be a problem, because researchers disseminate their results mainly amongst colleagues, extensionists and policy makers. However, it implies that research results only reach farmers in so far as extensionists and policy makers are willing and capable to incorporate those results in their policies, messages and guidelines! If I/EAFS would be disseminated in the traditional top-down way it would imply that researchers develop a general prototype on an experimental farm and policy makers and extensionists disseminate it amongst the farmers.

11.1 Promoting bottom-up dissemination through interactive prototyping with pilot farmers

There are various reasons why traditional top-down dissemination cannot be effective for I/EAFS:
- a general prototype cannot just be transferred from an experimental farm to any commercial farm in a region, because it requires adaptation to specific circumstances, notably the various types of soil and the various needs and goals of farmers in a region;
- the farm-specific adaptation of a general prototype mostly requires the adaptation of methods (MCR, I/ENM, EIM etc.) to such an extent that the resulting variant of the prototype should be tested again and improved;
- the elaboration of farm-specific variants of I/EAFS prototypes will exceed the capabilities of most extensionists.

These constraints can be overcome if research teams first elaborate a set of variants of prototypes covering regional variation in soil and farmers needs and goals and put that set at the disposal of the extension service! Consequently, sooner or later any research team should create a group of pilot farmers and draw up a representative set of prototypes variants with them. Interactive prototyping with pilot farmers is an excellent start for bottom-up dissemination, which would not only be more effective but also save a lot of time and money compared with traditional top-down dissemination of a general prototype from an experimental farm. For this reason the team of NL 2 has developed a model of interactive prototyping with pilot farms (Figure 6.1). Since it appears to work quite well, it has been accepted as a standard by the teams of the I/EAFS-Network. For interactive prototyping with 10 - 15 pilot farms, Step 4 can result in 10 - 15 variants of the prototype that cover the regional ranges of soil, climate and management.

Interactive prototyping can also create a group of capable and motivated pilot farmers, which is an indispensable technological and social base for dissemination throughout a region. Their farms can be used as demonstration farms and they can be involved in the training and guiding of farmers willing to convert. To disseminate the prototype variants in wider circles, regional extension services should be trained to participate in and gradually take over the innovation project. The interaction model (Figure 6.1) can be used to convert groups of farmers in a programme that lasts at least 4 years. Currently, a minority of the research teams in the I/EAFS network are still just prototyping on an experimental farm. The majority of teams have already formed a pilot group, though most of them have not yet put the model of interactive prototyping into practice.

11.2 Reinforcing bottom-up dissemination by top-down dissemination

Top-down dissemination by extensionists and policy makers, or even imposition of a prototype developed by researchers on an experimental farm, would meet a lot of resistance within a farming community and would not be effective. If, however, a region-wide set of prototype variants were to be made available through interactive prototyping with pilot farmers, bottom-up dissemination could be reinforced by a well-tuned top-down dissemination. This implies various measures and guidelines from policy makers, but also from processers, traders and consumer organisations, each directly or indirectly exerting pressure on farmers to convert to the available I/EAFS-variants. This is highlighted by A. El Titi and P. Denzinger (DE 1) in progress report 4 (Vereijken, 1998).

12. Conclusions and recommendations

The following conclusions and recommendations have been drawn up in the light of the results of the network participants in 1997, when focus was on improving and disseminating I/EAFS (Steps 4-5).

12.1 Improving prototypes on-farm (Step 4)

After the 3 initial steps of designing (see outline 1), the methodical way of prototyping I/EAFS is followed by:

(4) testing and improving the prototype, in general, and the methods, in particular, until the objectives as quantified in the set of parameters have been achieved (Parts 5 and 6 of prototype's identity card).

In 1997 three pilot projects that have at least 3 years results available have been selected to focus on this most labourious Step 4: B 1, DE 1 and NL 2 (Vereijken, 1998). To what extend have the three pilot projects met the needed progress? This will be highlighted based on the format for Step 4 (Chapter 5).

12.1.1 Establishing desired results in any parameter: per farm and as percentage of farms

Compared with prototyping on an experimental farm, prototyping with pilot farmers has the advantage of a multiple layout of the prototype. This enables testing and improving with variations of soil, crops and management, which may lead to a set of prototype variants covering the regional variation in farms. The state of the art (Part 6 of the prototype's identity card) of pilot projects can be expressed as the average achievement per parameter (left-hand circle, Figure 5.1) and as the percentage of farms achieving the desired result (right-hand circle). The latter could be done by just presenting the percentage achieved per parameter, but we have chosen to relate the achieved percentage to a desired percentage per parameter, which may be required or useful for the objectives covered. Consequently, in both circles the relative shortfall of achieved to desired result is presented for each parameter, which enables parameters to be ranked in ascending order of shortfall. In this way, the state of the art also indicates the future agenda: the work still to be done in order of priority.

To establish desired results in a parameter is not easy if there are no official (legal or trade) norms or guidelines at EU, state or regional level. Under such circumstances a desired result should be established by negotiation with the pilot farmers, and possibly with other groups whose interests are affected by the parameter in question. The third progress report gave examples of desired results that were too conformistic, too idealistic or too vague (Vereijken, 1996). This only concerned desired results in absolute terms, i.e. per farm. In the fourth report, the 3 pilot projects also present desired results in relative terms, i.e. as the desired percentage of farms to achieve the (absolute) desired result in any parameter (Vereijken, 1998). The desired percentages vary in B 1 from 30-100%, in DE 1 from 50 –100% and in NL 2 they are all 90%. The varying percentages are not highlighted. The team of NL 2 has not negotiated with the pilot farmers or other groups; 90% is set as desired to ensure the prototype is made acceptable, manageable and effective in any parameter for almost any farm in the pilot group, and thus for most farms in the region. Nevertheless, it is realised that regional farmers or other groups may be less demanding about the percentage of farms achieving the desired result in certain parameters. This would imply that achieving the desired result on average is the most important, and that certain farms may compensate through overperformance for the underperformance of others. However, this is socially and economically a delicate issue, because overperformers could claim a bonus and underperformers could refuse a malus!
In pilot projects, it is recommended that the desired percentage of farms to achieve the desired result in any parameter be established by negotiation with the pilot group and preferably other re-

gional groups whose interests are affected. As long as this has not happened, the percentage should be fixed at 90, to ensure the prototype is made acceptable, manageable and effective for most of the farms in the region for the parameters in question.

12.1.2 Establishing achieved results

Progress report 3 gave various examples of incorrect setting of achieved results (Vereijken, 1996). In addition, it may be erroneous to conclude that the prototype is profitable when the pilot farms achieve the desired Net Surplus. If the desired Net Surplus was already achieved in initial years, it may not be because the farm(s) in question converted to the prototype. The Net Surplus could even have been achieved in spite of the conversion! So only a stable level or a positive trend in the Net Surplus of farms for at least 3 years may be considered as a reliable indication of the profitability of the prototype.

It is recommended that achieved results be established by appropriate methods of sampling, observing and data processing, to prevent overall error from obscuring trends in the achieved results and from drawing premature or wrong conclusions.

12.1.3 Establishing the main cause of shortfall in results

Progress report 3 gave various examples of incorrectly establishing the cause of shortfalls in results (Vereijken, 1996). In addition, it is important to establish the cause of a persistent shortfall, to prevent stagnation in Step 4 and the risk of ending up with an unfinished prototype. It is also counterproductive to establish a wrong or a minor cause, such as ‘slow response’ or a minor method.
It is recommended that, in principle, only one main cause of a shortfall in results be established:
- *either the major method, as indicated in the theoretical prototypes (which is likely in initial years of testing);*
- *or a minor method, as indicated in the theoretical prototype (which may occur in later years of testing);*
- *or a slow response of the parameter in question (which may occur in initial years of testing and is likely in later years for inert parameters such as PAR, KAR and PSD).*

12.1.4 Establishing the first criterion not fulfilled by a method

The first criterion of a method that produces a shortfall in results may not be identified critically enough:
- in particular the criterion ‘effective’ may be too readily identified as the first criterion not being fulfilled, instead of one of the preceding criteria, i.e. 'not ready for use', 'manageable' or 'acceptable'.

Since most of the methods used in the network are new, it is hardly possible to state within a few years whether anyone of them is ready for use, manageable and acceptable, though not effective in achieving the desired result. Therefore the ‘effective’ criterion should be used with great care. Another reason for care in establishing whether a method is insufficiently or not at all effective is that this would call for revision of the theoretical prototype, by introducing a supporting method or skipping the method in question.
It is recommended that the first criterion not yet fulfilled by a method that is causing a shortfall in results be carefully established:
- *either ready for use (which is likely in initial years of testing),*
- *or manageable by the farmers (which may occur in initial years);*
- *or acceptable to the farmers (which may also occur in initial years);*
- *or effective (which may only occur in later years of testing).*

12.1.5 Establishing improvements of methods to fulfil consecutive criteria

The improving part of Step 4 is finalised by establishing targeted improvements of the methods causing a shortfall in results, to make them fulfill all 4 consecutive criteria. Subsequently, the testing part of Step 4 should be done again, to see if desired results will eventually be achieved
(if not, a new cycle of improving and testing is needed). Finalising the improving part of Step 4 places high demands on the expertise and creativity of the research team and farmers involved. This

vital stage of Step 4 received little attention in the projects on experimental farms in Report 3. In Report 4, the 3 selected pilot projects provide various examples of targeted improvements of methods, though the impression remains that there is insufficient expertise and creativity available for sufficient progress.

It is recommended to put more effort in establishing improvements of methods in line with the format (Chapter 5), to make more progress in this vital stage of Step 4.

12.2 Disseminating prototypes (Step 5)

Generally, 'dissemination' refers to the spreading of new information and technology. If it has been produced by insiders of the target group or by outsiders in close interaction with insiders, it could be called *bottom-up dissemination*. However, if the new information and technology has been produced by outsiders without or in scarce interaction with insiders, it should be called *top-down dissemination*.

Traditionally, agricultural researchers act as outsiders of the farming community, because they produce information and technology without any or only little interaction with farmers. Generally this is not considered a problem, because researchers disseminate their results mainly amongst colleagues, extensionists and policy makers. However, it implies that research results can only reach farmers in so far as extensionists and policy makers are willing and capable to incorporate those results in their messages and guidelines! Considering I/EAFS, traditional top-down dissemination would imply that researchers develop a general prototype on an experimental farm and policy makers and extensionists disseminate it amongst farmers.

12.2.1 Starting bottom-up dissemination by interactive prototyping with pilot farmers

There are various reasons why traditional top-down dissemination cannot be effective for I/EAFS:
- a general prototype cannot just be transferred from an experimental farm to any commercial farm in a region, because it requires adaptation to specific circumstances, notably the various types of soil and the various needs and wishes of the farmers in the region;
- farm-specific adaptation of a general prototype usually requires the adaptation of any method (MCR, I/ENM, EIM, etc.) to such an extent that the resulting prototype variant should again be tested and improved;
- elaboration of farm-specific variants of I/EAFS prototypes is usually beyond the capabilities of extensionists.

For these reasons, any team is recommended to make the final step of the methodical way to I/EAFS as follows:
(5) disseminating the prototype by pilot groups (<15 farmers), by regional networks (15-30 farmers) and, finally, by national networks (regional networks interlinked), with a gradual shift in supervision from researchers to extensionists.

So, sooner or later any research team should form a group of pilot farmers and draw up with them a representative set of prototypes variants. Such interactive prototyping with pilot farmers is an excellent start for bottom-up dissemination, which would not only be more effective but also save a lot of time and money in comparison to traditional top-down dissemination of a general prototype from an experimental farm. For this purpose the team of NL 2 has developed a model of interactive prototyping with pilot farms (Figure 11). As it appears to work quite satisfactorily, it has been accepted as a standard by the teams in the I/EAFS network. For interactive prototyping with 10 - 15 pilot farms, Step 4 can result in 10 - 15 variants of the prototype covering the regional ranges of soil, climate and management.

Interactive prototyping can also create a group of capable and motivated pilot farmers, which is an indispensable technological and social base for dissemination throughout a region. They can provide demonstration farms and can become involved in training and guiding of farmers willing to convert. To disseminate the prototype variants in wider circles, regional extension services should be trained to participate and gradually take over the innovation project. Currently, a minority of the research teams in the I/EAFS network is still just prototyping on an experimental farm. The majority of teams has already formed a pilot group, though in most cases the model of interactive prototyping has not yet been put into practice.

12.2.2 Reinforcing bottom-up dissimination by top-down dissemination

It would meet a lot of resistance within a farming community and would not be effective if extensionists and policy makers were to disseminate top-down, or even impose a prototype developed by researchers on an experimental farm. But if by interactive prototyping with pilot farmers a region-wide set of prototype variants were to become available, bottom-up dissemination could be reinforced by well-tuned top-down dissemination. This would imply various measures and guidelines from policy makers, but also processers, traders and consumer organisations, directly or indirectly exerting pressure on farmers to convert to the available I/EAFS variants. A. El Titi (DE 1) has elaborated a very successful and up till now unique combination of bottom-up and top-down dissemination in Baden- Württemberg (Chapter 7 in Report 4).

It is recommended that all teams try to reinforce bottom-up dissemination of their IAFS or EAFS prototype by a well-chosen set of top-down dissemination measures, as elaborated and highlighted by A. El Titi for the State of Baden-Württemberg, in general, and the Bruchsal region, in particular.

13. Epilogue

All over the world, agriculture is still being intensified, causing destabilisation of agro-ecosystems and environmental pollution. In developing countries it is understandable for various reasons, especially in those countries where food production can hardly keep pace with population increase. In industrialised countries it is absurd when one considers the growing surpluses of agricultural products, the decreasing income and employment in most rural areas and the growing concern of the consumers about the quality of their food. Fortunately, there is also a growing awareness that these immense problems cannot be solved one by one on an ad-hoc basis, but that a more comprehensive and sustainable approach of agriculture is needed. As a result, several new approaches have been proposed, such as sustainable (Allen & Van Dusen, 1988; Edwards et al., 1990), integrated (Vereijken & Royle, 1989) and alternative agriculture (National Research Council of USA, 1989). However, their use is limited because they are hardly defined in measurable terms, elaborated into concrete farming systems and tested for feasibility. Therefore, the current 5 steps method of prototyping has been developed to enable agronomists to design, test and improve more sustainable farming systems in interaction with pilot farms.

The method of prototyping I/EAFS presented here has its roots in two global organisations. The concept of IAFS is based on the work of the crop protectionists, assembled in the International Organisation for Biological and Integrated Control (IOBC). Initially, most working groups of IOBC aimed at the control of single pest species. However, this brought about various problems, such as insufficient cost effectiveness and the emergence of new pests. Therefore, they developed a wider scope and aimed at integrated protection of crops. During the last decade, the scope has further been widened to IAFS, comprising the entire crop rotation and also considering soil cultivation and fertilisation (Anonymous, 1977, Vereijken *et al.* 1986, El Titi *et al.* 1993). The concept of EAFS has been developed by the teams in the I/EAFS-network, searching for a more consistent and sustainable elaboration of IAFS. They have been inspired by the concept of organic farming, as defined by the standards and guidelines of the International Federation of Organic Agriculture Movements (IFOAM) (Geier, 1991). The great advantage of the organic concept is that it offers a market model of shared responsibility by producers and consumers for a sustainable and multifunctional management of the rural areas as agro-ecosystems. It is expressed by the principle of premium prices for the added ecological value of the products under label. This provides for the necessary economic base for the consistent and sustainable elaboration of IAFS, to be called EAFS. However, EAFS should go further than is demanded by the IFOAM guidelines for organic farming in sustainable and multifunctional management of the environment, nature/landscape and health/well-being of people and farm animals.

for the added ecological value of the products under label. This provides for the necessary economic base for the consistent and sustainable elaboration of IAFS, to be called EAFS. However, EAFS should go further than is demanded by the IFOAM guidelines for organic farming in sustainable and multifunctional management of the environment, nature/landscape and health/well-being of people and farm animals.

The method of prototyping I/EAFS presented here starts at the stage where most farming systems research stops, and that is the stage of analysis and diagnosis (Gibbon, 1994). However, the I/EAFS teams of the EU network, strong in agronomy and ecology, may improve their start by building on a more comprehensive and profound rural and farming systems analysis from research teams, strong in sociology and economy such as those led by Van der Ploeg (1995) and Sevilla Guzman (1994). The method of prototyping I/EAFS presented here is still provisionally elaborated considering the interaction with pilot farmers in general and the last step (5) of dissemination in particular. In this respect, the I/EAFS teams could also benefit from the expertise developed by teams, such as those led by Röling (1994). With this enlargement and reinforcement of their capacity, the teams of the I/EAFS-Network have excellent chances to succeed where up till now most farming systems researchers failed (Gibbon, 1994). Their work comes further than the step of diagnosis and analysis, and includes the subsequent steps of design, layout for testing and improving, and eventually dissemination.

Initial results are encouraging. Most teams are progressively achieving the desired results, although the effectiveness of prototyping can still be improved in various ways (Vereijken, 1996 and 1998). Nevertheless, the clear progress we achieved in our EAFS prototype for Flevoland (Fig. 5) may be considered as an example of the effectiveness of the prototyping in the I/EAFS network. This manual for prototyping I/EAFS marks the end of the current EU concerted action. The network will continue with F. Wijnands (NL1) following-up the author as convenor (annex 1).

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Annex I

Research Group on Integrated and Ecological Arable Farming Systems for EU and associated countries

EU countries	Participants	Projects	type	name	code
AUSTRIA **(A)**	Dr Christa Wutzl	University for Soil Culture Institute of Agronomy Gregor Mendelstr. 33 A-1180 Vienna Fax no. 43-1476543342	I/EAFS 1 exp. farm (in prep.)	-	A 1
BELGIUM **(B)**	Prof. Alain Peeters Ir Vincent van Bol	Université de Louvain Lab. d'Ecologie des Prairies Croix du Sud 5, (bte 1) 1348 Louvain-La-Neuve Fax no. 32-10472428	EAFS 7 pilot farms	Mid-Belgium	B 1
GERMANY **(DE)**	Dr Adel El Titi	State Inst. for Plant Protection Reinsburgstrasse 107 70197 Stuttgart 1 Fax no. 49-7116642498	IAFS 15 pilot farms	Baden-Württemberg	DE 1
	Dr. Michael Wildenhayn (Dr. Horst-Henning Steinmann)	Forschungs- und Studien-zentrum Landwirtschaft und Umwelt Von-Siebold-Str. 8 D-37075 Göttingen Fax no. 49-551394601	IAFS 1 exp. farm (4 pilot farms)	Niedersachsen	DE 2
DENMARK **(DK)**	Dr Gunnar Mikkelsen	Research Centre Foulum Dep. Forage Crops and Potatoes Postboks 23 8830 Tjele Fax no. 45-89991619	I/EAFS 1 exp. farm	Foulum	DK 1
	Dr Ib Sillebak Kristensen	Research Centre Foulum Production Systems Postboks 39 8830 Tjele Fax no. 45-89991200	EAFS 20 pilot farms	National Network	DK 2
SPAIN **(ES)**	Dr Ricardo Colmenares	Centro Invest. 'F.G. Bernaldez' C/ San Sebastián, 71 28791 Soto del Real (Madrid) Fax no. 34-18478130	EAFS 2 pilot farms (in prep.)	Manzanares	ES 1

FINLAND **(FIN)**	Dr Riikka Rajalahti	Dep. of Plant Production P.O. Box 27 00014 University of Helsinki Fax no. 358-9 708 5463	IAFS 7 pilot farms 1 exp. farm	Uusimaa	FIN 1
FRANCE **(F)**	Dr Philippe Girardin	INRA B.P. 507 68021 Colmar Cedex Fax no. 33-389224933	IAFS 17 pilot farms	Rhénane	F 1
	Dr Ivan Dlouhy Dr Daniel Cluzeau	University of Rennes Lab. Soil Ecology 35380 Paimpont Fax no. 33-0299618187			F 2
GREECE **(GR)**	Dr Kiriaki Kalburtji	Aristotle University Faculty of Agriculture Lab. Ecology and Env. Protection 54006 Thessaloniki Fax no. 30-31471795	EAFS (in prep.)	Kerkini	GR 1
ITALY **(I)**	Dr Enrico Raso	Dip. Di Scienze Agronomice Piazzale delle Cascine 18 50144 Florence Fax no. 39-55332472	I/EAFS 1 exp. farm	Montepaldi	I 1
	Dr Giampaolo Sarno	Research Center for Plant Production (C.R.P.V.) Via Emilia Levante, 18 40026 Imola (Bo) Fax no. 39-542609230	IAFS 3 pilot farms	Emilia-Romagna	I 3
IRELAND **(IRL)**	Dr Finnain Mac-Naeidhe	Johnstown Castle Research Centre - Wexford Fax no. 353-5342213	EAFS 10 pilot farms	Southeast and Midwest	IRL 1
LUXEMBURG **(L 1)**	Dr Jean Stoll	Federation of Herdbooks P.O. Box 313 9004 Ettelbruck Fax no. 352-810771			L 1

NETHERLANDS **(NL)**	Ir Frank Wijnands (coordinator from 1999 on)	Applied Research for Arable Farming and Field Production of Vegetables P.O. Box 430 8200 AK Lelystad Fax no. 31-320230479	I/EAFS 1 exp. farm	Nagele	NL 1
	Dr Pieter Vereijken	Research Institute for Agrobiology and Soil Fertility (AB-DLO) P.O. Box 14 6700 AA Wageningen Fax no. 31-317475952	EAFS 10 pilot farms	Flevoland	NL 2
PORTUGAL **(PT)**	Dr Mario Carvalho	University of Evora Department of Agronomy 7000 Evora Fax no. 35-1-66711163	IAFS (in prep.)	-	PT 1
SWEDEN **(S)**	Dr Carl-Anders Helander	Rural Economy and Agricultural Society P.O. Box 124 532 22 Skara Fax no. 46-51118631	I/EAFS 1 exp. farm	Logården	S 1
UNITED KINGDOM **(UK)**	Dr Vic Jordan	Long Ashton Research Station Long Ashton Bristol BS18 9AF Fax no. 44- 1275 394007	IAFS 1 exp. farm (8 pilot farms)	LIFE, (Southwest England)	UK 1
	Dr Sue Ogilvy	ADAS-High Mowthorpe Duggleby, Malton Y 017 8BP North Yorkshire Fax no. 44- 1944 738434	IAFS 6 exp. farms	LINK	UK 2

Countries outside EU

CZECH REPUBLIC **(CZ)**	Dr Jan Kren	Dep. General Plant Production Mendel University of Agriculture and Forestry Zemedelská 1 61300 BRNO Fax no. 00420-545133107	IAFS 2 exp. farms (in prep.)	South Moravia	CZ 1
Hungary **(HU)**	Dr Zoltán Berzsenyi	Agr. Res. Inst. Hung. Ac. Sc. H-2462 Martonvásár Hungary Fax no. 36-22460216			HU 1
POLAND **(PL)**	Dr Edward Majewski	Agricultural University Dep. Farm Management Nowoursynowska 166 02-787 Warsaw Fax no. 48-228431877	IAFS 8 pilot farms	Mazovia	PL 1
SLOVAKIA **(SL)**	Dr Magda Lacko- Bartosová	Agricultural University Dep. of Agricultural Systems Tr. A. Hlinku 2 94976 Nitra Slovakia Fax no. 421-87412835			SL 1