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2. Designing and Testing Prototypes

Progress Reports of the Research Network on Integrated and Ecological Arable Farming Systems for EU and associated countries (Concerted Action AIR 3 - CT920755)

AB-DLO
Wageningen, August 1995

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Summary

This second progress report of EU concerted action AIR-CT 920755 presents the state-of-the-art in European research on prototyping Integrated and Ecological Arable Farming Systems (I/EAFS). The basic objective is to establish a common frame of reference by elaborating and standardising the methodology which will be laid down and disseminated by 4 progress reports and finally by a manual (1993 - 1997)

The methodology of prototyping I/EAFS is elaborated as a methodical way involving 5 steps:

(1) *making a hierarchy of general and specific objectives (Part 1 of prototype's identity card);*
(2) *transforming the major (10) objectives into multi-objective parameters to quantify them and establishing the multi-objective methods needed to achieve the quantified objectives (Part 2);*
(3) *designing a theoretical prototype by linking parameters to methods and designing the methods in this context until they are ready for initial testing (Parts 3 and 4);*
(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 (Part 5);*
(5) *disseminating the prototype by pilot groups (<15 farmers), regional networks (15-30 farmers) and finally by national networks (regional networks interlinked) with a gradual shift in supervision from researchers to extensionists.*

This second progress report focuses on step (3) and the testing part of step (4). Nine teams with pilot projects have been selected to present the state-of-the-art in these steps as Part 3 (theoretical prototype), Part 4 (Multifunctional Crop Rotation) and Part 5 (agro-ecological layout) of their prototype's identity card.

The 9 identity cards clearly show the similarities and differences of the prototypes, but also their weak and strong sides, to the benefit of all participating projects, whether ongoing or in preparation.

The report ends with critical but constructive conclusions and recommendations, calling for further progress on the methodical way to more sustainable arable farming systems in Europe, for the short term (IAFS) and the long term (EAFS).

1 Introduction to the concerted action

In agreement with the programme of the concerted action (annex 1), the first progress report dealt with designing prototypes, on experimental farms in particular.

In this second progress report, the scope has been widened to testing prototypes, on pilot farms in particular. This implies considerably widening the initial research network to include teams of pilot projects. A major aim is for these teams also to follow the methodical way of IAFS prototyping, first of all by having the state-of-the-art of their pilot projects presented in terms of the common methodology.

The shift of focus from single experimental farms to groups of pilot farms in this second progress report is more than a mere consequence of considering the next step in prototyping. It also meets the strong recommendation of the first progress report to design, test and improve prototypes with the same group of pilot farms. This avoids the agro-ecological, agronomic and economic distortions of prototyping on an experimental farm and saves time and money, because prototyping on an experimental farm always requires continuation of testing and improving on pilot farms.

1.1 The first year reviewed

The first progress report deliberately avoided pinning down Integrated Arable Farming Systems (IAFS) by a general definition. Instead, IAFS was presented as a challenge that any research team should design, test, improve and disseminate in the context of its own region, after having established the major shortcomings of the conventional farming systems in relation to the major objectives to be achieved.

Teams may develop IAFS prototypes for the short term and/or for the long term. For the short term they develop an IAFS feasible for the main group of farmers. 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, nature/landscape and sustainability of food supply. Therefore, a more consistent integration of objectives is needed for a more sustainable development of the rural areas. Consequently, most 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 farmers. Contrary to short-term IAFS, these long-term IAFS place income/profit subordinate to abiotic environment, and rely on ecologically-aware consumers willing to pay premium prices for food products with high added value and a credible label.

At present, it seems Common Agricultural Policy (CAP) and national agricultural policies are increasingly being reconsidered to encourage the main group of farmers to switch to IAFS. However, it also seems to be becoming a principle of policy that European farmers should face a liberalising world market and try to survive with no or minimum government protection. As a result, transition to IAFS can only provide for a temporary alleviation, but not for a sustainable solution of the crisis of pollution of the environment, degradation of nature/landscape and overproduction, which is causing a further decline of income/employment in rural areas. Therefore, the development of IAFS for the long term is certainly the most crucial contribution our research network should deliver to Europe.

Without exception the 8 teams with long-term prototypes listed in the first progress report have opted to replace Chemical Crop Protection by Multifunctional Crop Rotation supported by Ecological Infrastructure Management and Integrated Crop Protection, the latter without pesticides of course. This is considered to be the only way 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. However, it should be explicitly stated that EAFS are not the same as the organic farming systems that currently feature under an official European label. 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 offers a model of producers and consumers sharing responsibility for the multifunctional management of the rural areas. Therefore, many teams are collaborating with a pilot group of organic farmers that have primarily been selected for their willingness to achieve more than is required by current minimal guidelines of the EU organic label.

Because IAFS for the short term and EAFS for the long term should complement each other, not compete each other, it is not sensible to develop them in separate research networks. So far, the differences in the social and ideological backgrounds of IAFS and EAFS have received more emphasis than their similarities (their complementary roles for our common future). This is counterproductive not only for sustainable development of the rural areas but also for the development of farming systems research into a full-grown discipline.

In Section 1.3 it is established, that there are still very few of I/EAFS pilot projects ongoing in Europe. This should be an extra incentive to European research teams on IAFS and EAFS to join our concerted action and support us developing a common network and a common methodical way of prototyping.

1.2 Scope of the second year

As elaborated in the first progress report of the concerted action, the basic design of I/EAFS implies 2 initial steps:

(1) making a hierarchy of general and specific objectives (prototype's identity card Part 1);
(2) transforming the major (10) objectives into multi-objective parameters to quantify them and establishing the multi-objective methods needed to achieve the quantified objectives (prototype's identity card Part 2).

However, most of the methods needed to carry out these steps are lacking or are not ready for use. As a result, the third step is to link parameters to methods in a theoretical prototype and to design the methods in conformity with their links until they are ready for initial use. The fourth step is to test and improve the prototype on-farm from year to year until its objectives have been achieved. Consequently, at the second workshop, 2 subsequent steps were discussed:

(3) designing a theoretical prototype by linking parameters to methods and designing the methods in this context until they are ready for initial use;
(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.

The first 3 steps may be done within a year, but step (4) consumes the most time and money because it implies laying out the prototype repeatedly during a range of years. Three factors make step (4) last so long:
- the pilot farmers need time to understand and accept the prototype in all its objectives and methods and to learn to manage it optimally;
- the research teams need time to optimise the prototype in all its methods;
- abiota (soil, groundwater) and biota (crops, flora and fauna) need time to respond reliably and steadily to the optimised prototype.

Even if pilot farmers and research teams only needed 1 year to come to an optimal layout, step (4) would require at least an extra 4 years for IAFS and 6 years for EAFS before each field would have gone through a complete crop rotation. Most of the turbulence in soil and crop responses only disappears after one cycle of the prototype, so only then can reliable responses from the major parameters be acquired. However, the precise number of years needed for testing and improving depends on the composition of the set of parameters, because these parameters differ greatly in speed of response, depending on their nature and also on how ambitious the targets that have been set (compare the targets of ≤ 50 or ≤ 25 mg nitrate l^{-1} groundwater)!

In general it can be stated that testing the prototypes is a matter of operating the set of parameters by comparing the results achieved with the desired results, as quantified in the Part 2 of the prototype's identity cards. Improving the prototypes is a matter of operating the set of methods, by relating the possible shortfall between achieved and desired results to the methods linked to the parameters in question, and by improving them in a targeted way.

Prototypes can be tested and improved on an experimental farm or with a group of pilot farmers. In Section 10.4 of the first progress report it was concluded that prototyping on an experimental farm may easily lead to agro-ecological, agronomic and economic distortions, because of un-representative scale and management and lack of replicates to cover the regional ranges of soil, climate, farm structure and farm management. Of course, that does not mean you cannot try to minimise these disadvantages and develop useful prototypes on an experimental farm. Nevertheless, you will always need to repeat steps (3) and (4) with a group of pilot farms to answer the question of feasibility and competitiveness of the new system, which is a prerequisite for the final step of dissemination. As a result, steps (3) and (4) should sooner or later be done together with a group of pilot farms. Therefore, a major challenge in this concerted action is to cover the entire methodological way of designing, testing and improving with a group of pilot farms. This could be called 'interactive' prototyping.

The scope of this second year is to consider steps (3) and (4) in more detail. Step (4) is only considered for the testing part because together with step (3) it offers sufficient subjectmatter.

The second part of step (4) concerning the improvement of prototypes will be considered in the third year, at a workshop and in a progress report, both entitled "Testing and Improving Prototypes". Subsequently, the scope of the fourth and last year will be "Improving and Disseminating Prototypes", As a result, the major steps of designing, testing and improving will each be considered during 2 years, to ensure that the methodology and state-of-the-art are elaborated and presented completely and successfully .

1.3 Layout of the second progress report

This second progress report is laid out as follows.

After presenting 9 selected teams and their pilot projects (Chapter 1.4),
Parts 1 and 2 of the identity cards (hierarchy of objectives and parameters/methods) of 4 incoming pilot projects are presented (Chapter 2).

Designing a theoretical prototype is explained and formats are proposed to design the methods of the EU shortlist in this context (Chapter 3).

Based on this format, the 9 selected pilot projects present a theoretical prototype as Part 3 of their prototype's identity card (Chapter 4).

Following a format for designing a Multifunctional Crop Rotation as the central method, the 9 selected pilot projects present an MCR as Part 4 of their prototype's identity card (Chapter 5).

Testing a prototype on-farm is explained and formats are proposed to operate the single parameters of the EU shortlist (Chapter 6).

The 9 selected pilot projects present the layout of their pilot group and a representative pilot farm as Part 5 of their prototype's identity card (Chapter 7), in a standardised way.

The organising teams of NL 1 and NL 2 present the state-of-the-art-of their pilot projects in testing of their IAFS (NL1) and EAFS (NL 2) prototypes (Chapters 8 and 9).

The second progress report ends with conclusions and recommendations (Chapter 10) and a list of selected new references.

Table 1. List of selected European pilot projects in I/EAFS prototyping ongoing in 1994

Specific criteria (explained in 1.4)		**B 1** Mid-Belgium	**DE 1** Baden-Württemberg	**DE 3** Nordrhein West-falen	**DK 2** National network	**F 1** Ferté-Vidame	**IRL 1** Southeast and Midwest	**NL 1** National network	**NL 2** Flevo-land	**PL 1** Mazovia
Duration (years)										
IAFS	≥ **4**	-	5	6	-	3	-	4	-	6
EAFS	≥ **6**	4	-	-	10	-	4	-	6	-
Number of farms										
IAFS	≥ **10**	-	15	10	-	8	-	38	-	15
EAFS	≥ **10**	8	-	-	20	-	11	-	10	-
Project's main objective										
Development (prototyping)	= **1**	1	1	1	1	1	1	1	1	1
Scientist years farm^{-1}										
Development	≥ **0.1**	0.13	0.15	0.13	0.1	0.15	0.2	0.03	0.15	0.25
Project full-timers	≥ **1**	1	1	2	2	1	1	0	1	0
Research leader										
% time involved	≥ **40**	100	40	100	70	100	60	50	70	50
Main activity of leader										
Designing farming systems	= **1**	1	1	1	1	1	1	1	1	1
Multi-objective methods	≥ ***									
Multifunctional Crop Rotation		*	*	*	*	*	*	*	*	*
Int. or Ecol. Nutrient Management		*	*	*	*	*	*	*	*	*
Integrated Crop Protection		*	*	*	*	*	-	*	-	*
Env. Exp.-based Pesticide Selection		-	-	-	-	-	-	-	-	*
Minimum Soil Cultivation		-	*	*	-	*	*	-	-	-
Ecol. Infrastructure Management		*	*	-	*	*	*	-	*	*
Farm Structure Optimisation		*	-	-	*	*	*	-	*	*

1.4 Selection of pilot projects

Research leaders and their projects have been selected for the workshop and progress report of this second year of concerted action on almost the same sets of general and specific criteria as used in the first year.

General criteria

(1) Up to 25 participants may attend the workshop, up to 3 from large countries and up to 2 from small countries.
(2) Participants must be the creative leaders of research teams on I/EAFS projects.
(3) Ongoing projects are preferred to projects in preparation, but the latter may be admitted if at an advanced stage of planning.
(4) In this second year, the programme of the concerted action stipulates that pilot projects are preferred to projects on experimental farms, but the latter may be admitted if a country does not have enough pilot projects to participate.

Based on these 4 general criteria, 23 research leaders from ongoing projects or projects in preparation have been invited to the workshop to be held 2-7 July in Wageningen (Annex 2). Of the 18 ongoing projects, 16 are projects on pilot farms and 2 are projects on an experimental farm. A pilot farm is a commercial farm with one prototype system being researched.
An experimental farm is a non-commercial farm, usually with more than one system being researched, therefore the systems and fields are mostly much smaller than on commercial farms.

Specific criteria

(1) *Project duration ≥ 4-6 years*
An IAFS or EAFS requires at least one period of a full rotation i.e. 4 or 6 years to be developed (explanation in Chapter 1.2).
(2) *Size of pilot group ≥ 10 farms*
Prototyping requires at least a pilot group of 10 farms to cover the regional ranges in soil, climate, farm structure and farm management.
(3) *Development = project objective number 1*
Only projects primarily aimed at development are expected to deliver an appropriate contribution to the concerted action. Comparison and demonstration have their use, of course, but should be subordinate.
(4) *Scientist years farm^{-1} ≥ 0.1*
Prototyping on pilot farms requires at least the above input from scientists. This is the experience of teams of the first wave.
(5) *Project full-timers ≥ 1*
Prototyping, whether on pilot farms or on an experimental farm, requires the total commitment of at least 1 scientist.
(6) *Research leader ≥ 40% involved*
The leadership of a team on I/EAFS prototyping, whether on pilot farms or an experimental farm, requires involvement for at least 2 days/week.
(7) *Main activity of research leader =design*
The leadership of a team on I/EAFS prototyping primarily requires creative input.
(8) *Research programme ≥ 3 methods of the 1993 European shortlist*
At least 3 multi-objective methods of the 1993 European shortlist should be considered in the research programme of any pilot project, to ensure there is sufficient common interest to merit joining the network.

Although these 8 specific criteria are far from ambitious from a professional point of view, in 1994 only DE 1, DE 3, DK 2 and NL 2 can fulfil them all (Table 1). However, it is reasonable to consider the criteria as future milestones, because prototyping of farming systems is still in its infancy. Therefore, another 5 pilot projects have been selected to describe their state-of-the-art in this report. They also have at least 1 scientist year in development of a prototype, so is the product of number of pilot farms (criterion 2) and scientist years farm^{-1} in development (criterion 4) ≥1. In addition, they have a research leader, spending at least 40 % of his/her time (criterion 6) in designing as a main activity (criterion 7).
The remaining pilot projects whether ongoing or in preparation (Annex 2), will be described in the third or fourth progress report, if they sufficiently fulfil the criteria by then.

2 Identity cards Parts 1 and 2 of selected incoming pilot projects

There are 4 newcomers in the group of 9 pilot projects selected for describing the state-of-the-art (Table 1). DE 3 and PL 1 are incoming teams with IAFS pilot projects. B 1 and DK 2 are incoming teams with EAFS pilot projects. Against the background of the updated European average after 2 years of concerted action (1993-1994), the 4 newcomers present the hierarchy of objectives of their prototypes graphically as Part 1 of their identity cards (Section 2.1). Subsequently, they present the set of multi-objective parameters and methods used in their prototypes to quantify and achieve the 10 major objectives as Part 2 of their identity cards (Section 2.2). See Progress Report 1 for Parts 1 and 2 of the remaining 5 pilot projects in the group.

2.1 Hierarchy of objectives as Part 1

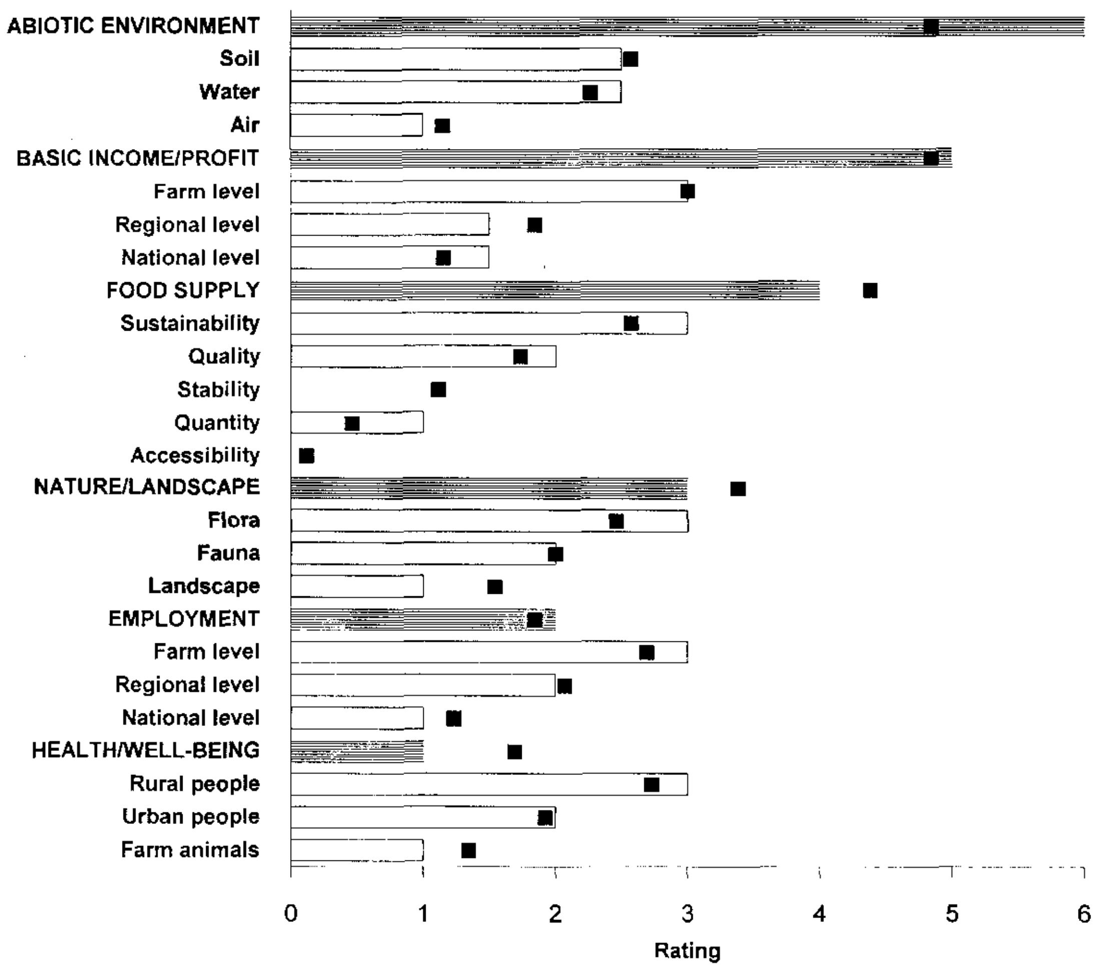


Figure 1.1.1 Hierarchy of objectives in IAFS prototyping in Nordrhein-Westfalen (DE 3) (squares - average of 13 European IAFS prototypes)

In Nordrhein-Westfalen the abiotic environment is the main objective, ahead of basic income/profit and food supply.
In abiotic environment, the focus is equally on protection of soil and groundwater against erosion and leaching of nitrate and pesticides. Both of these risks are important in the region, because of its predominantly light soils. Therefore, soil tillage is reduced, catch crops are grown and nutrient balances are drawn up at farm and field levels.
Basic income/profit of the pilot farms is the second objective, since it is under pressure from the shift of CAP to the world market and should not be suppressed further because of environmental innovation.
Food supply is the third objective, with the focus on sustainability. It should be safeguarded by safeguarding the long-term fertility of the vulnerable sandy and loamy soils.

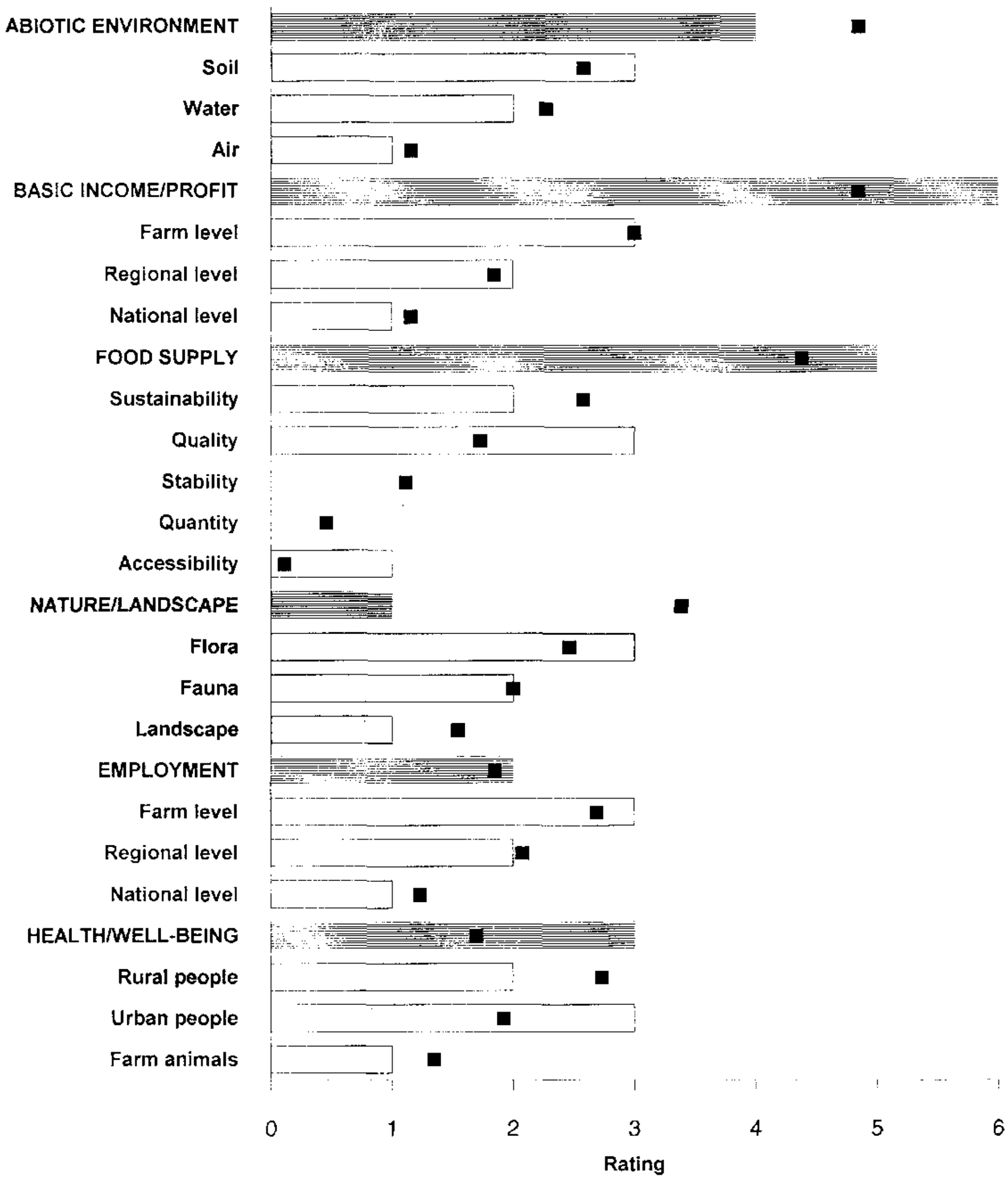


Figure 1.1.2 Hierarchy of objectives in IAFS prototyping in Mazovia (PL 1) (squares - average of 13 European IAFS prototypes)

In Mazovia basic income/profit is the main objective, ahead of food supply and abiotic environment.
Improving basic income/profit of the pilot farms is given the highest priority, because it has been strongly reduced as a result of the economic reforms in Poland. Therefore, ecological innovation is only feasible if profitable! Improving farm management is considered the best way to improve basic income/profit.
Food supply is the second objective. Quality is focused on to remain competitive on saturating markets and to meet the increasing demand for quality products. Attention to quality, sustainability and accessibility (prices) of food supply is considered to be the best support to farm income/profit and thus to ecological innovation.
Abiotic environment is the third objective, since the long-term viability of the farms is very dependent on this. Careful management of the soil is given priority, because it will result in clean water which is of equal importance.

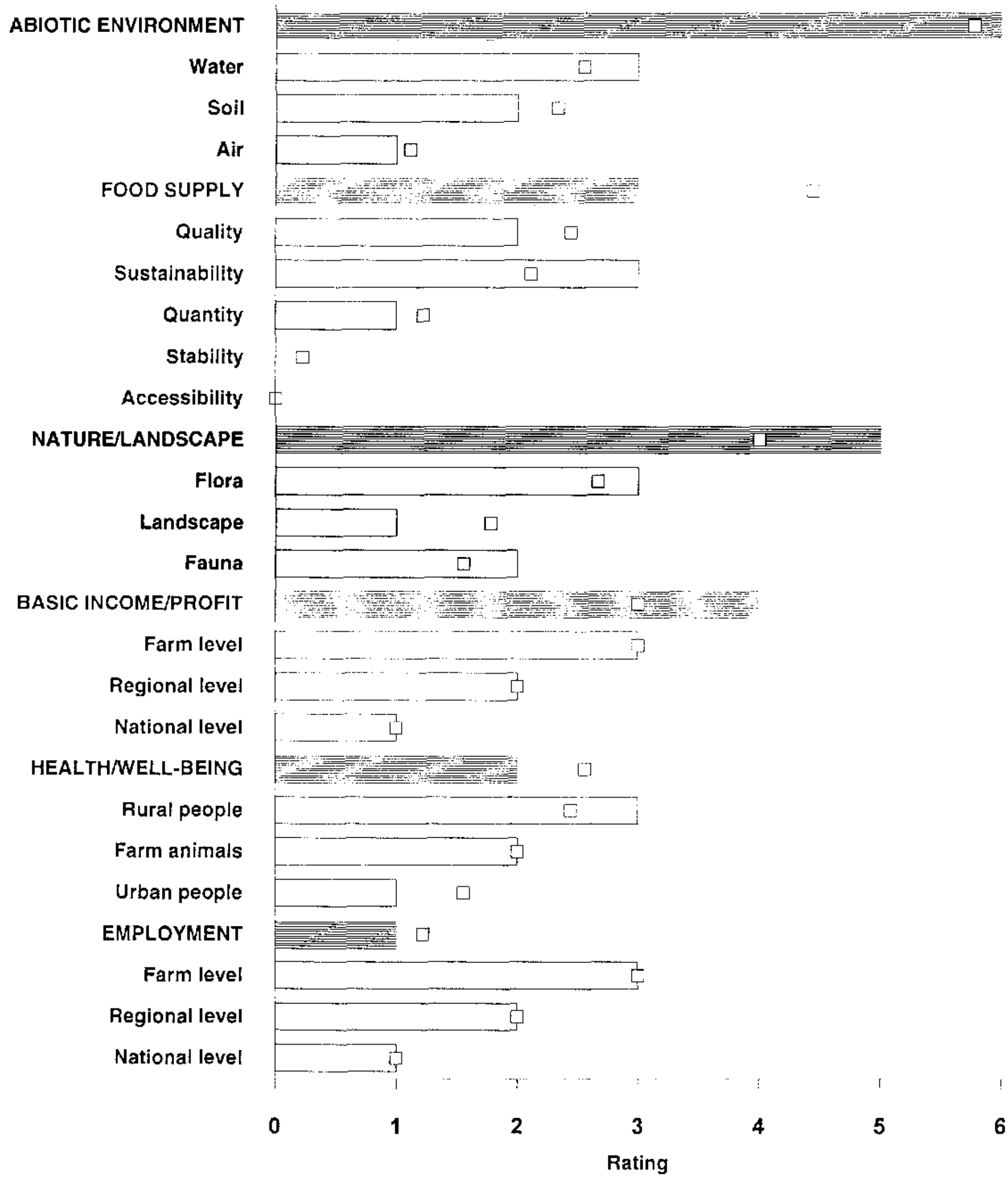


Figure 1.2.1 Hierarchy of objectives in EAFS prototyping in mid-Belgium (B 1).
(squares - average of 9 European EAFS prototypes)

In mid-Belgium abiotic environment is the main objective, ahead of nature/landscape and basic income/profit.
In abiotic environment, the focus is on water conservation because of the increasing pollution of sources of drinking water in the region. Since 1993, consumers have paid levies to finance purification.
Nature/landscape is the second objective, because it is deteriorating in the region as a result of urbanisation and industrialisation, including intensification of agriculture. As a result, the people are increasingly valuing nature/landscape as essential for the quality of life.
Basic income/profit is the third objective, to ensure the feasibility of the EAFS prototype at the farm level.

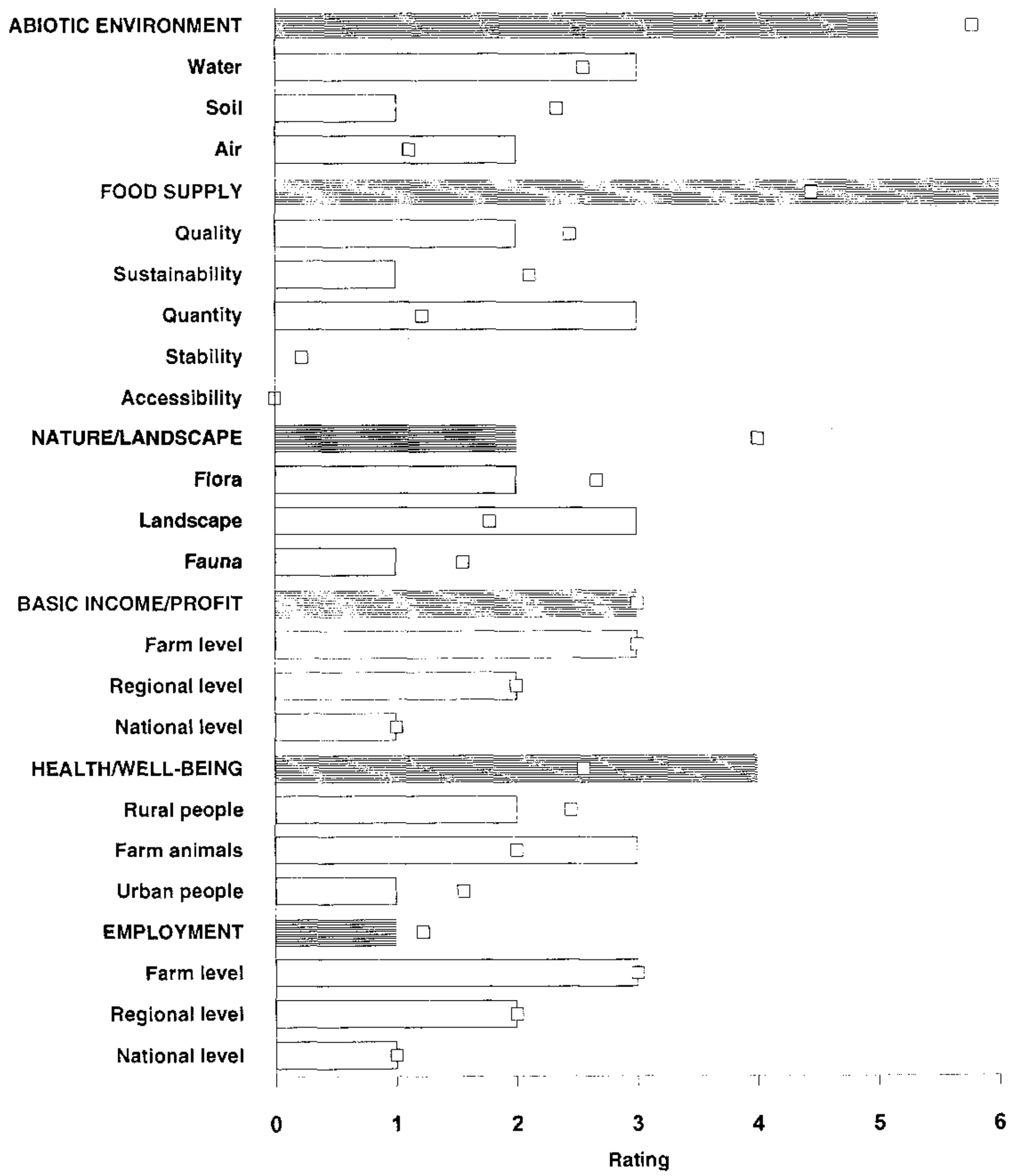


Figure 1.2.2 Hierarchy of objectives in EAFS prototyping in National Pilot Farm Network (DK 2). (squares - average of 9 European EAFS prototypes)

In Denmark (national network) food supply is the main objective, ahead of abiotic environment and basic income/profit.
In food supply, the focus is on quantity in relation to the inputs needed. It is considered of crucial importance for the potential of EAFS (whether or not mixed)to feed the population whilst achieving a sufficient basic income/profit.
Abiotic environment is the second objective, with the focus on water because of the increasing pollution by intensive animal husbandry.
Health/well-being is the third objective, with the focus on farm animals. It is considered of crucial importance for the development of sustainable mixed farming systems.

2.2 Parameters and methods as Part 2

Table 2.1.1 Quantifying and achieving objectives in IAFS prototyping in Nordrhein-Westfalen (DE 3)

Major objectives ranked	Major objectives quantified in multi-objective parameters	Major objectives achieved by multi-objective farming methods
1. Abiotic environment - Soil	1.1 SCI $\geq$ 0.9 1.2 OMAB = 1 1.3 PAB = 1 1.4 KAB = 1 1.5 pH = optimum for local soil/MCR 1.6 EEP<EEP of CAFS 1.7 PI < ?	1. MCR, MSC, INM, EEPS, ICP
2. Abiotic environment - Water	2.1 NAR < 45 kg ha^{-1} 2.2 NGW $\leq$ 11,2 mg l^{-1} see 1.6-1.7	see 1
3. Basic income/Profit - Farm level	3.1 QPI $\geq$ x $product^{-1}$ 3.2 NS $\geq$ NS of CAFS	3. FSO
4. Sustainability Food supply	see 1 and 2	see 1
5. Nature/Landscape - Flora	5.1 EI = 3 % 5.2 PSD = ? 5.3 Animal Species Diversity (ASD) = ?	5. EIM
6. Food supply - Quality	see 3.1	see 1
7. Basic income/Profit - Reg. level	see 3	see 3
8. Basic income/Profit - Nat. level	see 3	see 3
9. Abiotic environment - Air	see 1 and 2	see 1
10. Nature/Landscape - Fauna	?	see 5
	Total parameters: 13 EU, 1 local	Total methods: 7 EU, 0 local

In Nordrhein-Westfalen the major 10 objectives are quantified in 14 multi-objective parameters, 1 of which is not on the European list (Table 3 in Progress Report 1).
Parameter 5.3 specifies the number of target animal species $farm^{-1}$ to be achieved in the Ecological Infrastructure. The major 10 objectives as quantified in 14 parameters are achieved by 7 multi-objective methods, all on the European list (Table 4 in Progress Report 1).

Table 2.1.2 Quantifying and achieving objectives in IAFS prototyping in Mazovia (PL 1)

Major objectives ranked	Major objectives quantified in multi-objective parameters	Major objectives achieved by multi-objective farming methods
1. Basic income/Profit - Farm level	1.1 NS > 0 1.2 EE>x	1. FSO, INM, ICP
2. Food supply - Quality	2.1 QPI > 0.75 additional parameters	2. MCR, EIM see 1 (INM, ICP)
3. Abiotic environment - Soil	3.1 pH > 5.5 3.2 PAB = 1 3.3 KAB = 1 3.4 OMAB >1 3.5 EEP soil < x_s 3.6 NAR < x_n 3.7 SCI ≥ ?	3. MCL, EEPS see 1 (FSO, INM)
4. Basic income/Profit - Reg. level	see 1	see 1
5. Food supply - Sustainability	see 1.2 and 3	see 2
6. Health/Well-Being - Urban people	see 3 and 7	see 1 (ICP, INM)
7. Abiotic environment - Water	7.1 ND/GW < EU norm	see 1-3
	7.2 EEP groundwater < x_w	
8. Employment - Farm level	8.1 FE > x_e	
9. Health/Well-Being - Rural people	see 3 and 7	see 1 (ICP, INM)
10. Basic income/Profit - Nat. level	see 1	see 1
	Total parameters: 12 EU, 0 local	Total methods: 7 EU, 0 local

In PL1 the major 10 objectives are quantified in 12 multi-objective parameters and achieved by 7 multi-objective methods, all on the European lists (Tables 3 and 4 in Progress Report 1).

Table 2.2.1 Quantifying and achieving objectives in EAFS prototyping in mid-Belgium (B 1)

Major objectives ranked	Major objectives quantified in multi-objective parameters	Major objectives achieved by multi-objective farming methods
1. Abiotic environment - Water	1.1. NGW<11.2 mg l^{-1} (EU norm) 1.2 EEP-water = 0	1. MCR, ENM
2. Nature/Landscape - Flora	2.1 EI ≥ 5 % farm area 2.2 PSD = ? 2.3 FD = ?	2. EIM
3. Basic income/Profit - Farm level	3.1 NS > 0 3.2 QPI > x $product^{-1}$ 3.3 MKGI > 3000 L cow^{-1} yr^{-1} 3.4 MTGI > x Kg cow^{-1} yr^{-1}	3. MGM, FSO see 1
4. Abiotic environment-Soil	4.1 EEP-soil = 0 4.2 x < KAR < y * KAB > 1 if KAR < x KAB < 1 if KAR > y ** 4.2 x < PAR < y * KAB > 1 if PAR < x KAB < 1 if PAR > y **	4. see 1 and 3
5. Nature/Landscape - Fauna	see 2	see 2
6. Food supply - Quality	see 3.3	see 3
7. Basic income/Profit - Reg. level	see 3.1	see 3
8. Abiotic environment-Air	8. EEP air = 0	see 1
9. Food supply - Sustainability	see 1-8	see 2 and 3
10. Health/Well-being-Rural people	see 1-9	see 2 and 3
	Total parameters: 10 EU, 3 local	*Total methods: 4 EU, 1 local*

* For P and K the optimum ranges depend on clay and organic matter contents and vary from farm to farm. The optimum range for P differs between grass and other crops.

** If actual PAR or KAR is in optimum range, PAB or KAB = 1.

In mid-Belgium the major 10 objectives are quantified in 13 multi-objective parameters, of which 3 (2.3, 3.3 and 3.4) are not on the European list (Table 3 in Progress Report 1).
Parameter 2.3 is Flower Density (FD) and specifies the number of flowers per metre of Ecological Infrastructure to be achieved from month to month.
Parameter 3.3 is the Milk from Grass Index (MKGI) and specifies the share of annual milk production per cow to be based on grass. Similarly, parameter 3.4 is the Meat from Grass Index (MTGI) specifying the share of annual meat production to be based on grass. Thus, both parameters specify the degree of soilborne animal production.
The major 10 objectives as quantified in 13 parameters are achieved by 5 multi-objective methods, of which 1 (3.1) is not on the European list (Table 4 in Progress Report 1).
Method 3.1 is Multifunctional Grassland Management (MGM). Similarly to MCR, MGM is aimed at conserving soil fertility (physically, chemically and biologically) to sustain quality production in grass and milk/meat with minimal external inputs (fertilisers, feedstuffs, pesticides). Similarly to the annual crop plan of MCR, MGM is expressed in the annual grazing/mowing plan ('grazing calendar')

Table 2.2.2 Quantifying and achieving objectives in EAFS prototyping in Denmark (DK 2)

Major objectives ranked	Major objectives quantified in multi-objective parameters	Major objectives achieved by multi-objective farming methods
1. Food supply - Quantity	1.1 QPI ≥ x product^{-1}	1. MCR, MCL, ENM
2. Abiotic environment - Water	2.1 NAB = ? 2.2 KAB > 1 2.3 PAB > 1 2.4 NAR = ? 2.5 SCI > 0.65 2.6 EEP = 0	see 1
3. Food supply - Sustainability	see 1	see 1
4. Health/Well-being - Farm animals	?	4. ?
5. Abiotic environment - Air	see 2	see 1
6. Basic income/Profit - Farm level	6. NS = ?	6. FSO
7. Health/Well-being - Rural people	?	7. ?
8. Food supply - Quality	see 1.1	see 1
9. Basic income/Profit - Reg. level	see 6	see 6
10. Nature/Landscape - Landscape	10. EI ≥ 5 %	EIM
	Total parameters: 9 EU, 0 local	Total methods: 5 EU, 0 local

In Denmark the major 10 objectives are quantified in 9 multi-objective parameters, and achieved by 5 multi-objective methods, all on the European lists (Tables 3 and 4 in Progress Report 1).

Table 3. Shortlist of multi-objective parameters and methods * in I/EAFS prototyping 1994 (> 5 prototypes)

Parameters Name	Prototypes	**Methods** Name	Prototypes
NS (Net Surplus)	16	**MCR** (Multifunctional Crop Rotation)	16
EI (Ecological Infrastructure)	14	**INM, ENM** (Integr./Ecol. Nutrient Management, cover crops, recycling of organic waste and biol. N fixation included)	16
NAR (N Available Reserves)	14		
PAB, KAB (PK Annual Balances)	12	**EIM** (Ecological Infrastructure Management)	14
QPI (Quality Production Index)	12	**ICP** (Integrated Crop Protection)	11
SCI (Soil Cover Index)	11	**FSO** (Farm Structure Optimisation)	10
NGW, NDW (N Groundwater/Drainage Water)	11	**MSC** (Minimum Soil Cultivation)	7
OMAB (Organic Matter Annual Balance)	9	**EEPS** (Environment Exposure-based Pesticides Selection)	6
PI ** (Pesticide Index)	8		
PSD (Plant Species Diversity)	7		
EE (Energy Efficiency)	7		
EEP ** (Environment Exposure to Pesticides)	6		
PAR, KAR (PK Available Reserves)	6		

* See tables 3-4 of first progress report for definitions
** Contrary to EEP, PI is only useful if reference CAFS is available.

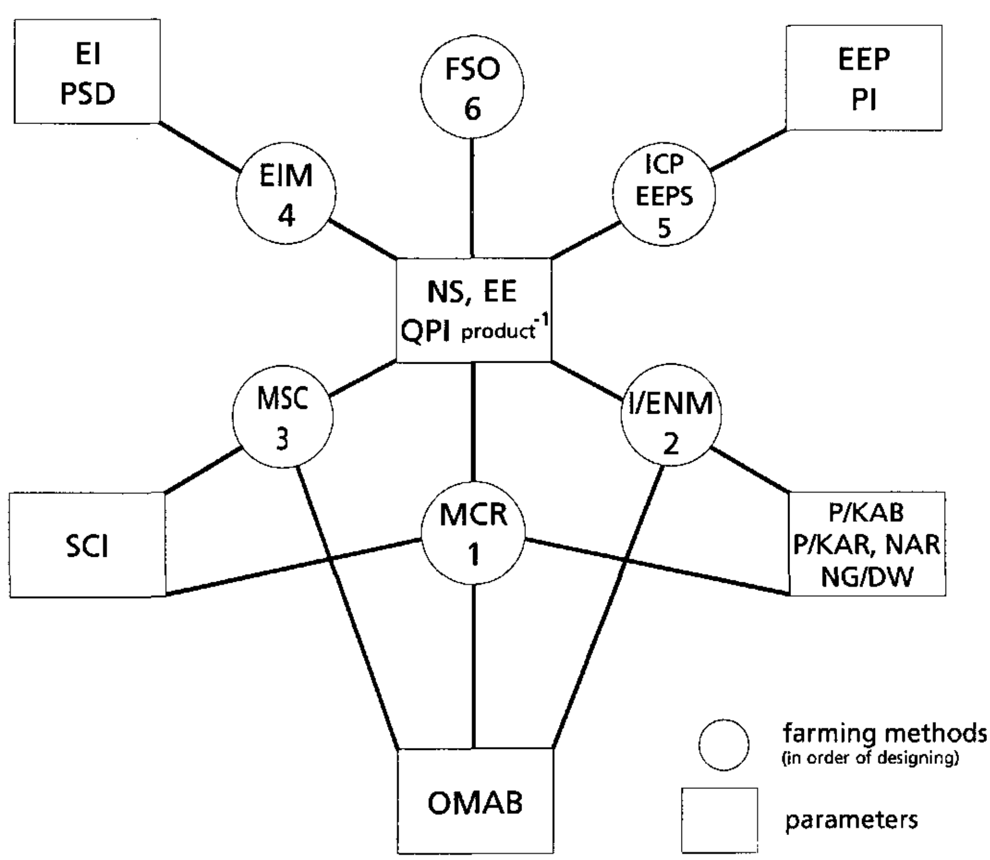


Figure 2 Basic theoretical prototype linking parameters and methods of the European shortlist

3 Designing a theoretical prototype and methods in this context

An updated European shortlist of the major parameters and methods needed has been drawn up, (Table 3) taking Part 2 of the identity cards of the incoming pilot projects (Tables 2.1.1-2.1.2 and 2.2.1-2.2.2) into account. Most of the methods have to be designed or redesigned, because they are non-existent or not ready for use. However, you cannot design them 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) at first you design a theoretical prototype by linking the methods to the parameters they should help to achieve (Section 3.1), before you proceed by designing the methods in their appropriate context (Section 3.2).

3.1 Linking parameters and methods in a theoretical prototype

In Fig. 2 the parameters and methods of the European shortlist are linked in a general theoretical prototype, with the methods numbered in order of designing based on agronomic, agro-ecological and economic considerations.

(1) *Multifunctional Crop Rotation (MCR)* plays a central role, as a major method to achieve desired results in multi-objective parameters of soil fertility and environment, as well as in the Quality Production Index of each product (QPI) and in the major parameters of economic and energy efficiency (NS and EE). So, first a well-balanced 'team' of crops should be designed, requiring the minimum of inputs that are polluting and based on fossil energy (nutrients, pesticides, machinery and fuel) to maintain soil fertility and crop vitality as a base for quality production.

(2) *Integrated Nutrient Management (INM)* or *Ecological Nutrient Management (ENM,* all nutrients from recycling of organic waste), should be designed to support MCR in achieving optimal QPIs by maintaining agronomically desired and ecologically acceptable nutrient reserves in the soil and with MSC, by maintaining an appropriate Organic Matter Annual Balance (OMAB), especially on soils susceptible to erosion and leaching.

(3) *Minimum Soil Cultivation (MSC)* should be designed to support MCR in achieving optimal QPIs by incorporating crop residues, controlling weeds and restoring physical soil fertility from compaction by machines, whilst maintaining the Soil Cover Index (SCI), a major parameter for sustainability of food supply, environment and nature/landscape. In addition, MSC should support MCR and I/ENM in maintaining OMAB on soils susceptible to erosion and leaching.

(4) *Ecological Infrastructure Management (EIM)* should be designed to support MCR in achieving optimal QPIs by providing airborne and semi-soilborne beneficials a place to overwinter, and recover and disperse in spring. In addition, EIM should achieve nature/landscape objectives.

(5) *Integrated Crop Protection (ICP) and Environment Exposure-based Pesticide Selection (EEPS)* should jointly be designed to support MCR and EIM in achieving optimal QPIs by selectively controlling remaining harmful species with minimal exposure of the environment to pesticides. The latter applies especially to IAFS, where MCR cannot be fully exploited since predominantly short-term profitable crops must be grown to remain competitive on the world market. However, pesticides in ICP should be progressively replaced by EEPS to achieve ever lower EEP (or PI).

(6) *Farm Structure Optimisation (FSO)* should be designed to determine the minimum amounts of land, labour and capital goods needed to achieve the required Net Surplus and Energy Efficiency of the I/EAFS. For many regions or farms this may imply a considerable scaling up of the farm area. IAFS at Nagele may serve as an example (Section 9.4 of first progress report).

This theoretical prototype linking the European shortlist methods and parameters is proposed as a base for all European I/EAFS research teams to build their own region-specific prototype from the set of European and local parameters and methods in their prototype's identity card Part 2 (Table 6 in Progress Report 1 or Table 2 in this Progress Report 2).

Format A Potential crops in your MCR in order of profitability, with their major characteristics for preserving biological and physico-chemical soil fertility (set-aside included)

crop	biological		physical (ratings)				chemical (N ratings)	
no.	species	group[1]	cover[2]	rooting[3]	compaction[4]	structure[3+4]	offtake[5]	transfer[6]
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
mean of crop selection								

Format B Designing an MCR of ≥ 4 (IAFS) or ≥ 6 (EAFS) blocks

block	crop	biological		physical (ratings)		chemical (N ratings)		
no.	no.	species	group	cover [2]	structure [3+4]	offtake[5]	transfer[6]	need[7]
I	1							
II								
III								
IV								
V								
VI								
VII								
VIII								
mean of crop rotation		share species^{-1} ≤	share group^{-1} ≤					

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 <u>and</u> winter = -4, no cover in autumn <u>or</u> 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 offtake by harvested crop product 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..

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 offtake (block x) minus N transfer (block x-1). N need is net N input to be provided by manure or N fertiliser.

3.2 Designing methods in the context of a theoretical prototype

Irrespective of prototyping on experimental farms or pilot farms, all European projects would benefit from a standardised design of methods, notably those on the shortlist (Table 3). Therefore, in this second year the concerted action should focus on designing methods and - if they are ready for initial use - on testing and improving them on the basis of their links in a theoretical prototype (Chapters 3-4).

Subsequently, in this section formats are presented for achieving an initial design of the methods needed, starting with MCR in a central role and finishing with FSO as a mostly indispensable method for rendering an agronomically and ecologically optimised prototype economically optimal too.

3.2.1 Designing a Multifunctional Crop Rotation (MCR)

Brief definition:
MCR is a basic and comprehensive method to preserve soil fertility in biological, physical and chemical terms and to sustain Quality Production with a minimum of inputs (pesticides, manual and machine labour, fertilisers and support energy).

(1) *Identifying and characterising potential crops for your region or farm (format A):*
- 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 listed in format A or adapted to your region.

(2) *Drawing up an MCR based on (1) and simultaneously fulfilling a multi-functional set of demands (format B):*
- filling the first rotation block with crop no. 1.;
- filling subsequent blocks while preserving biological soil fertility by limiting crop frequencies to ≤ 25 % in IAFS and ≤ 16.7 % in EAFS and crop group frequencies to ≤ 50 % in IAFS and ≤ 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;
- 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;
- filling single blocks by 2 or 3 crops with corresponding characteristics, if needed for reasons of limited labour capacity or 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 and promoted 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 (Chapter 7).

3.2.2 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 analagously, by combining inorganic and organic fertilisers or biological N fixation instead of organic fertiliser and biological N fixation.

3.2.3 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.

3.2.4 Designing Ecological Infrastructure Management (EIM)

Brief definition:
EIM is a method additional to MCR to 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).
In addition, EIM is a method for rendering single farms and entire production areas habitable for wild flora and fauna and enjoyable for people.

(1) *Establishing a minimum area of the farm to be devoted to EI:*
- 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 EI;
- establishing the area of buffer strips along or around these elements needed for appropriate EIM.

(2) *Establishing a plan of EIM aimed at long-term objectives for the flora, fauna and landscape:*
- establishing which target species of flora and fauna should be enhanced;
- establishing how EIM 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.

3.2.5 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 EIM 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.

3.2.6 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.

4 Part 3 of the identity cards of the 9 selected pilot projects

In line with the set of parameters and methods in Part 2 of their prototype's identity card, the teams of the 9 selected European pilot projects present their theoretical prototype as Part 3. This shows the major and the minor methods to be followed to achieve the desired result for each parameter. Vice versa, it also shows which parameters are supported by a method and thus indicates the overall impact of a method. Consequently, the theoretical prototype defines the context and the order of designing the methods, as the teams briefly explain in their Parts 3.
The 5 theoretical IAFS prototypes are presented in Section 4.1 (Figs 2.1.1 - 2.1.5).
The 4 theoretical EAFS prototypes are presented in Section 4.2 (Figs 2.2.1 - 2.2.4).
The state-of-the-art is briefly considered in Section 4.3.

4.1 Theoretical prototypes of the 5 IAFS projects

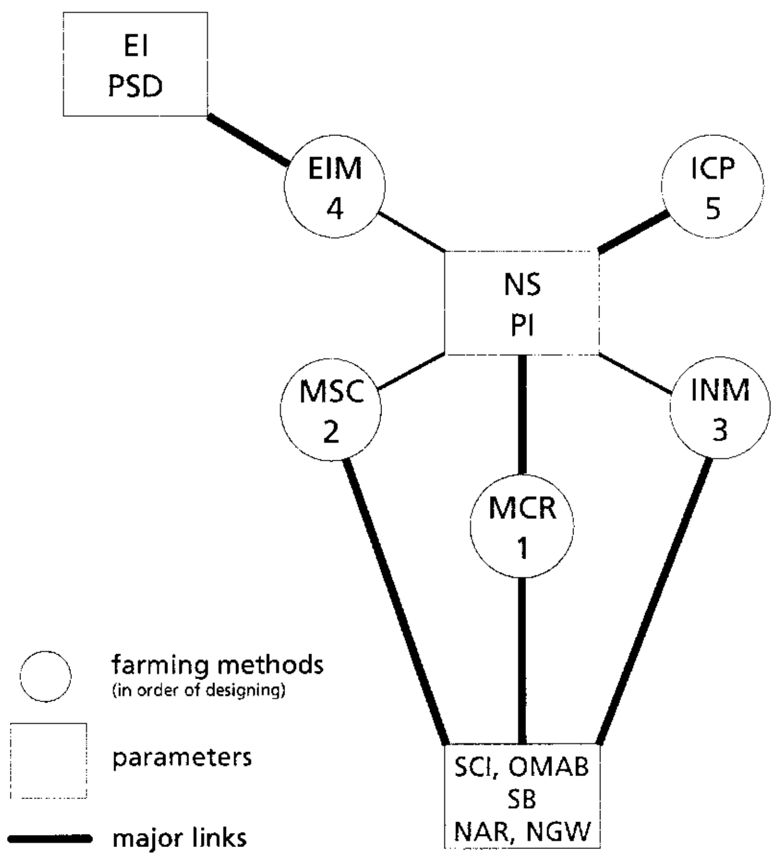


Figure 2.1.1 Theoretical IAFS prototype of Baden-Württemberg (DE 1)

In Baden Württemberg, the major 10 objectives as quantified in 9 parameters are achieved by 5 multi-objective methods, designed and made ready for use in the order that follows.

(1) Multifunctional Crop Rotation (MCR) is the major method to achieve desired results in Net Surplus (NS), Soil Cover Index (SCI) and Organic Matter Annual Balance (OMAB). It is also a method supporting Pesticide Index (PI), Soil Biodiversity (SB), N Available Reserves (NAR) and N Ground Water (NGW).
(2) Minimum Soil Cultivation (MSC) is the major method to achieve desired results in Soil Biodiversity. It is also a method supporting Net Surplus, Pesticide Index, Soil Cover Index, Organic Matter Annual Balance, N Available Reserves and N Ground Water.
(3) Integrated Nutrient Management (INM) is the major method to achieve desired results in N Available Reserves and N Ground Water. It is also a method supporting Net Surplus, Pesticide Index, Soil Cover Index, Organic Matter Annual Balance and Soil Biodiversity.
(4) Ecological Infrastructure Management (EIM) is the major method to achieve desired results in Ecological Infrastructure (EI) and Plant Species Diversity (PSD). It is also a method supporting Net Surplus and Pesticide Index.
(5) Integrated Crop Protection (ICP) is the major method to achieve desired results in Pesticide Index. It is also a method supporting Net Surplus.

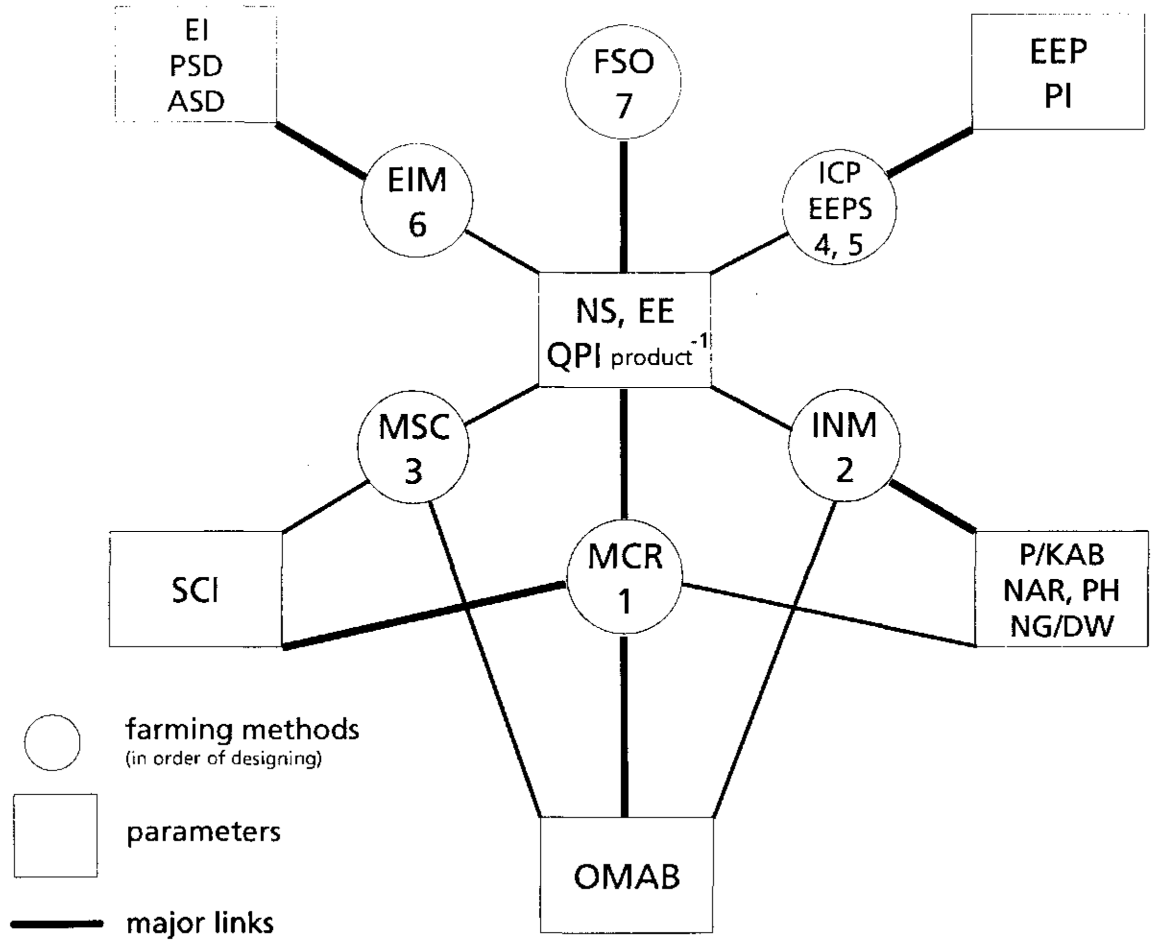


Figure 2.1.2 Theoretical IAFS prototype of Nordrhein-Westfalen (DE 3)

In Nordrhein-Westfalen, the major 10 objectives as quantified in 14 parameters are achieved by 7 multi-objective methods, designed 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}) Net Surplus (NS), Energy Efficiency (EE), Soil Cover Index (SCI) and Organic Matter Annual Balance (OMAB). It is also a method supporting PK Annual Balances (P/KAB), N Available Reserves (NAR), N Ground or Drainage Water (NG/DW) and pH.

(2) Integrated Nutrient Management (INM) is the major method to achieve desired results in PK Annual Balances, N Available Reserves, N Ground or Drainage Water and pH. It is also a method supporting Quality Production Indices, Net Surplus, Energy Efficiency and Organic Matter Annual Balance.

(3) Minimum Soil Cultivation (MSC) is a supporting method for achieving desired results in Quality Production Indices, Net Surplus, Soil Cover Index and Organic Matter Annual Balance.

(4) Integrated Crop Protection (ICP) and Environment Exposure-based Pesticide Selection(EEPS) are the two major methods for achieving desired results in Environment Exposure to Pesticides (EEP) and Pesticide Index (PI). They are also methods supporting the Quality Production Indices, Net Surplus and Energy Efficiency.

(5) Ecological Infrastructure Management (EIM) is the major method for achieving desired results in Ecological Infrastructure (EI), Plant Species Diversity (PSD) and a local parameter called Animal Species Diversity (ASD). It is also a method supporting the Quality Production Indices, Net Surplus and Energy Efficiency.

(6) Farm Structure Optimisation (FSO) is the finalising method to achieve the desired result in Net Surplus and Energy Efficiency, if the current amounts of land, labour and capital goods of the pilot farms fail to do so with the capital goods of the agronomically and ecologically optimised prototype IAFS.

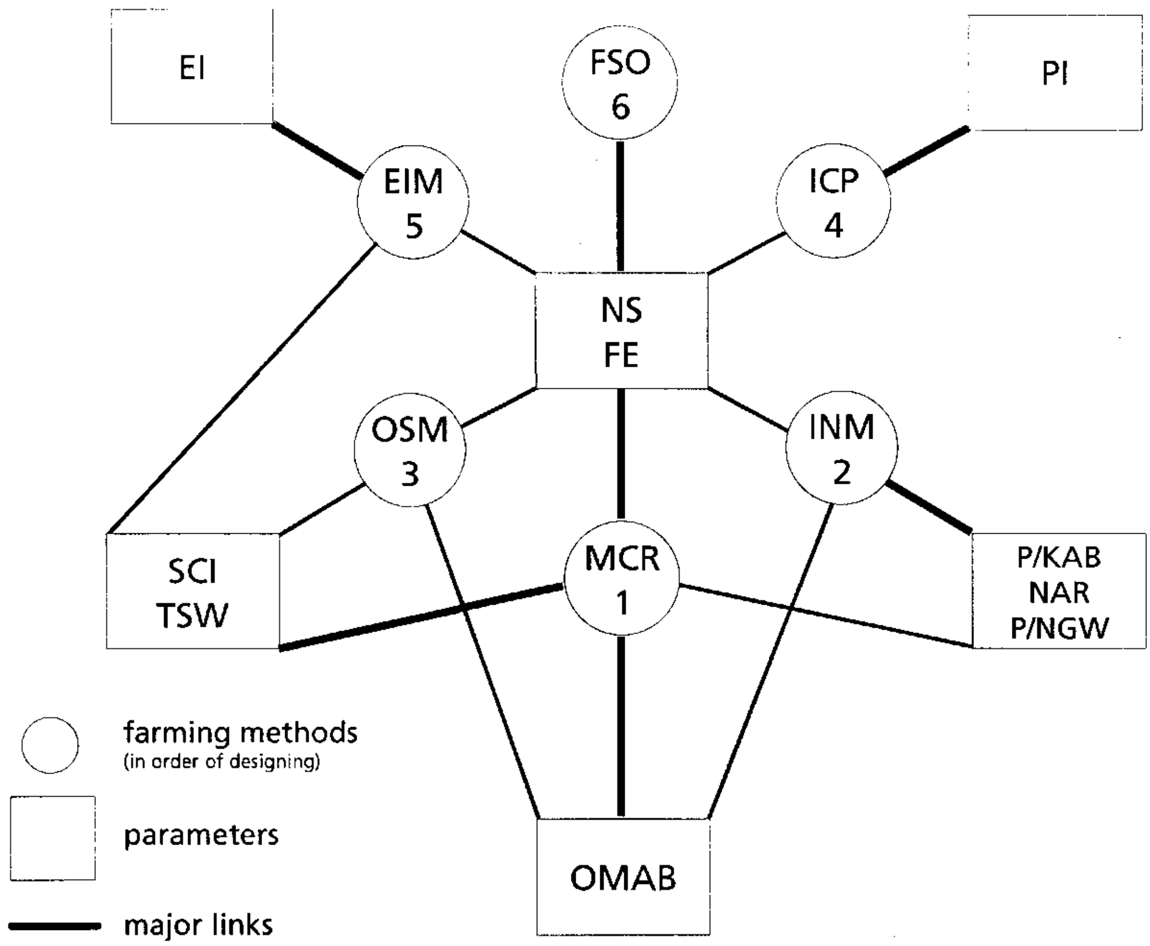


Figure 2.1.3 Theoretical IAFS prototype of La Ferté-Vidame (F 1)

In La Ferté-Vidame, the major 10 objectives as quantified in 12 parameters are achieved by 6 multi-objective methods, designed and made ready for use in the order that follows.

(1) Multifunctional Crop Rotation (MCR) is the major method to achieve desired results in Net Surplus (NS), Farm Employment (FE), Organic Matter Annual Balance (OMAB), Soil Cover Index (SCI) and a local parameter called Turbidity Shallow Water (TSW). It is also a method supporting P and K Annual Balances (P/KAB), N Available Reserves (NAR), N Ground Water (NGW) and a local parameter called P Ground Water(PGW).
(2) Integrated Nutrient Management (INM) is the major method to achieve desired results in P and K Annual Balances, N Available Reserves, N and P Ground Water. It is also a method supporting Net Surplus, Farm Employment and Organic Matter Annual Balance.
(3) Optimum Soil Management (OSM) is a supporting method to achieve desired results in Net Surplus, Farm Employment, Soil Cover Index, Turbidity Shallow Water and Organic Matter Annual Balance.
(4) Integrated Crop Protection is the major method to achieve desired results in Pesticide Index (PI). It is also a method supporting Net Surplus and Farm Employment.
(5) Ecological Infrastructure Management (EIM) is the major method to achieve desired results in Ecological Infrastructure (EI). It is also a method supporting Net Surplus, Farm Employment, Soil Cover Index and Turbidity Shallow Water.
(6) Farm Structure Optimisation (FSO) is the finalising method to achieve the desired results in Net Surplus and Farm Employment, if the current amounts of land, labour and capital goods of the pilot farm fail to do so with the agronomically and ecologically optimised prototype IAFS.

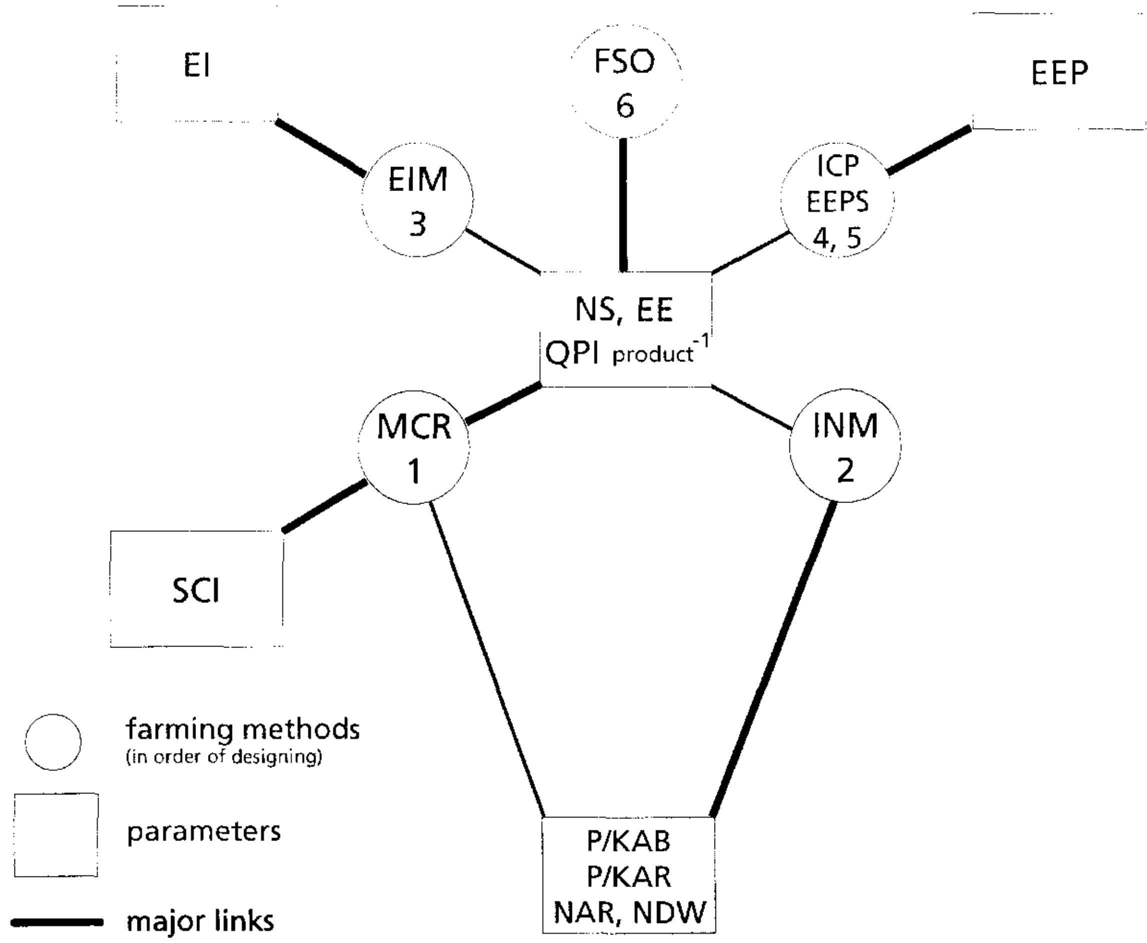


Figure 2.1.4 Theoretical IAFS prototype of National Network (NL 1)

In the National Network of NL, the major 10 objectives as quantified in 12 parameters are achieved by 6 multi-objective methods, designed 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}), Net Surplus (NS), Energy Efficiency (EE) and Soil Cover Index (SCI). It is also a method supporting P and K Annual Balances (P/KAB), P and K Available Reserves (P/KAR), N Available Reserves (NAR) and N Drainage Water (NDW).

(2) Integrated Nutrient Management (INM) is the major method to achieve desired results in PK Annual Balances and Available Reserves, N Available Reserves and N Drainage Water. It is also a method supporting Quality Production Indices, Net Surplus and Energy Efficiency.

(3) Ecological Infrastructure Management (EIM) is the major method to achieve desired results in Ecological Infrastructure (EI). It is also a method supporting Quality Production Indices, Net Surplus and Energy Efficiency.

(4,5) Integrated Crop Protection (ICP) and Environment Exposure-based Pesticide Selection (EEPS) are the two major methods to achieve desired results in Environment Exposure to Pesticides. They are also supporting Quality Production Indices, Net Surplus and Energy Efficiency.

(6) Farm Structure Optimisation (FSO) is the finalising method to achieve desired results in Net Surplus and Energy Efficiency, if the current amounts of land, labour or capital goods of the pilot farms fail to do so with the agronomically and ecologically optimised prototype IAFS.

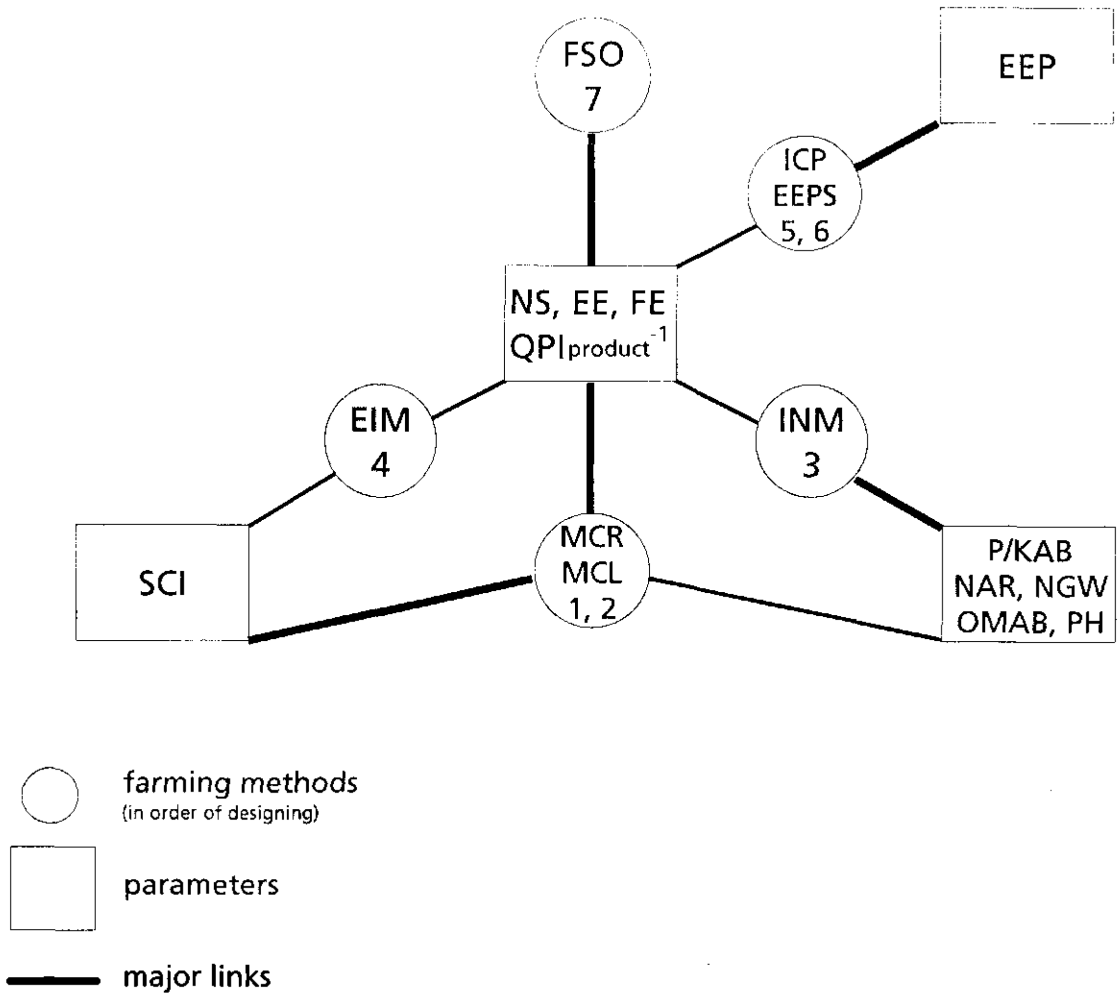


Figure 2.1.5 Theoretical IAFS prototype of Mazovia (PL 1)

In Mazovia, the major 10 objectives as quantified in 12 parameters are achieved by 7 multi-objective methods, which will be designed and made ready for use in the order that follows.

(1,2) Multifunctional Crop Rotation (MCR) and Mixing Crops and Livestock (MCL) are the two major methods to achieve desired results in Quality Production Indices (QPI product^{-1}), Net Surplus (NS), Energy Efficiency (EE), Farm Employment (FE) and Soil Cover Index (SCI). They are also supporting P and K Annual Balances (P/KAB), N Available Reserves (NAR), N Ground Water (NGW), Organic Matter Annual Balance (OMAB) and pH.

(3) Integrated Nutrient Management (INM) is the major method to achieve desired results in P and K Annual Balances, N Available Reserves, N Ground Water, Organic Matter Annual Balance and pH. It is also a method supporting Quality Production Indices, Net Surplus and Farm Employment.

(4) Ecological Infrastructure Management (EIM) is a supporting method to achieve desired results in Quality Production Indices, Net Surplus, Farm Employment and Soil Cover Index.

(5,6) Integrated Crop Protection (ICP) and Environment Exposure-based Pesticide Selection (EEPS) are the two major methods to achieve the desired results in Environment Exposure to Pesticides (EEP). They are also supporting Quality Production Indices, Net Surplus and Farm Employment.

(7) Farm Structure Optimisation (FSO) is the finalising method to achieve the desired results in Net Surplus and Farm Employment, if the current amounts of land, labour or capital goods of the pilot farms fail to do so with the agronomically and ecologically optimised prototype IAFS.

4.2 Theoretical Prototypes of the 4 EAFS projects

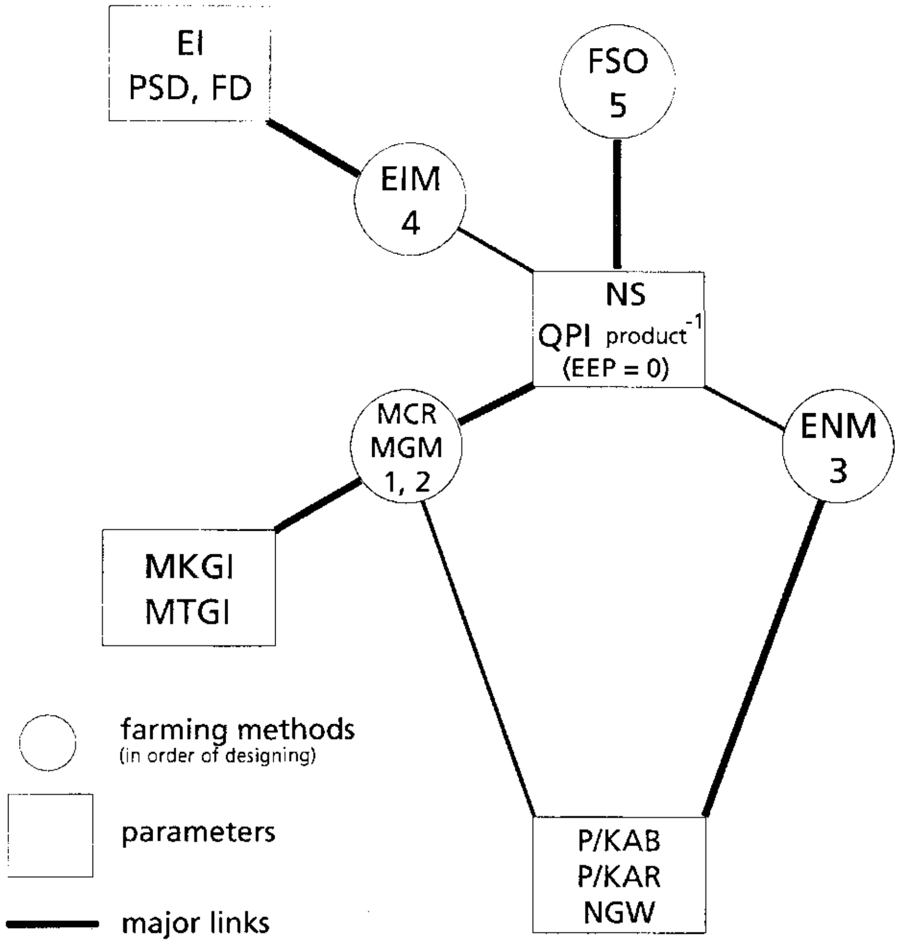


Figure 2.2.1 Theoretical EAFS prototype of mid-Belgium (B 1)

In mid-Belgium, the major 10 objectives as quantified in 13 parameters are achieved by 5 multi-objective methods, designed and made ready for use in the order that follows.

(1,2) Multifunctional Crop Rotation (MCR) and Multifunctional Grassland Management (MGM) are the two major methods to achieve desired results in Quality Production Indices (QPI product^{-1}) without using pesticides (EEP=0), Net Surplus (NS) and 2 local parameters called Milk from Grass Index (MKGI) and Meat from Grass Index (MTGI). They are also supporting P and K Annual Balances (P/KAB), P and K Available Reserves (P/KAR) and N Ground Water (NGW).

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

(4) Ecological Infrastructure Management is the major method to achieve Ecological Infrastructure (EI), Plant Species Diversity (PSD) and a local parameter called Flower Density (FD). It is also a method supporting Quality Production Indices (without using pesticides) and Net Surplus.

(5) 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.

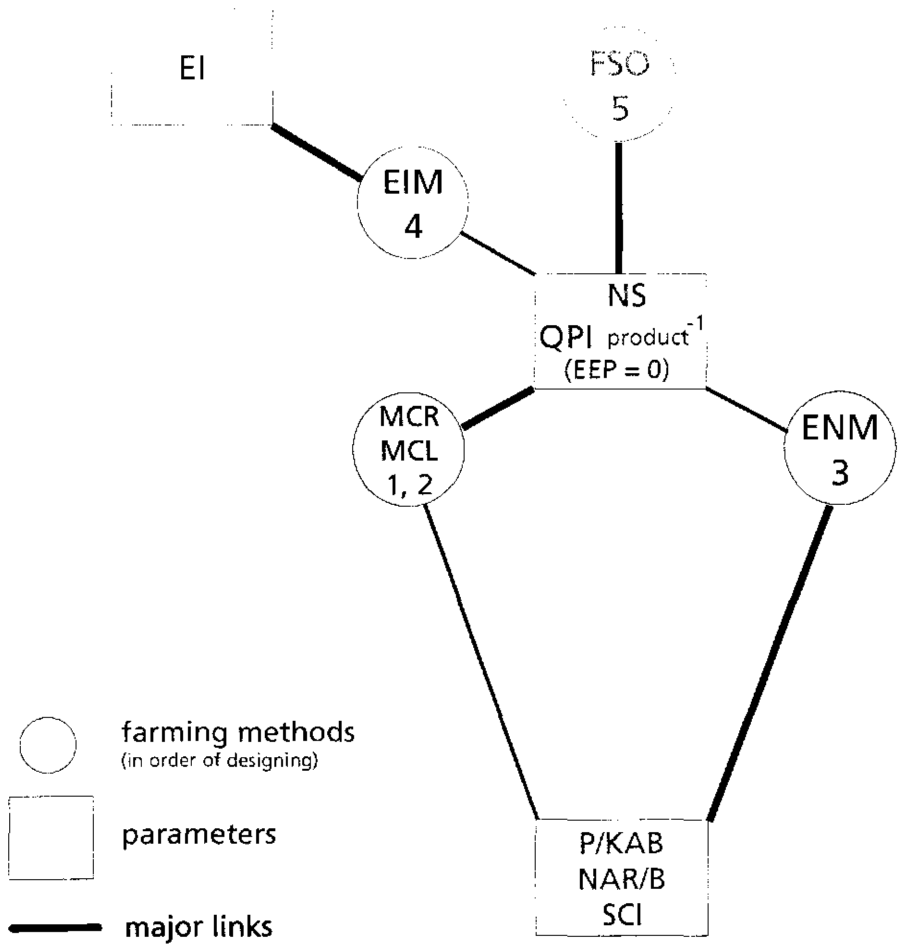


Figure 2.2.2 Theoretical EAFS prototype of National Network (DK 2)

In the National Network of DK, the major 10 objectives as quantified in 9 parameters are achieved by 5 multi-objective methods, designed and made ready for use in the order that follows.

(1,2) Multifunctional Crop Rotation (MCR) and Mixing Crop and Livestock (MCL) are the two major methods to achieve desired results in Quality Production Indices (QPI products^{-1}) without using pesticides (EEP=0), and Net Surplus (NS). They are also supporting P and K Annual Balances (P/KAB), N Annual Balance (NAB, local parameter) N Available Reserves (NAR) and Soil Cover Index (SCI).

(3) Ecological Nutrient Management (ENM) is the major method to achieve desired results in P and K Annual Balances, N Available Reserves, N Annual Balance and Soil Cover Index. It is also a method supporting Quality Production Indices (without pesticides) and Net Surplus.

(4) Ecological Infrastructure Management (EIM) is the major method to achieve the desired result in Ecological Infrastructure (EI). It is also a method supporting Quality Production Indices (without pesticides) and Net Surplus.

(5) 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.

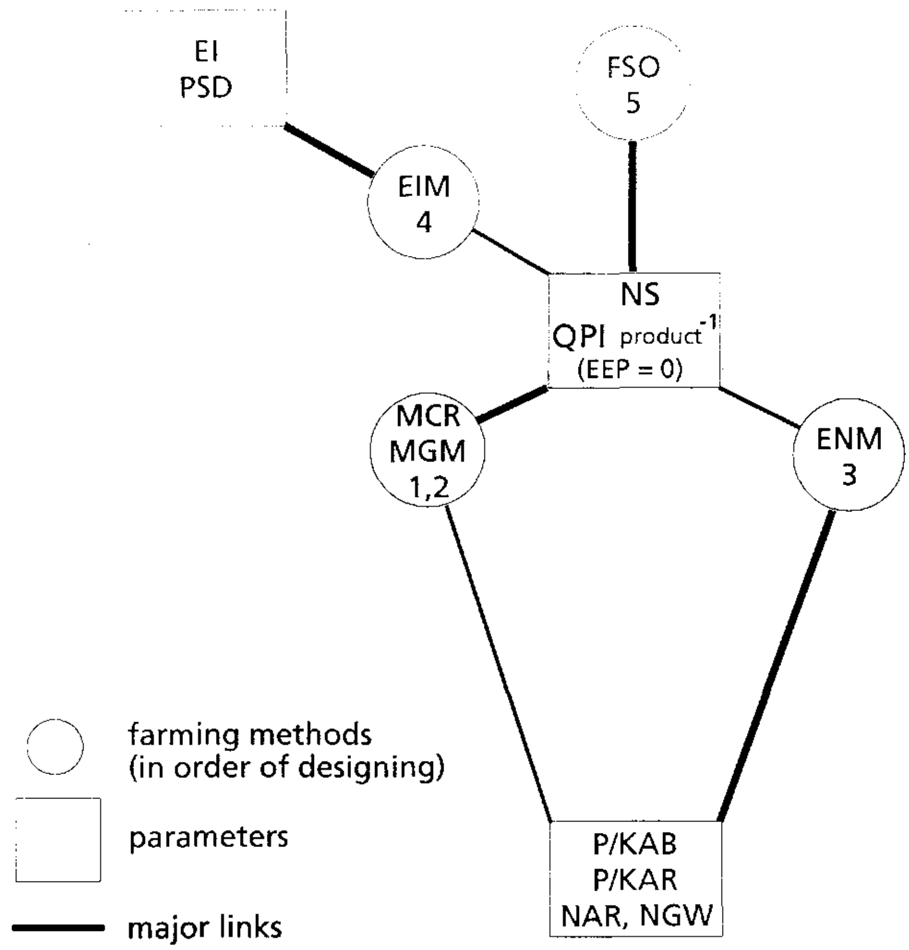


Figure 2.2.3 Theoretical EAFS prototype of Southeast and Midwest (IRL 1)

In southeast and midwest Ireland, the major 10 objectives as quantified in 11 parameters are achieved by 5 multi-objective methods, designed and made ready for use in the order that follows.

(1,2) Multifunctional Crop Rotation (MCR) and Multifunctional Grassland Management (MGM) are the two major methods to achieve desired results in Quality Production Indices (QPI product^{-1}) without using pesticides (EEP=0), and Net Surplus (NS). They are also supporting P and K Annual Balances (P/KAB), P and K Available Reserves (P/KAR), N Available Reserves (NAR) and N Ground Water.

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

(4) Ecological Infrastructure Management is the major method to achieve Ecological Infrastructure (EI) and Plant Species Diversity (PSD). It is also a method supporting Quality Production Indices (without using pesticides) and Net Surplus.

(5) 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.

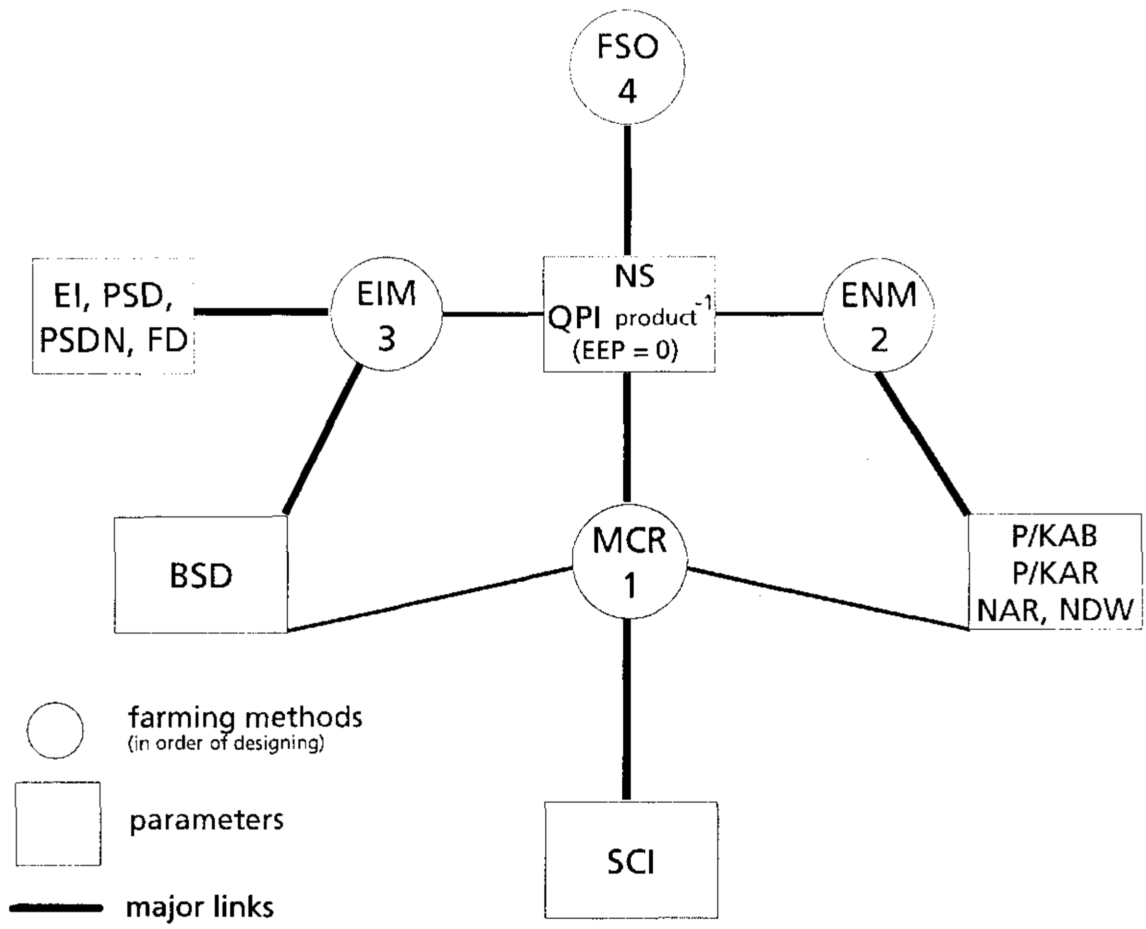


Figure 2.2.4 Theoretical EAFS prototype of Flevoland (NL 2)

In Flevoland, the major 10 objectives as quantified in 15 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 Soil Cover Index (SCI). It is also a method supporting P and K Annual Balance (P/KAB), P and K Available Reserves (P/KAR), N Available Reserves (NAR), N Drainage Water (NDW) and Bird Species Diversity (BSD).

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

(3) Ecological Infrastucture Management (EIM) is the major method to achieve desired results in Ecological Infrastructure (EI), Bird Species Diversity, Plant Species Diversity (PSD) and local parameters of flora: Plant Species Distribution (PSDN) and Flower Density (FD). 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.

4.3 State-of-the-art in theoretical prototyping

Designing a theoretical prototype and the methods in this context is an indispensable step (3) in a methodical way of prototyping I/EAFS. Designing a theoretical prototype implies carefully linking the methods to the parameters established in step (2). As a result, the theoretical prototype shows which are the major and minor methods for achieving the desired result in any parameter. Moreover, the theoretical prototype shows what is the overall impact of any method, and thus reveals the order and context in which the methods should be designed.

Only if a consistent theoretical prototype has been designed and the methods have been sufficiently elaborated for initial use can you proceed to step (4), testing and improving the prototype in practice until the objectives as transformed and quantified in the set of multi-objective parameters have achieved. However, most of the 9 theoretical prototypes presented were drawn up while the team was already testing! As a result, the testing programme should be thoroughly revised and made consistent with the first 3 steps! This implies that testing with parameters which do not occur in the theoretical prototypes should be abandoned. Otherwise, parameters occurring in the theoretical prototype and not yet used in testing should be made ready for use by assessing which results are desired and how they can be quantified in practice.

Major revision of the ongoing testing programme may be embarrassing and painful for your team, but it is always better than proceeding along a path of comparative research and ending up with a report on an inconsistent and incomplete prototype.

5 Part 4 of the identity cards of the 9 selected pilot projects

The teams of the 9 selected European pilot projects present a representative variant of their Multifunctional Crop Rotation (MCR) as Part 4, in line with the formats for designing an MCR (Subsection 3.2.1.)
In format A they first present the selection of the most profitable crops eligible for the MCR of the pilot farm in question, with their major characteristics in terms of biological, physical and chemical soil fertility. Subsequently, in format B they present the MCR which optimally complies with the multifunctional set of demands (Subsection 3.2.1.). The 5 IAFS-MCRs are presented in Section 5.2 (Tables 4.1.1 - 4.1.5), as are the 4 EAFS-MCRs (Tables 4.2.1 - 4.2.4).
The MCRs are briefly evaluated in Section 5.3, in terms of the multifunctional set of demands.

5.1 Multifunctional Crop Rotations of the 5 IAFS projects

Table 4.1.1 Multifunctional Crop Rotation of IAFS prototype in Baden-Württemberg (DE 1)

A. Selection of crops by pilot farm 10 (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]	offtake[5]	transfer[6]
1	sugar beet	chen.	0	1	-4	-3	3	2
2	winter wheat	cer.	0	3	-1	2	3	1
3	durum wheat	cer.	0	3	-1	2	3	1
4	spring barley	cer.	0	3	-1	2	2	1
5	maize	maize	0	1	-2	-1	3	1
6	oil seed rape	cruc.	0	2	-1	1	3	2
7	winter rye	cer.	0	3	-1	2	2	1
8	sunflower	comp.	0	3	-1	2	2	1
9	pea	leg.	0	2	-1	1	0	2
10	set-aside	leg.	0	3	-1	2	0	3
mean of crop selection			0	2.4	-1.4	1.0	2.1	1.5

B. Multifunctional Crop Rotation of pilot farm 10.

block	crop	biological		physical (ratings)		chemical (N ratings)		
no.	no.	species	group[1]	cover[2]	structure[3+4]	offtake[5]	transfer[6]	need[7]
I	1	sugar beet	chen.	0	-3	3	2	2
II	2	winter wheat	cer.	0	2	3	1	1
III	10	set-aside	leg.	0	2	0	3	-1
IV	5	maize	maize	0	-1	3	1	0
V	2/3	winter/durum wheat	cer.	0	2	3	1	2
VI	4	spring barley	cer.	0	2	2	1	1
mean of crop rotation		share species^{-1} ≤ 0.33	share group^{-1} ≤ 0.5	0	0.7	2.3	1.5	0.8

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 offtake by harvested crop product 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..
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 offtake (block x) minus N transfer (block x-1). N need is net N input to be provided by manure or N fertiliser.

Table 4.1.2 Multifunctional Crop Rotation of IAFS prototype in Nordrhein-Westfalen (DE 3)

A. Selection of crops by pilot farm 5 (crops in order of profitability).

crop no.	biological species	group[1]	physical (ratings) cover[2]	rooting[3]	compaction[4]	structure[3+4]	chemical (N ratings) offtake[5]	transfer[6]
1	sugar beet	chen.	-2	1	-4	-3	3	2
2	wheat	cer.	-2	3	-1	2	3	1
3	maize (CCM)	maize	-2	1	-2	-1	3	2
4	oilseed rape	cruc.	-2	3	-1	2	2	2
5	oats	oats	-2	3	-1	2	2	1
6	field bean	leg.	-4	3	-1	2	0	3
7	flax	lin.	-4	2	-1	1	1	1
8								
9								
10								
mean of crop selection			-2.6	2.4	-1.6	-0.7	2.0	1.7

B. Multifunctional Crop Rotation of pilot farm 5.

block no.	crop no.	biological species	group[1]	physical (ratings) cover[2]	structure[3+4]	chemical (N ratings) offtake[5]	transfer[6]	need[7]
I	1/4	s.beet/rape	chen./cruc.	-2/-2	-3/2	3/2	2/2	2/1
II	2	wheat	cer.	-2	2	3	1	1
III	6/5	bean/oats	leg./cer.	-4/-2	2/2	0/2	3/1	-1/1
IV	3	maize	maize	-2	-1	3	2	1
V	2	wheat	cer.	-2	2	3	1	2
mean of crop rotation		share species^{-1} ≤ 0.4	share group^{-1} ≤ 0.5	-2.2	0.9	2.5	1.6	1.1

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 offtake by harvested crop product 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..

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 offtake (block x) minus N transfer (block x-1). N need is net N input to be provided by manure or N fertiliser.

Table 4.1.3 Multifunctional Crop Rotation of IAFS prototype in la Ferté-Vidame (F 1)

A. Selection of crops by pilot farm 2 (crops in order of profitability).

crop no.	biological species	biological group[1]	physical (ratings) cover[2]	physical (ratings) rooting[3]	physical (ratings) compaction[4]	physical (ratings) structure[3+4]	chemical (N ratings) offtake[5]	chemical (N ratings) transfer[6]
1	oilseed rape	cruc.	0	2	-1	1	2	2
2	pea	leg.	-4	2	-1	1	0	3
3	wheat	cer.	-2	3	-1	2	3	1
4	barley	cer.	-2	3	-1	2	2	1
5	maize	maize	-2	3	-2	1	3	2
6	set-aside	grass	0	3	0	3	0	2
7	set-aside	leg.	0	2	-2	0	0	2
8								
9								
10								
mean of crop selection			-1.4	2.6	-1.1	1.4	1.6	1.9

B. Multifunctional Crop Rotation of pilot farm 2.

block no.	crop no.	biological species	biological group[1]	physical (ratings) cover[2]	physical (ratings) structure[3+4]	chemical (N ratings) offtake[5]	chemical (N ratings) transfer[6]	chemical (N ratings) need[7]
I	1/2	rape/pea	cruc./leg.	0/-4	1/1	2/0	2/3	1/-1
II	3	wheat	cer.	-2	2	3	1	1/0
III	4	barley	cer.	-2	2	2	1	1
IV	7	set-aside	leg.	0	3	0	2	-1
V	3	wheat	cer.	-2	2	3	1	1
VI	4	barley	cer.	-2	2	2	1	1
mean of crop rotation		share species^{-1} ≤ 0.33	share group^{-1} ≤ 0.67	-1.7	2.0	1.8	1.4	0.4

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 offtake by harvested crop product 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..

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 offtake (block x) minus N transfer (block x-1). N need is net N input to be provided by manure or N fertiliser.

Table 4.1.4 Multifunctional Crop Rotation of IAFS prototype in central clay region of National Network (NL 1)

A. Selection of crops by pilot farm 8 (crops in order of profitability).

crop no.	biological species	group[1]	physical (ratings) cover[2]	rooting[3]	compaction[4]	structure[3+4]	chemical (N ratings) offtake[5]	transfer[6]
1	carrot	umbel.	-2	1	-4	-3	3	1
2	potato (seed)	solan.	-2	1	-2	-1	3	2
3	chicory	umbel.	-2	1	-4	-3	2	1
4	potato (ware)	solan.	-2	1	-4	-3	3	1
5	sugar beet	chen.	-2	1	-4	-3	2	1
6	onion	lil.	-2	1	-2	-1	3	1
7	bean	leg.	-2	2	-1	1	0	2
8	pea	leg.	-2	2	-1	1	0	2
9	winter wheat	cer.	0	3	-1	2	3	1
10	spring barley	cer.	-2	3	-1	2	2	1
mean of crop selection			-1.8	1.6	-2.4	-0.8	2.1	1.3

B. Multifunctional Crop Rotation of pilot farm 8.

block no.	crop no.	biological species	group[1]	physical (ratings) cover[2]	structure[3+4]	chemical (N ratings) offtake[5]	transfer[6]	need[7]
I	1/6	carrot/onion	umbel./lil.	-2/-2	-3/-1	3/3	1/1	2/2
II	5	sugar beet	chen.	-2	-3	2	1	1
III	9	winter wheat	cer.	0	2	3	1	2
IV	4	ware potato	solan.	-2	-3	3	1	2
mean of crop rotation		share species^{-1} ≤0.25	share group^{-1} ≤0.25	-1.5	-1.5	2.7	1	1.7

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 offtake by harvested crop product 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..
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 offtake (block x) minus N transfer (block x-1). N need is net N input to be provided by manure or N fertiliser.

Table 4.1.5 Multifunctional Crop Rotation of IAFS prototype in Mazovia (PL 1)

A. Selection of crops by pilot farm 5 (crops in order of profitability).

crop no.	biological: species	group[1]	physical (ratings): cover[2]	rooting[3]	compaction[4]	structure[3+4]	chemical (N ratings): offtake[5]	transfer[6]
1	sugar beet	chen.	-2	1	-4	-3	3	1
2	potato	solan	-2	1	-2	-1	2	1
3	winter wheat	cer.	0	3	-1	2	2	1
4	oilseed rape	cruc.	0	2	-1	1	3	1
5	winter triticale	cer.	0	3	-1	2	2	1
6	spring barley	cer.	-2	3	-1	2	2	1
7	spring barley/pea	cer./leg.	-2	2	-1	1	1	1
8	grass	grass	0	3	-1	2	2	1
9	red clover	leg.	0	3	-1	2	0	2
10								
mean of crop selection			-0.9	2.3	-1.4	0.9	1.8	1.1

B. Multifunctional Crop Rotation of pilot farm 5.

block no.	crop no.	biological: species	group[1]	physical (ratings): cover[2]	structure[3+4]	chemical (N ratings): offtake[5]	transfer[6]	need[7]
I	1	sugar beet	chen.	-2	-3	3	1	2
II	3/6	w.wheat/s.barley	cer.	0/-2	2/2	2/2	1/1	1
III	6/9/2	s.barley/potato	cer./solan.	-2/0/-2	2/2/-1	2/0/2	1/2/1	1/-1/1
IV	3	winter wheat	cer.	0	2	2	1	1/0/1
V	3/7	w.wheat/s.barley/pea	cer./leg.	0/-2	2/1	2/1	1/í	1/0
VI	5/2	triticale/potato	cer./solan.	0/-2	2/-1	0/-22/2	1	1
VII	8	grass	grass	0	2	20	1	1
mean of crop rotation		share species^{-1} ≤0.25	share group^{-1} ≤0.5	-0.9	0.9	2.0	1.0	0.9

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 offtake by harvested crop product 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..
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 offtake (block x) minus N transfer (block x-1). N need is net N input to be provided by manure or N fertiliser.

5.2 Multifunctional Crop Rotations of the 4 EAFS projects

Table 4.2.1 Multifunctional Crop Rotation of EAFS prototype in mid-Belgium (B 1)

A. Selection of crops by pilot farm 1 (crops in order of profitability).

crop no.	biological species	biological group[1]	physical (ratings) cover[2]	physical (ratings) rooting[3]	physical (ratings) compaction[4]	physical (ratings) structure[3+4]	chemical (N ratings) offtake[5]	chemical (N ratings) transfer[6]
1	grassclover	grass/leg.	0	3	-2	1	2	2
2	potato	solan.	-4	1	-2	-1	3	2
3	maize	maize	-4	2	-2	0	3	2
4	winter wheat	cer.	-2	3	-1	2	3	1
5	triticale	cer.	-2	3	-1	2	3	1
6	oats	oats	-2	3	-1	2	2	1
7	rye	cer.	-2	3	-1	2	2	1
8	spelt	cer.	-2	3	-1	2	2	1
9								
10								
mean of crop selection			-2.3	2.6	-1.4	1.3	2.4	1.5

B. Multifunctional Crop Rotation of pilot farm 1.

block no.	crop no.	biological species	biological group[1]	physical (ratings) cover[2]	physical (ratings) structure[3+4]	chemical (N ratings) offtake[5]	chemical (N ratings) transfer[6]	chemical (N ratings) need[7]
I	1	grassclover	grass/leg.	0	1	2	2	0
II	1	grassclover	grass/leg.	0	1	1	2	-1
III	1	grassclover	grass/leg.	0	1	1	2	-1
IV	2	potato	solan.	-4	-1	3	2	1
V	4	winter wheat	cer.	-2	2	2	1	0
VI	3	maize	maize	-4	0	3	2	2
VII	5/6	triticale/oats	cer./oats	-2	2	2	1	0
VIII	5/6	triticale/oats	cer./oats	-2	2	2	1	1
mean of crop rotation		share species^{-1} ≤ 0.167	share group^{-1} ≤ 0.25	-1.8	1.0	2.0	1.6	0.3

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 <u>and</u> winter = -4, no cover in autumn <u>or</u> 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 offtake by harvested crop product 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..
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 offtake (block x) minus N transfer (block x-1). N need is net N input to be provided by manure or N fertiliser.

Table 4.2.2 Multifunctional Crop Rotation of EAFS prototype of National Network (DK 2)

A. Selection of crops by pilot farm 1 (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]	offtake[5]	transfer[6]
1	grassclover	grass/leg.	0	3	-1	2	1	2
2	wheat	cer.	-2	3	-1	2	3	1
3	oats	cer.	-2	3	-1	2	2	1
4	barley	oats	-2	3	-1	2	2	1
5	pea/bean	leg.	-2	3	-1	2	0	2
6	sugar beet	chen.	-2	1	-4	-3	3	1
7	lucerne	leg.	0	3	-1	2	0	3
8	potato	solan.	-2	1	-2	-1	3	2
9	carrot	umbel.	-2	1	-4	-3	3	1
mean of crop selection			-1.6	2.3	-1.8	0.6	1.9	1.4

B. Multifunctional Crop Rotation of pilot farm 1.

block	crop	biological		physical (ratings)		chemical (N ratings)		
no.	no.	species	group[1]	cover[2]	structure[3+4]	offtake[5]	transfer[6]	need[7]
I	1	grassclover	grass/leg.	0	2	1	2	0
II	1	grassclover	grass/leg.	0	2	1	2	-1
III	2	wheat	cer.	-2	2	3	1	1
IV	4/5	barley/bean	cer./leg.	-2/-2	2/2	2/0	1/2	1/-1
V	3	oats	oats	-2	2	2	1	1/0
mean of crop rotation		share species^{-1} ≤ 0.25	share group^{-1} ≤ 0.35	-1.2	2	1.6	1.5	0.1

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 offtake by harvested crop product 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..
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 offtake (block x) minus N transfer (block x-1). N need is net N input to be provided by manure or N fertiliser.

Table 4.2.3 Multifunctional Crop Rotation of EAFS prototype in Southeast and Midwest (IRL 1)

A. Selection of crops by pilot farm 8 (crops in order of profitability).

crop no.	biological species	group[1]	physical (ratings) cover[2]	rooting[3]	compaction[4]	structure[3+4]	chemical (N ratings) offtake[5]	transfer[6]
1	wheat	cer.	-2	3	-1	2	3	1
2	bean	leg.	-2	2	-1	1	0	2
3	grassclover	grass/leg.	0	3	-1	2	2	2
4								
5								
6								
7								
8								
9								
10								
mean of crop selection			-1.3	2.7	-1	1.7	1.7	1.7

B. Multifunctional Crop Rotation of pilot farm 8

block no.	crop no.	biological species	group[1]	physical (ratings) cover[2]	structure[3+4]	chemical (N ratings) offtake[5]	transfer[6]	need[7]
I	1	wheat	cer.	-2	2	3	1	1
II	2	bean	leg.	-2	1	0	2	-1
III	3	grassclover	grass/leg.	0	2	2	2	0
IV	3	grassclover	grass/leg.	0	2	2	2	0
V	1	wheat	cer.	-2	2	3	1	1
VI	3	grassclover	grass/leg.	0	2	2	2	1
VII	3	grassclover	grass/leg.	0	2	2	2	0
VIII	3	grassclover	grass/leg.	0	2	2	2	0
mean of crop rotation		share species^{-1} ≤ 0.40	share group^{-1} ≤ 0.52	-0.8	1.9	2.4	2.8	0.3

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 <u>and</u> winter = -4, no cover in autumn <u>or</u> 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 offtake by harvested crop product 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..
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 offtake (block x) minus N transfer (block x-1). N need is net N input to be provided by manure or N fertiliser.

Table 4.2.4 Multifunctional Crop Rotation of EAFS prototype of Flevoland (NL 2)

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

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

B. Multifunctional Crop Rotation of pilot farm 6.

block no.	crop no.	biological species	group[1]	physical (ratings) cover[2]	structure[3+4]	chemical (N ratings) offtake[5]	transfer[6]	need[7]
I	1/5	carrot/sugar beet	umbel./chen.	-2/-2	-3/-3	3/3	1/1	2
II	6	pea, bean	leg.	-2	1	0	2	-1
III	2	potato	solan.	-2	-1	3	2	1
IV	10	grassclover	grass/leg.	0	2	2	2	0
V	3/4	onion/celeriac	lil./umbel.	-4/-2	-1/-3	2/2	1/1	0
VI	7	wheat	cer.	-2	2	3	1	2
VII								
VIII								
mean of crop rotation		share species^{-1} ≤ 0.167	share group^{-1} ≤ 0.25	-1.8	-0.2	2.2	1.5	0.7

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 <u>and</u> winter = -4, no cover in autumn <u>or</u> 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 offtake by harvested crop product 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..
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 offtake (block x) minus N transfer (block x-1). N need is net N input to be provided by manure or N fertiliser.

5.3 State-of-the-art in designing MCRs

In all 9 theoretical prototypes presented in Chapter 4, 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 (SCI, OMAB, EEP, P/KAR etc), as well as in the Quality Production Indices (QPIs product^{-1}) and the major parameters of economic and energy efficiency (NS and EE). 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.

Being by far the most major method, and also the first to be designed, MCR is an appropriate Part 4 of your identity card, after your theoretical prototype as Part 3. Because of their central role, the MCRs of the 9 selected pilot projects need a more detailed evaluation, based on the set of multifunctional demands (Subsection 3.2.1). Table 5 suggests that only PL 1 has succeeded in designing an MCR fulfilling all demands. Most teams have not yet succeeded in designing an MCR with sufficient soil cover (SCI!), as a major preventive measure against erosion by wind or water. Neither have most teams succeeded in sufficiently diversifying their MCR by limiting the share species^{-1}, as a major preventive measure against weeds and soilborne pests and diseases (Chapter 7 in Progress Report 1). In particular, the teams of F 1 and IRL 1 have built in high risks, because their MCRs also have too high a share group^{-1} of phytopathologically related crop species. Except for NL 1 and NL 2, all teams have succeeded in designing an MCR with a balance between crops that degrade soil structure (by compaction at harvest) and crops that restore soil structure (by intensive rooting). Finally, all teams have succeeded in designing an MCR with a minimum need for N input, compensating for N offtake by products largely by fixing N biologically and transferring N efficiently from residues of crops.

Overall, it should be concluded that most Crop Rotations need to be improved before they can properly be called Multifunctional and can act as the sound base of an I/EAFS prototype able to achieve an ambitious set of objectives.

Table 5 Evaluation of Multifunctional Crop Rotations of selected pilot projects in 1994 *

Multifunctional demands (explained in 3.2.1)		**B 1** Mid-Belgium	**DE 1** Baden-Württemberg	**DE 3** Nordrhein West-falen	**DK 2** National network	**F 1** Ferté-Vidame	**IRL 1** Southeast and Midwest	**NL 1** National network	**NL 2** Flevo-land	**PL 1** Mazovia
Share species^{-1}										
IAFS	**≤ 0.25**	-	≤ 0.33	≤ 0.40	-	≤ 0.33	-	≤ 0.25	-	≤ 0.25
EAFS	**≤ 0.167**	≤ 0.167	-	-	≤ 0.25	-	≤ 0.40	-	≤ 0.167	-
Share group^{-1}										
IAFS	**≤ 0.50**	-	≤ 0.50	≤ 0.50	-	≤ 0.67	-	≤ 0.25	-	≤ 0.50
EAFS	**≤ 0.33**	≤ 0.25	-	-	≤ 0.35	-	≤ 0.52	-	≤ 0.25	-
Soil cover										
IAFS	**≥ -1**	-	0	-2.2	-	-1.7	-	-1.5	-	-0.9
EAFS	**= 0**	-1.8	-	-	-1.2	-	-0.8	-	-1.8	-
Soil structure										
IAFS	**≥ -1**	-	0.7	0.9	-	2.0	-	-1.5	-	0.9
EAFS	**≥ 0**	1.0	-	-	2.0	-	1.9	-	-0.2	-
N need										
IAFS	**≤ 2**	-	0.8	1.1	-	0.4	-	1.7	-	0.9
EAFS	**≤ 1**	0.3	-	-	0.1	-	0.3	-	0.7	-

* Tables 4.1.1 -4.1.5 (IAFS) and 4.2.1-4.2.4 (EAFS)

6 Testing a prototype on-farm

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 you have followed all preceding steps with the greatest accuracy. Therefore, it is useful to take a critical retrospective view before you proceed to step (4):

- does your hierarchy of objectives really cover the shortcomings of conventional arable farming (IAFS) or organic farming (EAFS) in your 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 you are really innovating and not just slightly ahead of the main group of farmers) (step 1)?
- have you really transformed the objectives in the appropriate set of multi-objective parameters (not too few but certainly not too many parameters!) and have you quantified each objective appropriately (not more but certainly not less ambitious than needed) and have you established the appropriate set of methods needed (not too many single-objective and too few multi-objective methods) (step 2)?
- should your theoretical prototype be redesigned to link up with possible changes in the first two steps (step 3)?

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. Laying out a prototype and testing it against the major European parameters will be discussed, below.

6.1 Laying out a prototype on pilot farms

If you have designed all the methods of your theoretical prototype, 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.

(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;
  - variant of Integrated or Ecological Nutrient Management;
  - variant of Ecological Infrastructure Management;
  - etc.

6.2 Testing with the European parameters

To test a prototype in practice there must be a carefully considered set of parameters which has been used to accurately quantify the objectives. This will be highlighted for the major parameters of the European-theoretical prototype (Fig. 2, page 16).

6.2.1 *Testing with Quality Production Indices (QPIs)*

Brief definition:
QPI is a comprehensive parameter of quality and quantity of crop production = 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 diseases whether or not in relation to conditions of weather, soil or preservation (PI = 0) or if the product has not been marketed because of unacceptable low quality whether or not in relation to a surplus on the market (QI = 0).

(1) *Quantifying losses in quality (prices kg $^{-1}$):*
- dividing achieved price by 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).

(2) *Quantifying losses in production (kg ha^{-1}):*
- estimating losses before (ripening stage), during or after harvest;
- calculating field produced kg ha^{-1} = pre-harvest losses + post-harvest losses + marketed kg ha^{-1} ;
- dividing marketed kg ha^{-1} by field produced kg ha^{-1} (Production Index).
- assigning possible production losses to assessed or probable causes (any cause ≥ 5 % of estimated field production);

(3) *Quantifying and interpreting* QPIs:
- calculating crop-wise QPI = Quality Index * Production Index
- deciding to improvements of methods if there are shortfalls between desired and achieved QPIs based on assessed causes of possible underperformance of crops.

6.2.2 *Testing with phosphorus, kalium and nitrogen parameters*

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
(P/KAB > 1, = 1 or < 1, if P/KAR is below, in or beyond desired range).
Nitrogen Available Reserves (NAR) is the environmentally acceptable range of N_{min} Soil reserves (0-100 cm) at start of leaching period (NAR < 45 kg ha^{-1} on sand and NAR < 70 kg ha^{-1} on clay, approximately corresponding to EU norm NG/DW).
Nitrogen Ground/Drainage Water (NG/DW) is the environmentally acceptable content of N_{min} in groundwater or drainage water (NG/DW < 11.3 mg l^{-1} = EU norm for drinking water, NG/DW < 5.6 mg l^{-1} = EU guideline for drinking water).

(1) *Testing with P and K parameters:*
- 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) (KAB in similar way);
- comparing actual P/KAB and desired P/KAB, and improving INM or ENM if needed.

(2) *Testing with N parameters:*
- establishing desired range of NAR to meet desired NDW or NGW for your IAFS or EAFS (EU norm or EU guideline?);
- monitoring actual NAR of each field (possibly also NDW or NGW);
- establishing which fields/crops have an NAR > desired range (or ND/GW > desired range).
- improving INM or ENM and if needed MCR to reduce the NAR of single fields/crops to such extent that overall the prototype desired ranges of NAR and NDW or NGW are being achieved.

6.2.3 Testing with 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 soil 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
(1) Establishing desired range OMAR > x
(2) Monitoring actual OMAR of fields
(3) Establishing OMAB > 1 if OMAR < x (and OMAB ≤ 1 if OMAR ≥ x).
(4) Improving I/ENM, MSC and if needed MCR accordingly.
(5) Establishing if shortfall between actual and desired OMAR is gradually made good.

6.2.4 Testing with Soil Cover Index (SCI)

Brief definition:
SCI is the extent to which the soil of a field or a farm is covered by crops or crop residues, during a crucial period or overall 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 fully fallow throughout the crucial period of the year.

(1) Establishing desired ranges of SCI $month^{-1}$ or $period^{-1}$:
- in view of the need for soil cover throughout the 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 throughout the farm or on individual fields, to benefit fauna and landscape.

(2) Monitoring and calculating actual SCI $month^{-1}$ or $period^{-1}$:
- Monitoring SCI $month^{-1}$ field by field ($0 \leq x \leq 1$);
- calculating SCI $period^{-1}$ by field or by farm. The latter is a weighted average of fields (including Ecological Infrastucture and permanent set-aside) throughout the farm, taking into account the size of the fields in ha).

(3) Improving MCR and MSC if actual SCI < desired SCI.

6.2.5 Testing with Ecological Infrastructure (EI) and related Plant Species Diversity (PSD)

Brief definitions:
EI is the part of the farm laid out and managed as a network of linear and non-linear habitats and corridors for wild flora and fauna, including buffer strips.
PSD is the occurrence of target plant species in the EI, to be specified in space and time. A target plant species is a species both attractive for people to recreate and for animals to feed on or shelter in.

(1) Establishing possible shortfalls between actual and desired EI:
- in share of farm area;
- in layout as a network of linear and non-linear elements including buffer strips.

(2) Establishing possible shortfalls between actual and desired PSD:
- spatially: throughout the farm or per element or per subelement;
- temporally: throughout the year or in crucial months for recreationists or for procreating or migrating animals.

(3) Improving EI and PSD in the case of shortfalls:
- in spatial continuity;
- in temporal continuity.

6.2.6 *Testing with Environment Exposure to Pesticides (EEP)*

Brief definition:
EEP is specified as EEP air, EEP soil and EEP groundwater by pesticide, crop or farm.
EEP air = active ingredients (kg ha^{-1}) * vapour pressure (Pa at 20-25 °C);
EEP soil = active ingredients (kg ha^{-1}) * 50 % degradation time (days);
EEP groundwater = EEP soil (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).

(1) *Quantifying EEPs air, soil, water at 3 levels:*
  - by pesticide (ha^{-1});
  - by crop (sum of pesticides ha^{-1} $crop^{-1}$);
  - by farm (weighted average of pesticides ha^{-1} $crop^{-1}$).
(2) *Ranking EEPs by pesticide * ha treated;*
(3) *Establishing possible shortfalls between actual and desired EEPs by farm;*
(4) *Improving EEPs per farm in the case of shortfalls:*
  - replacing high ranked pesticides by non-chemical protective measures or less ranked pesticides;
  - reducing EEPs of high ranked pesticides by reducing the dose by band spraying, spot-wise treatment or repeated low-dose treatments.

6.2.7 *Testing with Net Surplus (NS)*

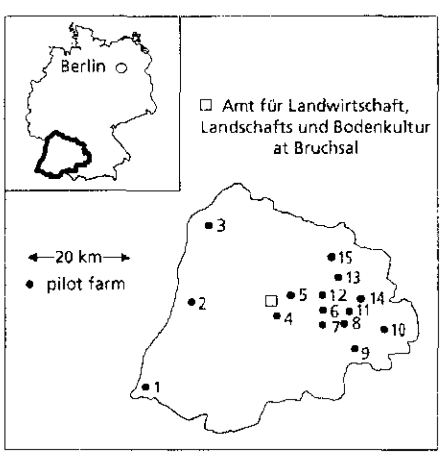
Brief definition:
NS is gross revenues minus all costs, including a payment for all labour hours, equal to payment for comparable labour in other economic sectors.
Range of NS:
NS < 0 implies labour has not equally been paid and the farm has made no profit.
NS = 0 implies equal payment of labour, though no profit.
NS > 0 implies both equal payment and profit.

(1) *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.
(2) *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).

7 Part 5 of the identity cards of the 9 selected pilot projects

In Progress Report 1, the layout of the prototype (mostly in experimental farms) was presented as Part 3 of the identity card. In this Progress Report 2, the theoretical prototype has been inserted as Part 3 and the Multifunctional Crop Rotation as Part 4. Consequently, the layout of the prototype (on pilot farms) is shifted to Part 5. Because the pilot projects have at least 10 farm variants, only the layout of 1 representative variant is presented: the one for the pilot farm, whose MCR design is presented in Part 4. As a result, each team presents both design and layout of MCR as its central method. In addition to presenting the layout of a representative farm variant, Part 5 presents some basic agro-ecological data on the pilot farms in the group, including their location in the region. The 5 layouts of the IAFS projects are presented in Section 7.1 (Figs. 3.1.1-3.1.5). The 4 layouts of the EAFS projects are presented in Section 7.2 (Figs. 3.2.1-3.2.4). The layouts are briefly evaluated in Section 7.3, in terms of a set of agro-ecological criteria.

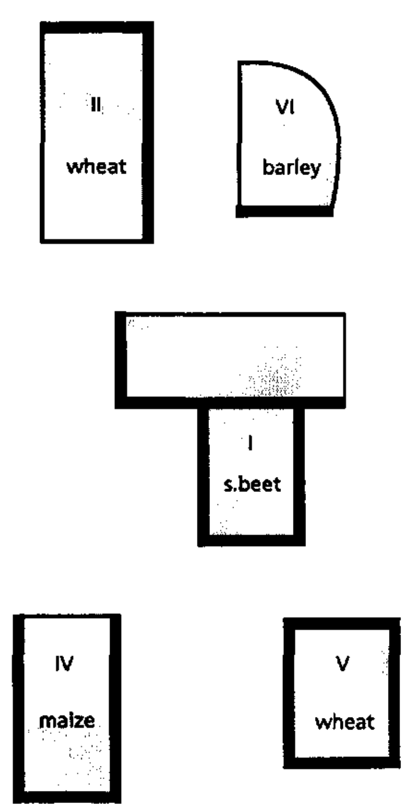
7.1 Layouts of the 5 IAFS projects



Baden-Württemberg

15 IAFS-pilot farms

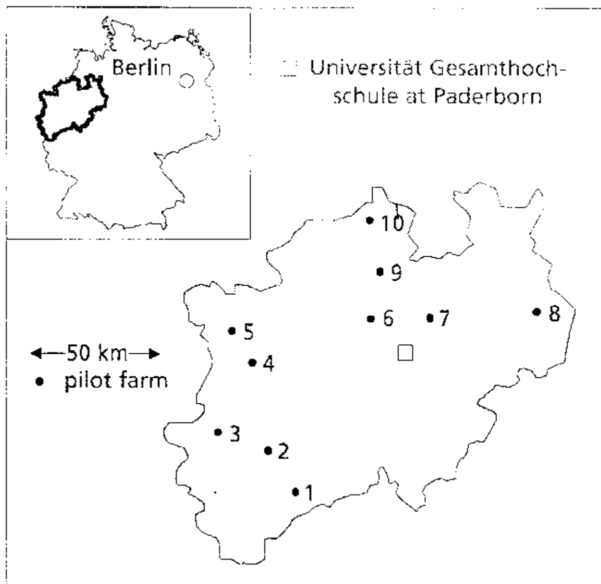
$farm^{-1}$	(lowest - highest)
production area	35 - 240 ha
field adjacency	0.1 - 0.6
mean field size	2 - 6 ha
mean field length/width	2 - 4
crop rotation blocks	4 - 6
adj. of subsequent blocks	? - ?
share of cereals	0.33 - 0.5
share of ecol. infrastructure	0.03 - 0.06



pilot farm 10:

□ IAFS (32 ha)
I-VI Crop rotation blocks 1994
▬ Ecological Infrastructure
←200 m→

Figure 3.1.1 Layout of IAFS pilot project Baden Württemberg (DE 1)



Nordrhein-Westfalen

10 IAFS-pilot farms

farm^{-1}	(lowest - highest)
production area	35 - 86 ha
field adjacency	? - 1
mean field size	2.4 - 6.5 ha
mean field length/width	1 - 5
crop rotation blocks	4 - 6
adj. of subsequent blocks	0 - 0.5
share of cereals	0.2 - 0.5
share of ecol. infrastructure	0.01 - 0.07

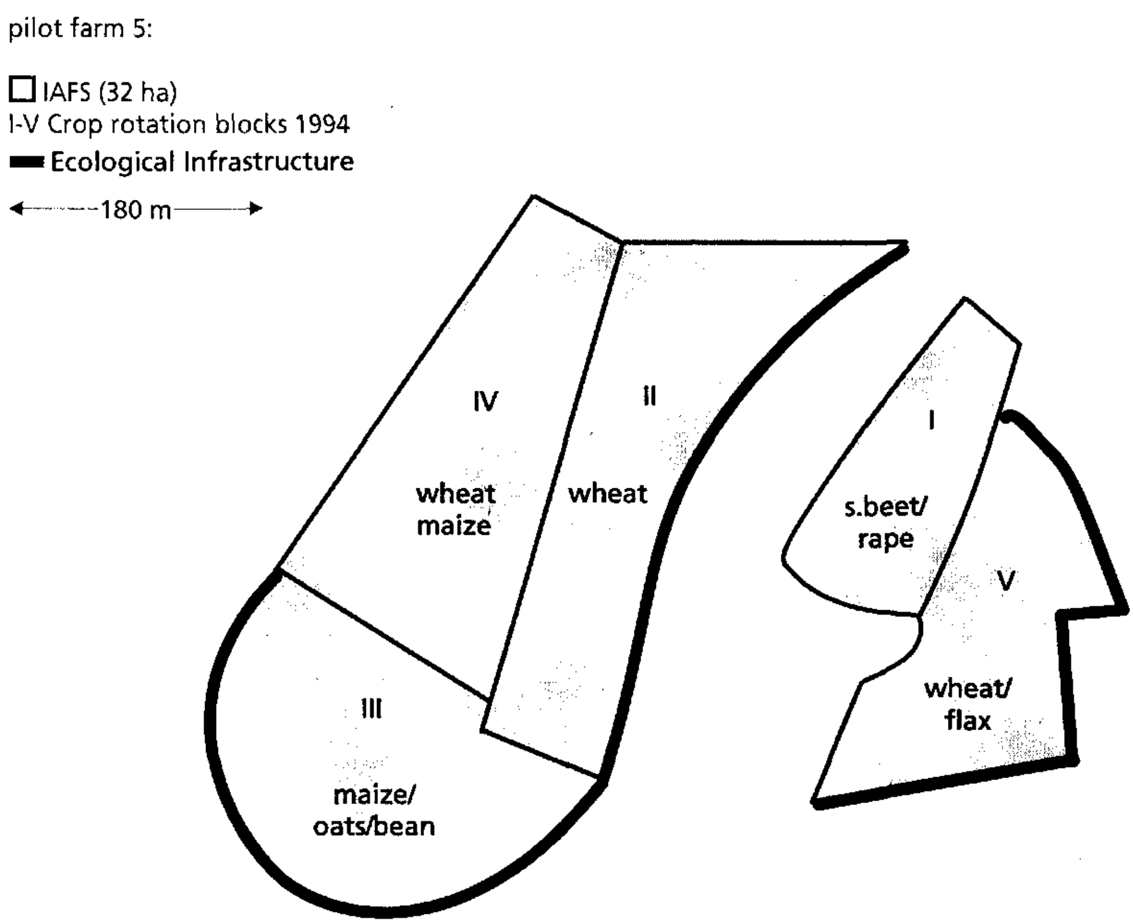
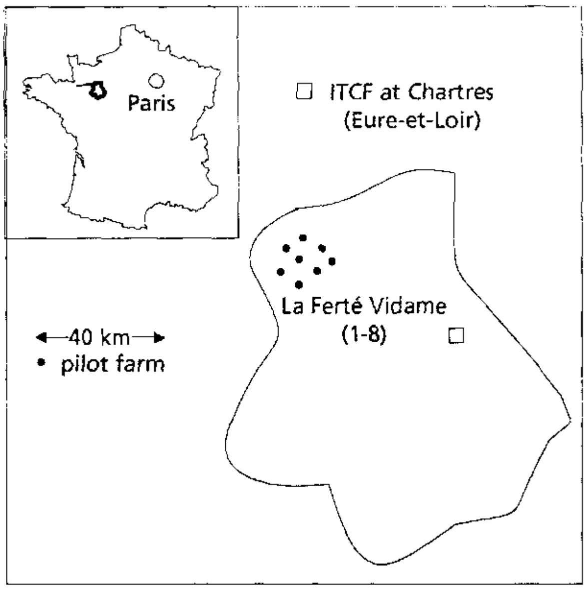


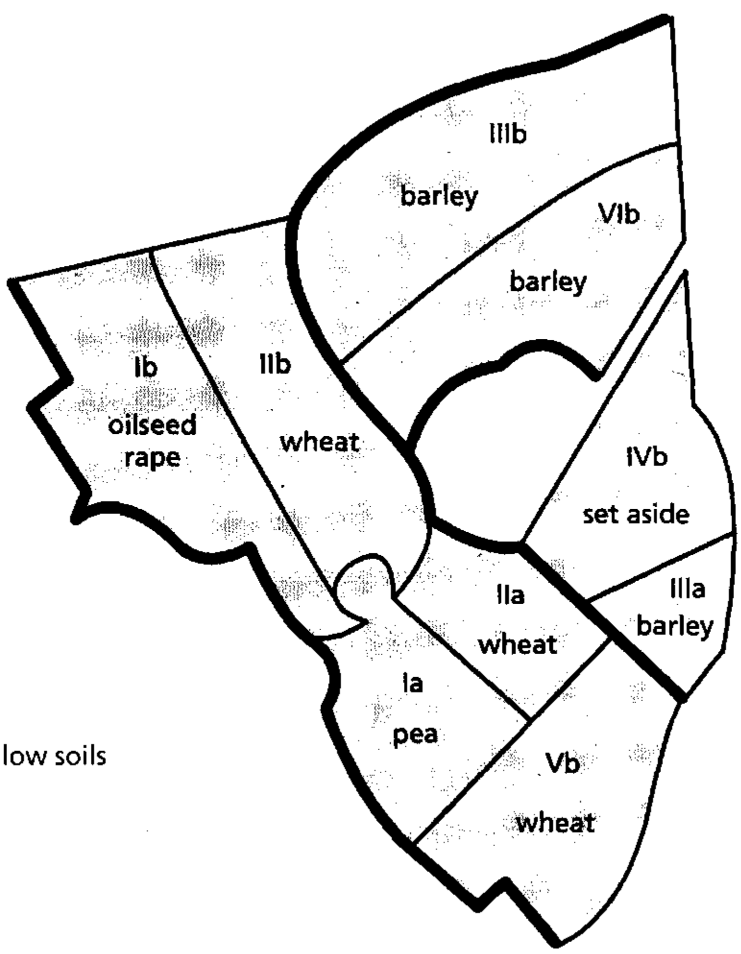
Figure 3.1.2 Layout of IAFS pilot project Nordrhein-Westfalen (DE 3)



La Ferté Vidame (Eure-et-Loir)

8 IAFS-pilot farms

farm⁻¹	(lowest - highest)
production area	65 - 248 ha
field adjacency	0.3 - 1
mean field size	5.5 - 11.8 ha
mean field length/width	1.1- 3.3
crop rotation blocks	3 - 6
adj. of subsequent blocks	0.1 - 0.4
share of cereals	0.35 - 0.75
share of ecol. infrastructure	0.02 - 0.12

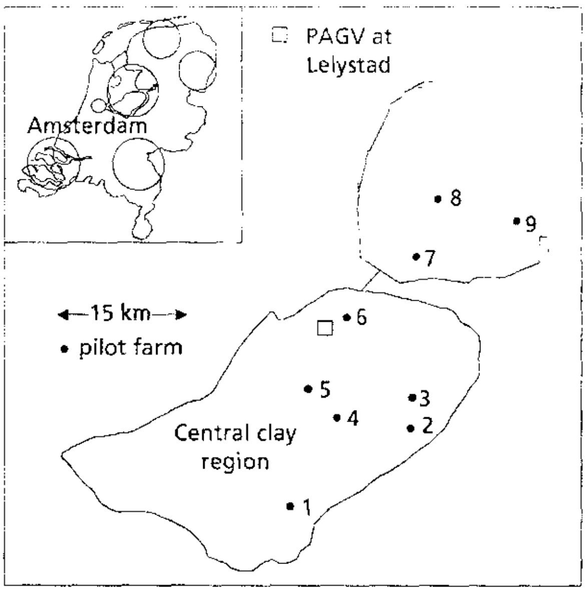


pilot farm 2:

□ IAFS (66 ha)
I-VI Crop rotation blocks 1994
a-b rotations of deep and shallow soils
▬ Ecological Infrastructure

←300 m→

Figure 3.1.3 Layout of IAFS pilot project La Ferté-Vidame



National Network (5 regions)

9 IAFS-pilot farms (central clay region)

$farm^{-1}$	(lowest - highest)
production area	30 - 50 ha
field adjacency	1 - 1
mean field size	4 - 12 ha
mean field length/width	1 - 2
crop rotation blocks	3 - 5
adj. of subsequent blocks	0 - 0.5
share of cereals	0.2 - 0.5
share of ecol. infrastructure	0.01 - 0.02

pilot farm 8:

☐ IAFS (48 ha)
I-IV Crop rotation blocks 1994
▬ Ecological Infrastructure
←150 m→

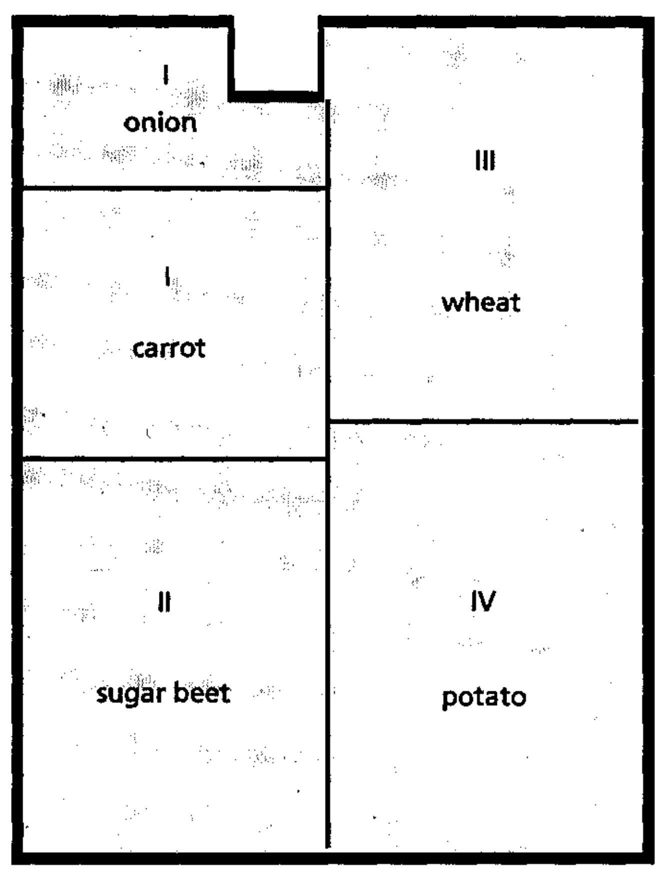
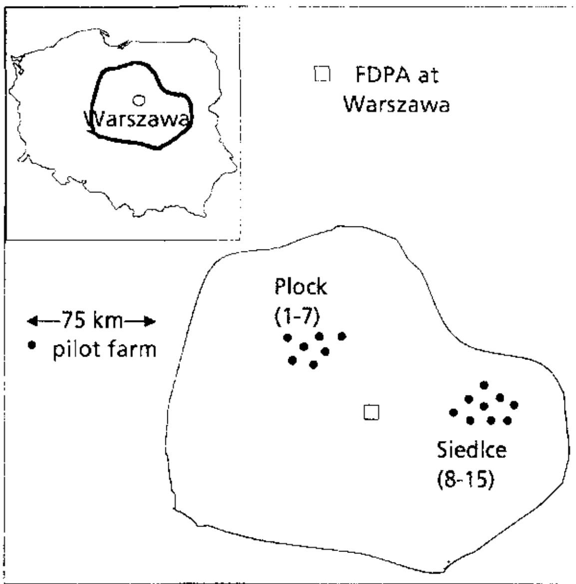


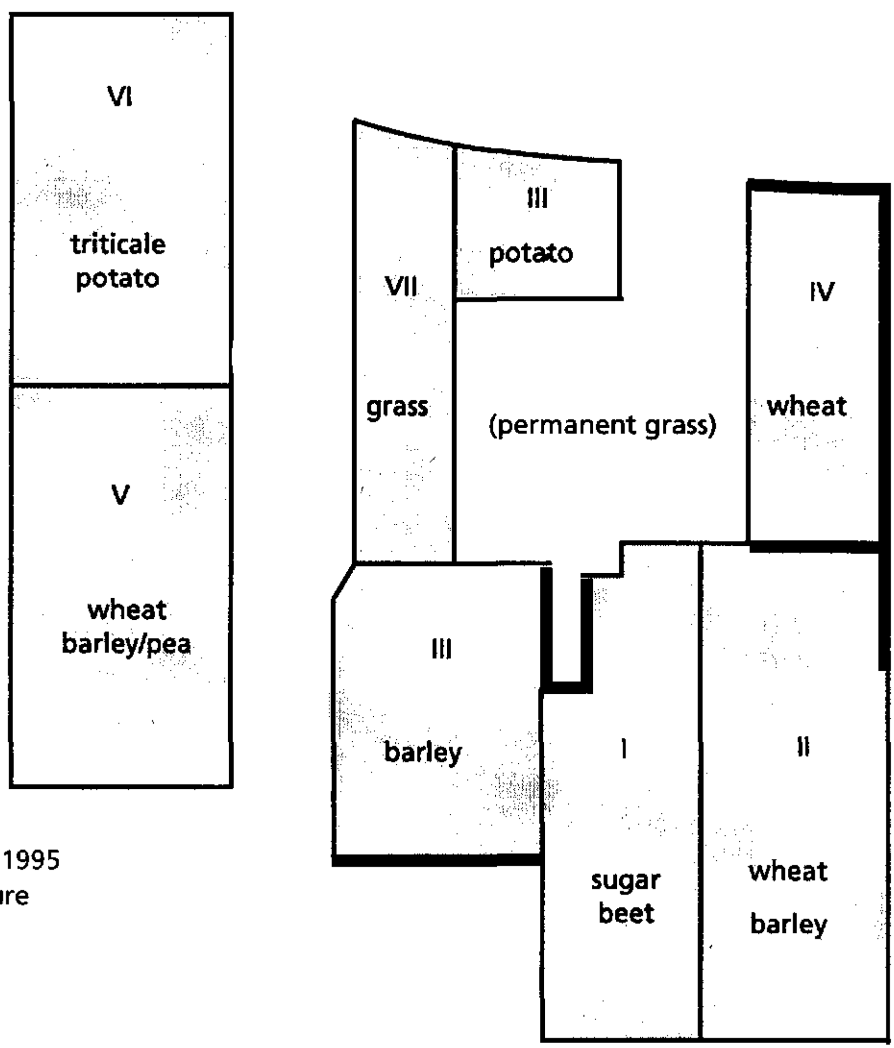
Figure 3.1.4 Layout of IAFS pilot project National Network (NL 1)



Mazovia

15 IAFS-pilot farms

$farm^{-1}$	(lowest - highest)
production area	9 - 22 ha
field adjacency	0.4 - 1
mean field size	0.5 - 5.5 ha
mean field length/width	2.5 - 10
crop rotation blocks	3 - 7
adj. of subsequent blocks	0.16 - 0.64
share of cereals	0. 3 - 0.7
share of ecol. infrastructure	0.01 - 0.04

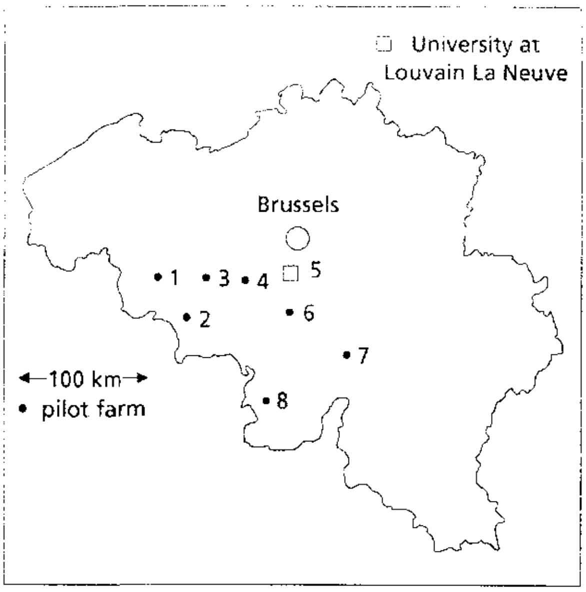


pilot farm 5:

☐ IAFS (14 ha)
I-VII Crop rotation blocks 1995
▬ Ecological Infrastructure
←150 m→

Figure 3.1.5 Layout of IAFS pilot project Mazovia (PL 1)

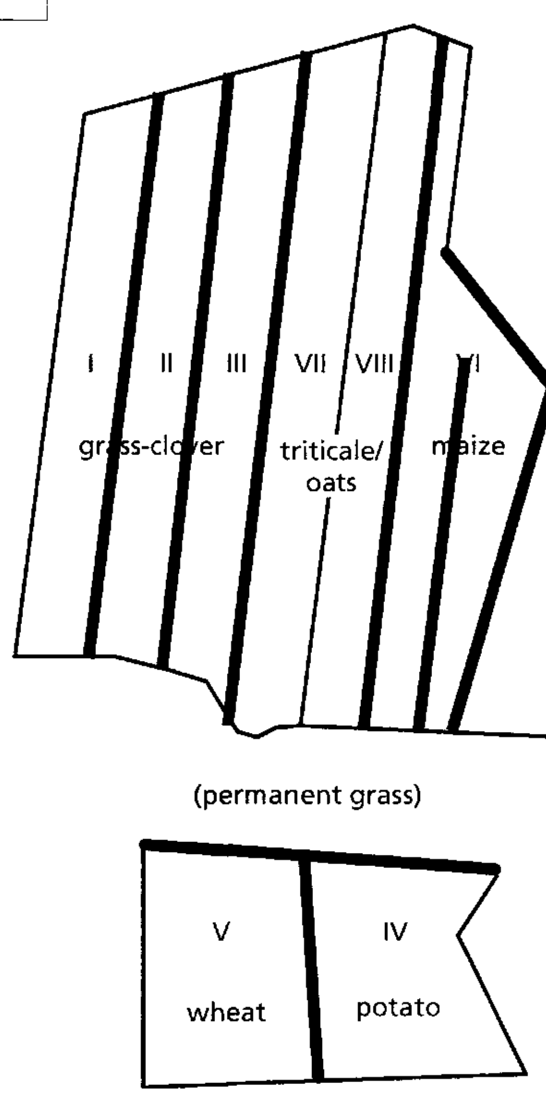
7.2 Layouts of the 4 EAFS projects



Mid-Belgium

8 EAFS-pilot farms

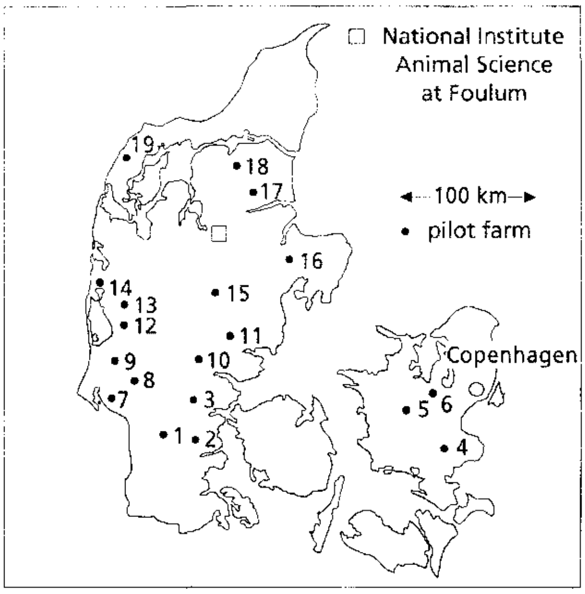
farm^{-1}	(lowest - highest)
production area	27 - 79 ha
field adjacency	0.5 - 1
mean field size	1.2 - 2.9 ha
mean field length/width	? - ?
crop rotation blocks	6 - 12
adj. of subsequent blocks	? - 1
share of cereals	0.3 - 0.6
share of ecol. infrastructure	0.02 - 0.04



pilot farm 1:

□ EAFS (32 ha)
I-VIII Crop rotation blocks 1994
▬ Ecological Infrastructure
←——200 m——→

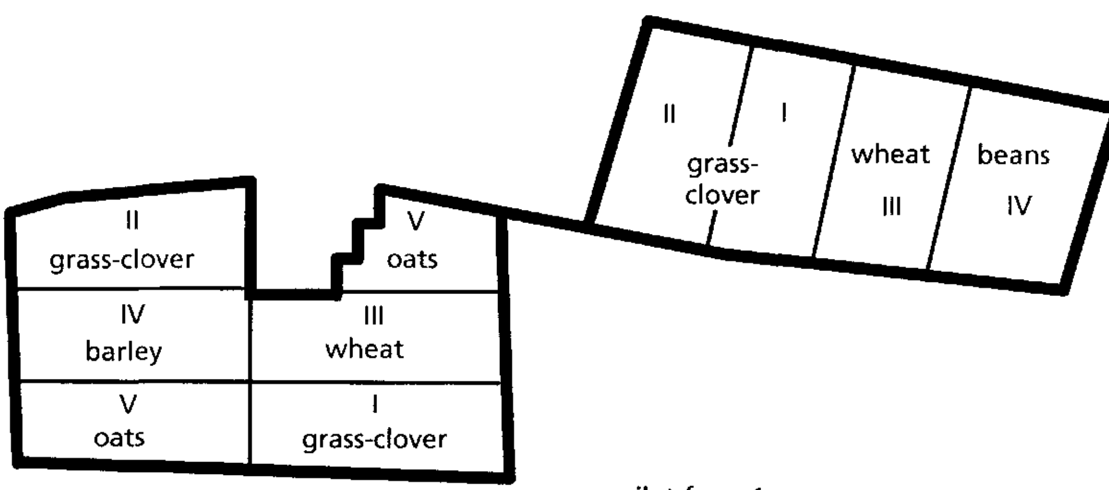
Figure 3.2.1 Layout of EAFS pilot project mid-Belgium (B 1)



National Network

19 EAFS-pilot farms

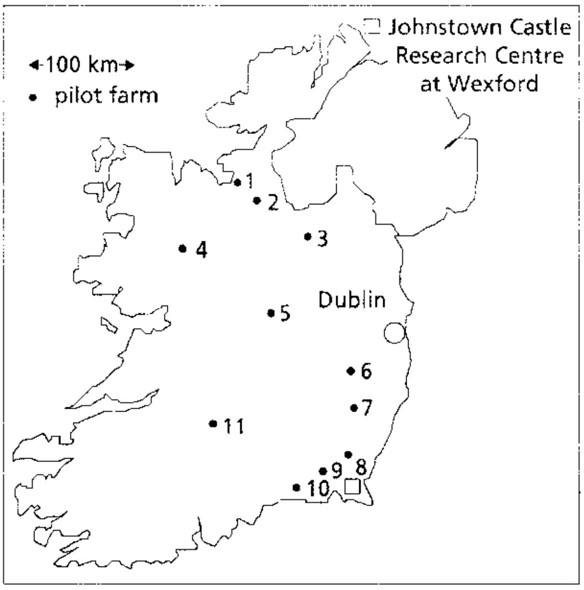
$farm^{-1}$	(lowest - highest)
production area	50 - 96 ha
field adjacency	0.5 - 1
mean field size	2 - 15 ha
mean field length/width	1 - 5
crop rotation blocks	5 - 12
adj. of subsequent blocks	? - ?
share of cereals	? - ?
share of ecol. infrastructure	? - ?



pilot farm 1:

□ EAFS (63 ha)
I-V Crop rotation blocks 1994
▬ Ecological Infrastructure
←—? m—→

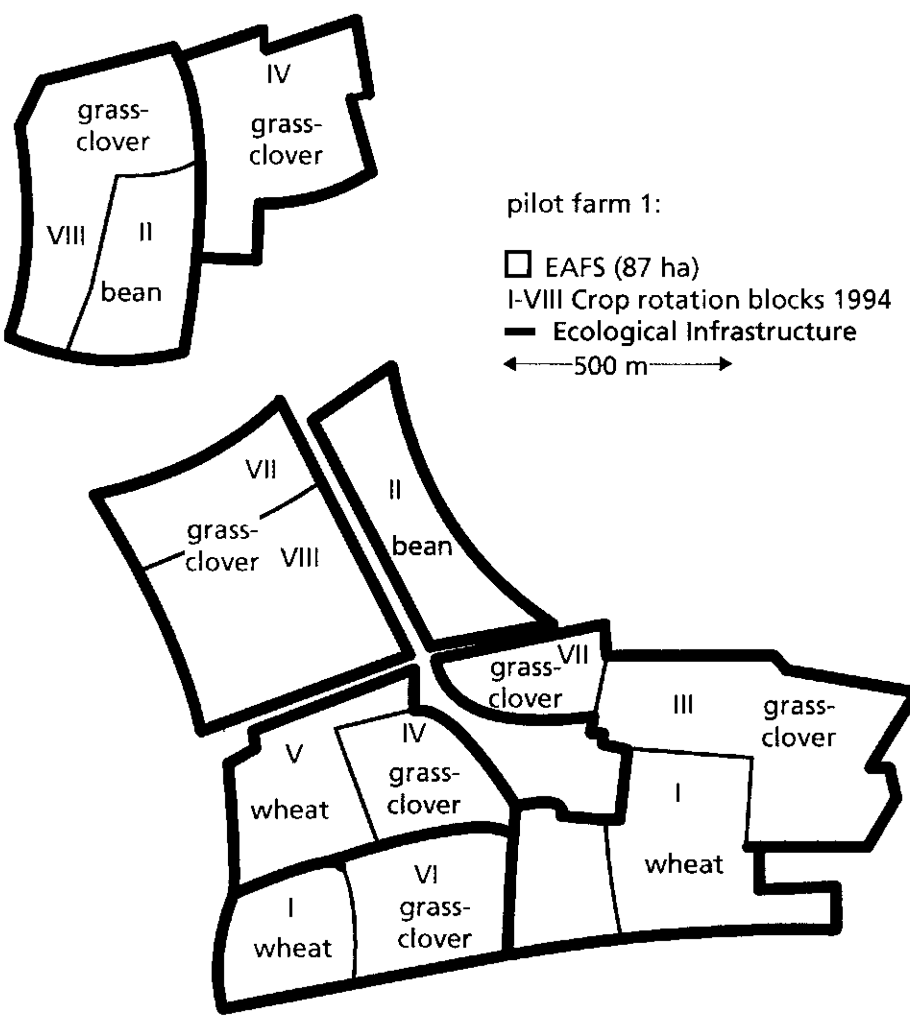
Figure 3.2.2 Layout of EAFS pilot project National Network (DK 2)



Southeast and Midwest Ireland

10 EAFS-pilot farms

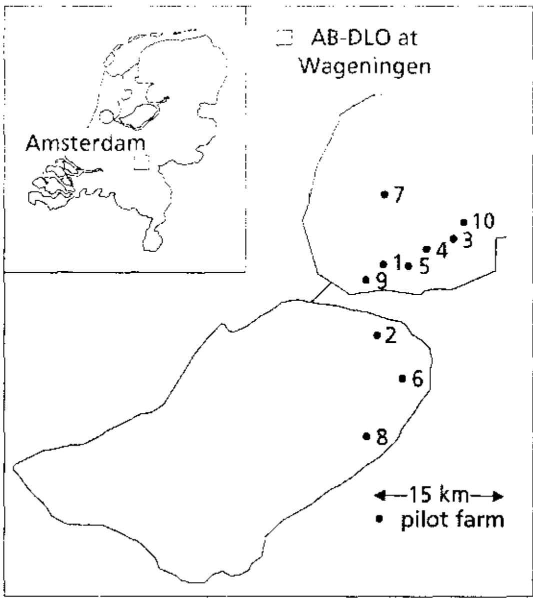
$farm^{-1}$	(lowest - highest)
production area	8 - 93 ha
field adjacency	1 - 1
mean field size	1.7 - 5.2 ha
mean field length/width	1.3 - 3.1
crop rotation blocks	6 - 10
adj. of subsequent blocks	? - ?
share of cereals	0 - 0.2
share of ecol. infrastructure	0.03 - 0.09



pilot farm 1:

☐ EAFS (87 ha)
I-VIII Crop rotation blocks 1994
▬ Ecological Infrastructure
◄—500 m—►

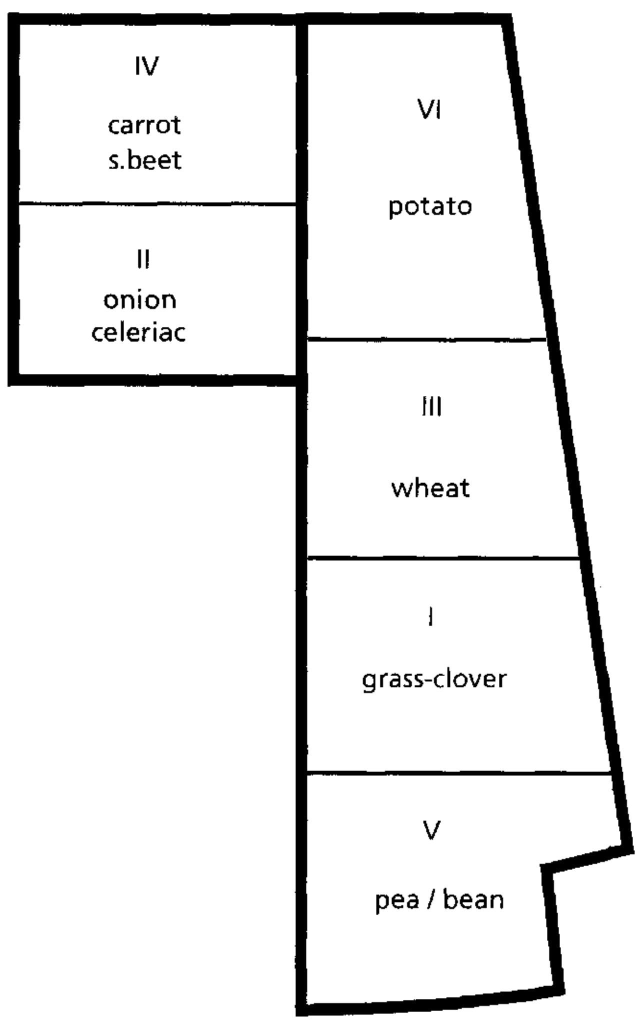
Figure 3.2.3 Layout of EAFS pilot project Southeast and Midwest (IRL 1)



Flevoland

10 EAFS-pilot farms:

$farm^{-1}$	(lowest - highest)
production area	23 - 44 ha
field adjacency	1 - 1
mean field size	4 - 7 ha
mean field length/width	1 - 3
crop rotation blocks	6 - 6
adj. of subsequent blocks	0 - 0.33
share of cereals	0.16 - 0.33
share of ecol. infrastructure	0.04 - 0.06



pilot farm 6:

☐ EAFS (36 ha)
I-VI Crop rotation blocks 1994
▬ Ecological Infrastructure
←300 m→

Figure 3.2.4 Layout of EAFS pilot project Flevoland (NL 2)

Table 6. Agro-ecological evaluation of layouts of prototypes in selected European pilot projects in 1994 *

Agro-ecological criteria (explained in 7.4 of Progress Report 1)		**B 1** Mid-Belgium	**DE 1** Baden-Württemberg	**DE 3** Nordrhein Westfalen	**DK 2** National network	**F 1** Ferté-Vidame	**IRL 1** Southeast and Midwest	**NL 1** National network	**NL 2** Flevoland	**PL 1** Mazovia
Field adjacency										
IAFS	**= 1**		0.1-0.6	0.3-1		0.3-1		1-1		0.4-1
EAFS	**= 1**	0.5-1			0.5-1		1-1		1-1	
Field size (ha)										
IAFS	**≥ 1**		2-6	2-7		6-12	: -	4-12		1-6
EAFS	**≥ 1**	1-3			2-15		2-5		4-7	
Field length/width										
IAFS	**≤ 4**		2-4	1-5		1-3		1-2		3-10
EAFS	**≤ 4**	?			1-5		1-3		1-3	
Crop rotation blocks										
IAFS	**≥ 4**		4-6	4-6		3-6		3-5		3-7
EAFS	**≥ 6**	6-12			5-12		6-10		6-6	
Subsequent blocks adjacency										
IAFS	**= 0**		?	0-0.5		0.1-0.4		0-0.5		0.2-0.6
EAFS	**= 0**	?-1			?		?		0-0.3	
Share of cereals										
IAFS	**≤ 0.5**		0.3-0.5	0.2-0.5		0.4-0.8		0.2-0.5		0.3-0.7
EAFS	**≤ 0.3**	0.3-0.6			?		0-0.2		0.2-0.3	
Ecological infrastructure										
IAFS	**≥ 0.05**		0.03-0.06	0.01-0.07		0.02-0.12		0.01-0.02		0.01-0.04
EAFS	**≥ 0.05**	0.02-0.04			?		0.03-0.09		0.04-0.06	
Presence of valid layouts										
IAFS			-	±		-		-		-
EAFS		-			?		±		±	

* See Figs. 3.1.1-3.1.5 (IAFS) and 3.2.1-3.2.4 (EAFS).

[solid box] None of the pilot farms can meet the criterion

[dotted box] Some of the pilot farms can meet the criterion

7.3 State-of-the-art in laying out prototypes

When you have designed a theoretical prototype and the methods in this context, you can lay out the prototype for a first year of testing and improving (step 4). In Progress Report 1 (Chapter 7) it is explained that I/EAFS prototypes need an agro-ecological layout to be effective and achieve the desired results.The underlying concept is that I/EAFS should be an agro-ecological whole consisting of a 'team' of steadily interacting and rotating crops, plus their accompanying (beneficial or harmful) flora and fauna. From this concept a set of 7 agro-ecological criteria has been drawn up to characterise the layouts of the 9 selected pilot projects (Figs. 3.1-3.2) and subsequently to evaluate them (Table 6).

From Table 6 it appears that most layouts of prototypes still fall seriously short of meeting the 7 agro-ecological criteria. In 1994, only some agro-ecologically valid layouts were present, in DE 3, IRL 1 and NL 2. After minor revision, some could also be present in B 1, F 1, NL 1 and PL 1. However, most pilot projects need major revision to achieve agro-ecologically valid layouts of all prototype variants, because many of the pilot farms have one or more fields not adjacent to the others, and therefore their prototype variants cannot be laid out as an agro-ecological whole, which is a prerequisite for an agro-ecological identity.

There are various options for revising the layout of your prototype variants, depending on what value you attach to the criterion of field adjacency. The most consistent is to select only those pilot farms in which all fields are adjacent (permanent grassland included). Another consistent solution is to lay out the prototype only on the part of the farm with adjacent fields, so as to exclude non-adjacent fields. A compromise would be to include 1 or 2 non-adjacent fields if they can be connected to the other fields by the ecological infrastructure. In any case, teams with ongoing projects or projects in preparation are strongly recommended to lay out their prototypes as an agro-ecological whole, for several reasons.

Only if the farming system is an agro-ecological whole:
- can the prototype achieve sufficient agro-ecological identity in the midst of a turbulent and distorting environment, dominated by monocultures and short rotations with a chronic imbalance between beneficial and harmful flora and fauna and chronic use of pesticides to compensate for this imbalance.
- can the prototype achieve desired results in multi-objective parameters, which directly depend on an agro-ecological identity, such as Ecological Infrastructure requiring sufficient spatial continuity (for flora, fauna and recreation), and Exposure of Environment to Pesticides and Quality Production, both requiring sufficient support from beneficial flora and fauna.
- can the prototype achieve desired results in multi-objective parameters, which indirectly depend on an agro-ecological whole, insofar as that whole supports a management which is effective and efficient in timing and input of labour and energy. In principle, all parameters are involved, including Net Surplus and Energy Efficiency.

Most pilot projects still have many more fields than rotation blocks, comparing the range in production area farm^{-1} to the range in mean field size farm^{-1}. Apparently, most teams have not yet designed and laid out an appropriate MCR variant on most of their farms. Therefore, it is concluded that most teams still have to proceed to step (4) of the methodical way, which is to do with the testing and improving of the prototype on-farm. This implies that there is still sufficient scope to improve both the design and the layout of the prototype variants!

8 Focus on testing an IAFS prototype in pilot project NL-1.

Research team: F. Wijnands, P. van Asperen, G. van Dongen, S. Janssens

8.1 Introduction

In the Netherlands, IAFS prototypes have been developed region-wise on 3 experimental farms with region-specific crop rotations and cropping systems (Wijnands and Vereijken, 1992).
A national network has been set up to test and disseminate IAFS prototypes by 5 pilot groups in the 5 major regions of arable farming (Wijnands, 1992). This network is intended to support the Dutch government's policy to change to integrated production in agriculture (Anonymous, 1990; Anonymous, 1991).
This chapter focuses on the testing of the IAFS prototype that was developed on the Nagele experimental farm for the central clay region (Chapter 9, Progress Report 1). The prototype was initially tested for a limited period only ('90-'93, Fig. 3.1.4) in collaboration with a group of 9 pilot farms in that region. Consequently, the major objectives, as quantified in 10 multi- objective parameters, (Table 6.1.7, Progress Report 1) have only partially been achieved .

8.2 Results of testing

The test results are presented in the order of the 6 major methods needed to achieve the objectives established in the theoretical prototype (Fig. 2.1.4 in Chapter 4).

(1) MULTIFUNCTIONAL CROP ROTATION (MCR).

MCR is the major method to achieve desired results in Quality Production Indices (QPI product^{-1}), Net Surplus (NS) and Soil Cover Index (SCI). The MCR variants of the 9 pilot farms were designed and laid out in accordance with the demands made of MCRs by the IAFS, as specified in Subsection 3.2.1 for the temporal dimension and in Section 7.3 for the spatial dimension. Table 4.1.4 specifies the MCR for pilot farm 1, a representative variant for the region.
We have not yet tested with QPI and SCI because they are not yet ready for use. We have tested with NS but the farms were still converting to the prototype at the time, so the results cannot be considered as representative for an optimised prototype. However, testing with NS at an initial stage enables various farm strategies to be established to achieve the desired results.

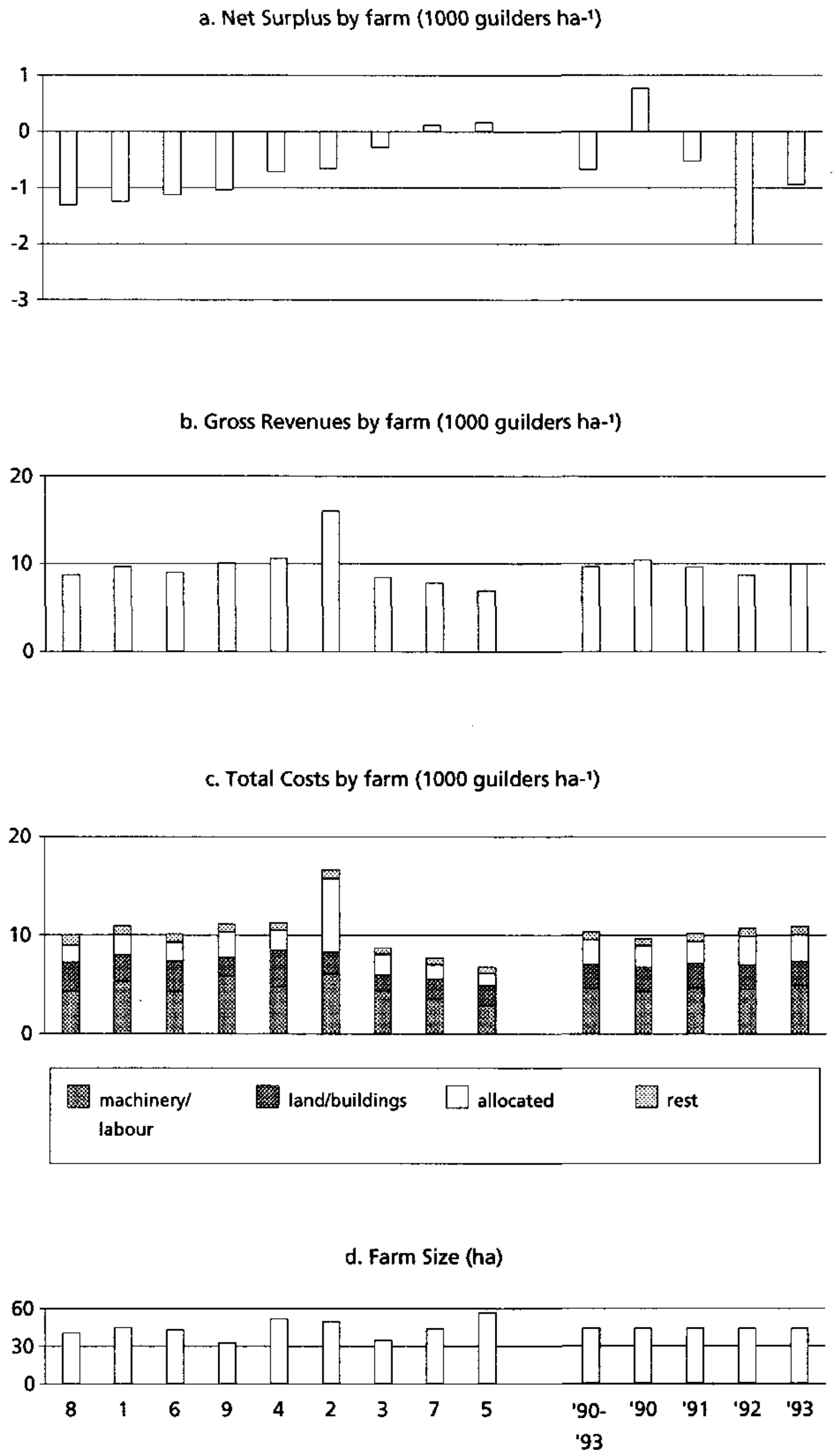
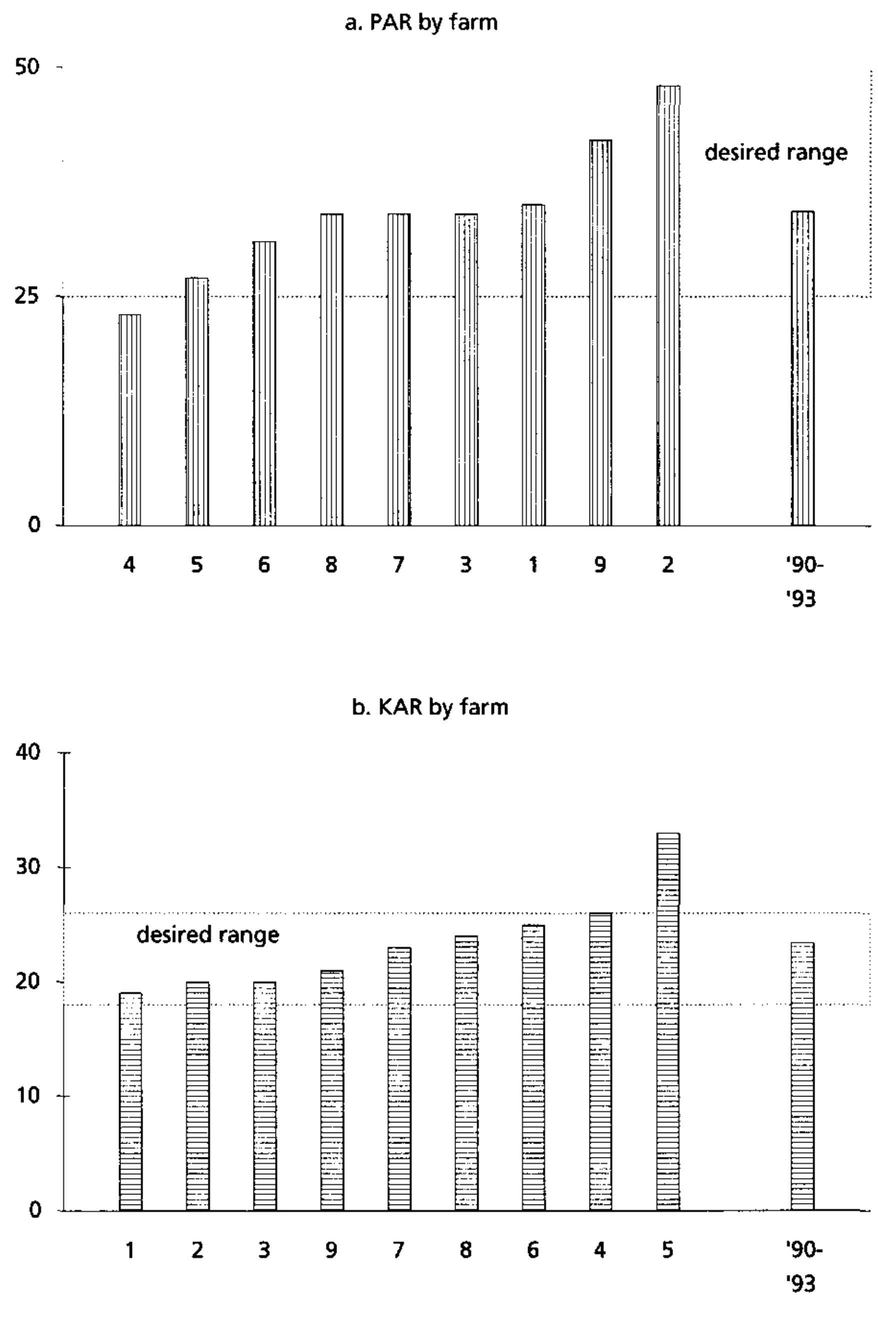


Figure 4.1. Net Surplus (NS) of the 9 pilot farms ('90-'93) (a) related to Gross Revenues (b), Total Costs (c) and Farm Size (d), all ranked by increasing NS.

Fig. 4.1 presents the Net Surplus (NS) of the 9 pilot farms, averaged over '90-'93. Only farms 7 and 5 achieve the desired NS (≥0). NS is not clearly related to any of the underlying parameters; the lack of a relationship is particularly evident in farm size, financial yield and costs. There is a positive correlation between the costs of machinery/labour and financial yield ($r^2 = 0.75$) and allocated costs and financial yield ($r^2 = 0.8$). Farm 2 was excluded in the correlations, since it includes an animal husbandry unit. Higher costs seem unavoidable if high financial yields are to be obtained.

In the range from farms 8 to 4, NS increases because the financial yield increases gradually while the total costs remain relatively stable. These farms are following a cost-effective intensification strategy. In the range from farms 3 to 5, NS increases with farm size and the MCR is more extensive (more cereals, less potatoes). The decrease in yield is overweighed by the decreasing costs (allocated, machinery/labour). These farms are following a low cost strategy.

From Fig. 4.1 it is apparent that Farm Structure Optimisation (FSO), optimising and rationalising inputs of land, labour and capital (machinery/buildings) is a crucial finalising method to achieve an adequate NS. FSO has not yet been applied because the remaining agronomic and agro-ecological parameters of the prototypes still need to be optimised.



Desired ranges correspond with range called 'agronomically good' by the extension service. Beyond these ranges the risks of exceeding norms for P and K in shallow waters are ecologically unacceptable.
a. PAR = mg P2O5/ l soil, 1:60 extraction with water (Pw count)
b. KAR = mg K2O/ 100 g of air dry soil, 1:10 extraction with 0.1 n HCl (K count)

Figure 4.2. P/K Available Reserves (P/KAR) of the 9 pilot farms ('90-'93), ranked by increasing PAR (a) and increasing KAR (b).

(2) INTEGRATED NUTRIENT MANAGEMENT (INM)

INM is the major method for achieving desired results in PK Available Reserves (P/KAR) and PK Annual Balances (P/KAB), N Available Reserves (NAR), N Drainage Water (NDW) and Energy Efficiency (EE).

Fig. 4.2 presents the PAR and KAR of the 9 pilot farms averaged over '90-'93. Most farms have P/KAR in the desired range. Only farm 5 exceeds the desired KAR.

Fig. 4.3 presents the PAB and KAB of the 9 pilot farms averaged over '90-'93. However, most farms have a PAB > 1 and a KAB < 1. The more PAB exceeds 1, the greater the risk of exceeding the desired range. At present we do not know to what extent PAB may be permitted to exceed 1, to compensate for P fixation on these calcareous soils. Similarly, we do not know to what extent KAB can be below 1, assuming (as most farmers do at present) net K mineralization from these young marine clay soils. Therefore we have been cautious when quantifying the desired result in P/KAB, by assessing a provisional norm P/KAB = 1. Nevertheless, some extreme achievements need to be critically discussed with the pilot farms, such as the PAB for farms 6, 3 and 2.

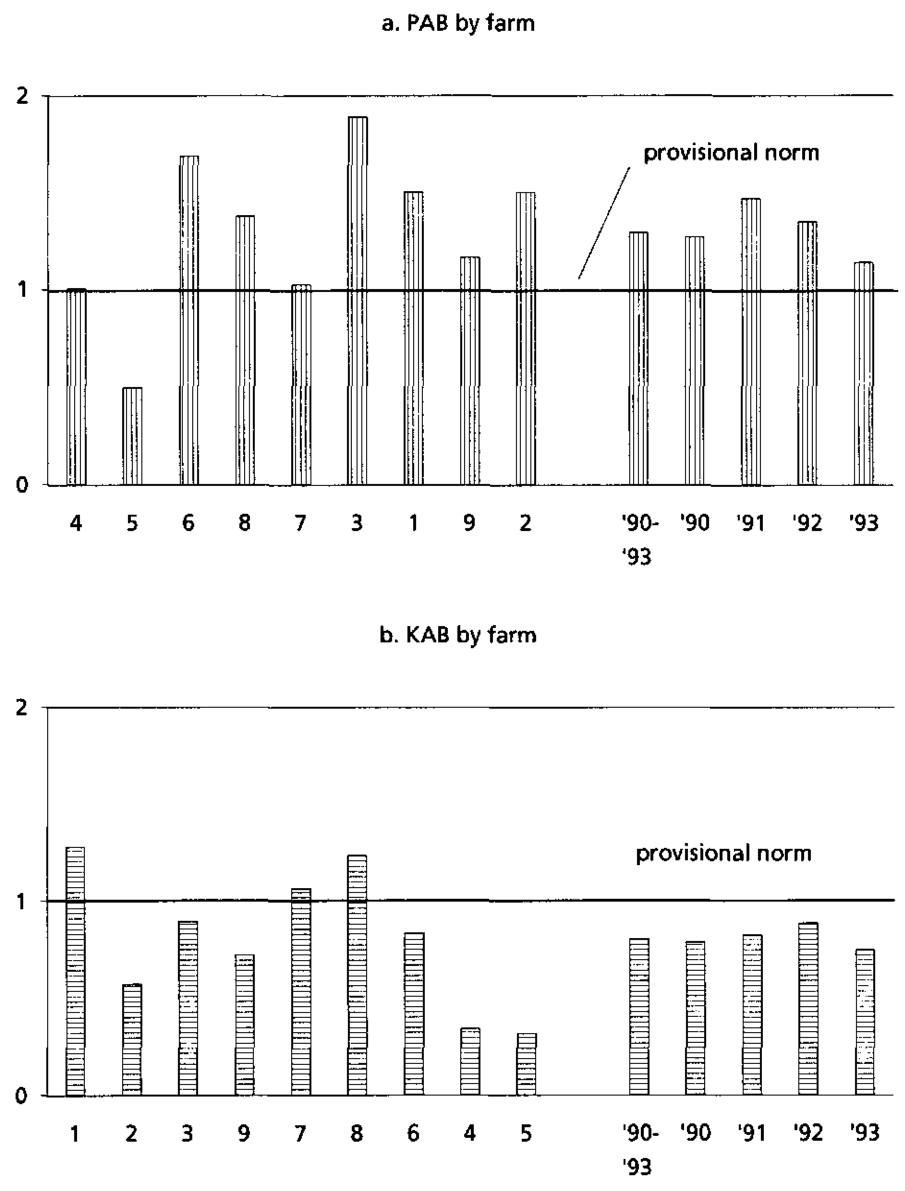
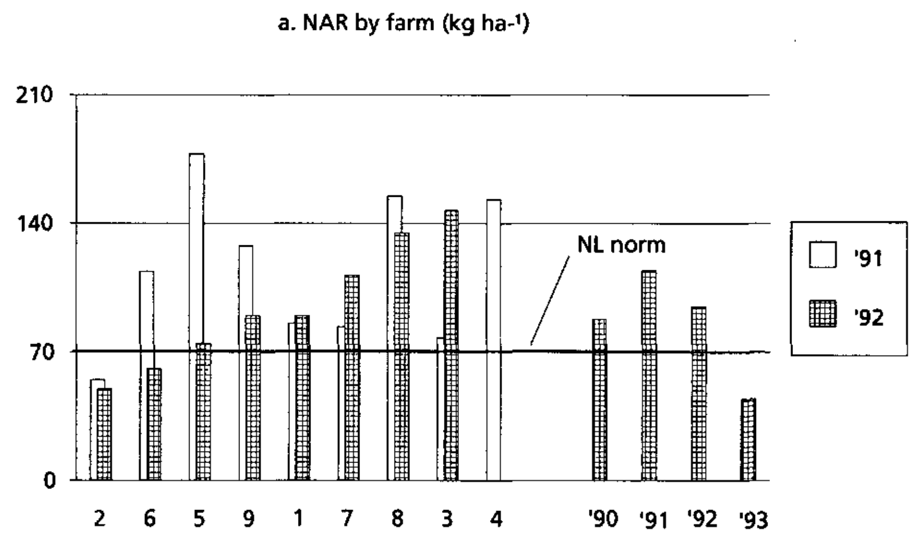


Figure 4.3. P/K Annual Balances (P/KAB) of the 9 pilot farms ('90-'93), ranked by increasing PAR (a) and increasing KAR (b) (see Fig. 4.2).

Fig. 4.4 presents the NAR of the 9 pilot farms in '91 and '92. Except for farm 2, all farms exceed the provisional NL norm of 70 kg ha^{-1}. This norm is considered as a desired result, since it complies fairly well with the norm of 11 mg l^{-1} nitrate-N in Drainage Water (NDW). (In the Netherlands, the EU norm for drinking water (11 mg l^{-1} nitrate-N) is also applied to shallow groundwater and consequently to drainage water 2 m below the soil surface). The NAR of '93 is an artefact, because the leaching period had already started in August. Since the NAR is assessed around 1 November the value is an underestimate of the amount of N at risk of leaching. The NAR varies greatly over farms and the average NAR over the group is 20 to 50% above the NL norm.

The main cause of a high NAR is cropping with potatoes and sown onions (Fig 4.4b). These crops need a high N input because of their low N recovery. Per farm the average share of these risky crops in the area fluctuates from 25 to 40% and their average contribution to NAR by farm ranges from 40 to 70%.



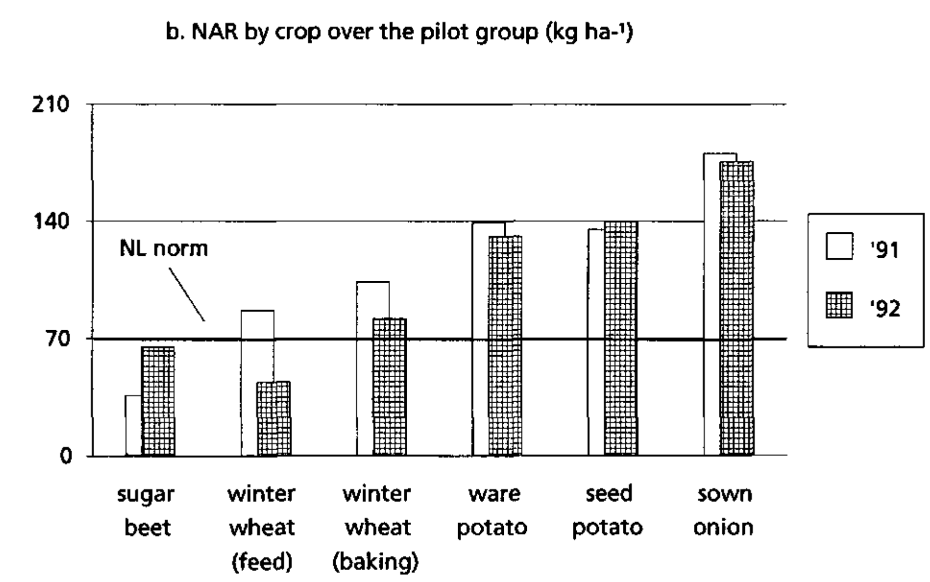


Figure 4.4. N Available Reserves (NAR) of the 9 pilot farms (a) and of the 6 prevalent crops (b), ranked by increasing NAR.

Fig. 4.5 presents the NDW for 3 pilot farms. In most cases they exceeded the NL norm. (The low NDW of '93 is mainly due to the precipitation surplus being twice the average). As with the NAR, the risky crops ware potato and sown onions have a great impact in these results (Fig. 4.6). Nevertheless their impact varies from farm to farm. Farm 1 has a relatively high share of risky crops, however succeeds in keeping the NDW relatively low. The other crops hardly contribute to the farm NDW. Farm 4 is located on very young marine clay with a high mineralization potential that increases overall NDW by crop in spite of the farm having the lowest mineral N input of the group. The peak NDW of '91 is mainly due to ware potato. Farm 6 is intermediate, but has a relatively high NDW from non-risk crops. This is mainly based on baking wheat (additional N input with low recovery).

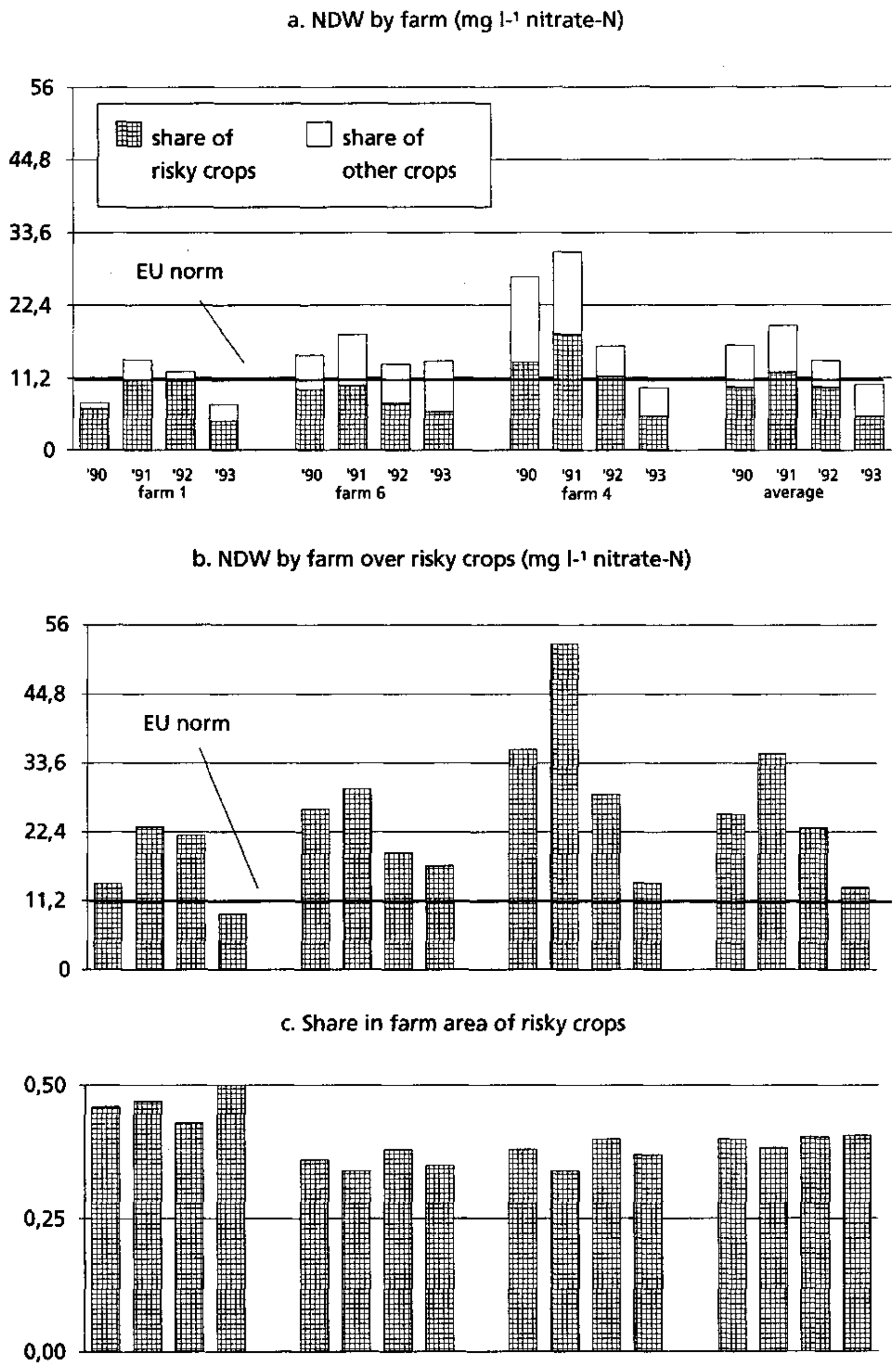


Figure 4.5. Nitrate in Drainage Water (NDW) of 3 pilot farms (a), over risky crops (b) and share in farm area of risky crops (c).

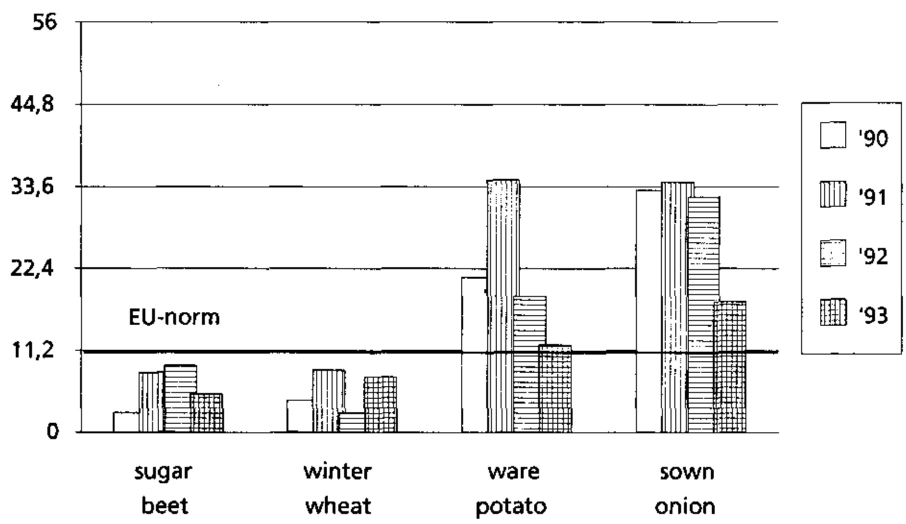


Figure 4.6. Nitrate in Drainage Water (NDW) by crop (mg l^{-1} nitrate-N).

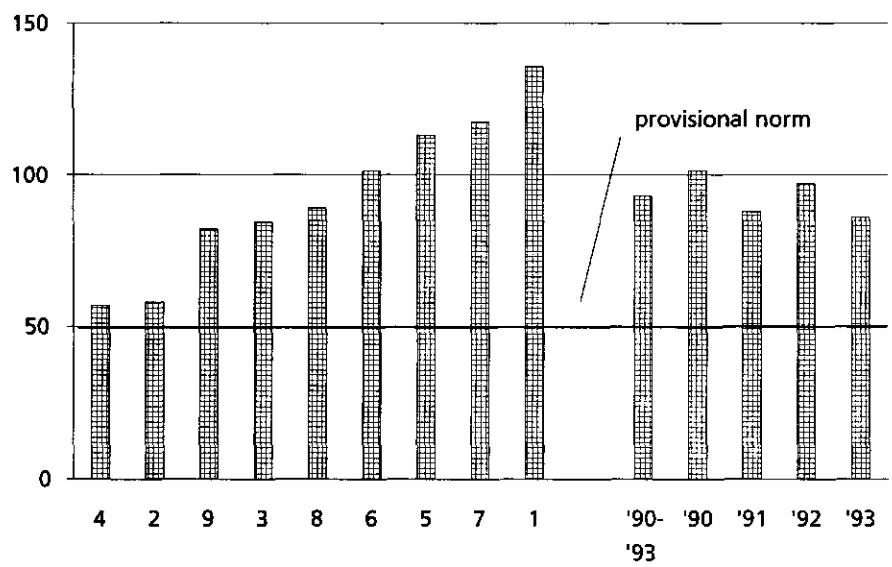


Figure 4.7. Mineral N Input (MNI) of the 9 pilot farms ('90-'93) (kg ha^{-1}) as an additional parameter to Energy Efficiency (EE), ranked by increasing MNI.

In terms of P/KAR, NAR and NDW INM is ready for use and is increasingly effective, but it is still neither fully accepted nor well managed by the pilot farms. The decreasing average PAB shows that P/KAR is being increasingly accepted and its management is improving. If INM for NAR and NDW where accepted, there would be a decrease in N fertilisation for potatoes and sown onion and the management of applying manure to the stubble would improve with respect to dosing, timing and the use of green manure.

INM aims at replacing mineral NPK by manure. The use of manure has been generally accepted by the farmers; it is applied in early autumn, since soil conditions generally hinder its application in spring.

The mineral N is the main energy input on an arable farm. Therefore Mineral N Input (MNI) is used as a local parameter additional to Energy Efficiency (EE). Fig. 4.7 presents the MNI for the 9 pilot farms averaged over '90-''93. This N is additional to N from manure. If the manure were applied in spring instead of in autumn, N recovery could be at least doubled, to the benefit of the environment (NDW) and sustainability of food supply (EE). This would result in a provisional norm for MNI = 50 kg N per ha (based on results of Nagele '91-'94). So on average some 40 kg more should be saved.

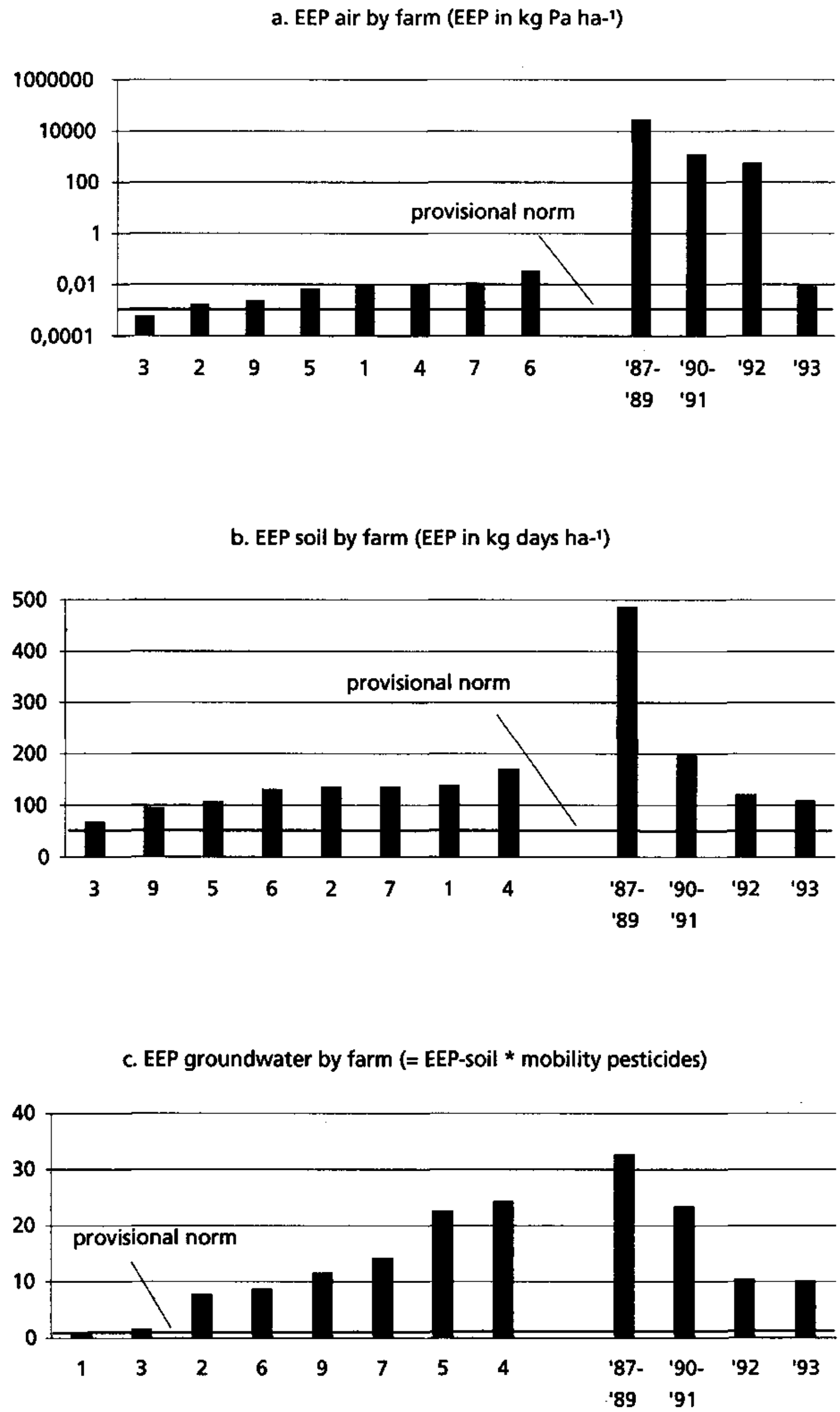


Figure 4.8. Environment Exposure to Pesticides (EEP)-air (a), -soil (b) and -ground water (c) of 8 pilot farms ('93), ranked by respectively increasing EEP-air, -soil and -ground water

(3) ECOLOGICAL INFRASTRUCTURE MANAGEMENT (EIM)

Ecological Infrastructure Management (EIM) is the major method for achieving desired results in Ecological Infrastructure (EI). No variants of EIM have been designed and laid out as yet, for lack of research capacity. Consequently, farms have not been tested on EI.

(4/5) INTEGRATED CROP PROTECTION (ICP) AND ENVIRONMENT EXPOSURE BASED PESTICIDES SELECTION (EEPS)

ICP and EEPS are the two major methods to achieve desired results in Environment Exposure to Pesticides (EEP). During the project, farm-specific variants of ICP were designed and laid out. EEPS has not yet been designed. Nevertheless, the pesticide use by pilot farms has been tested with EEP, to get EEP ready for use.

Fig. 4.8 presents the EEP in terms of air, groundwater and soil (henceforth refered to as EEP-air, EEP-water and EEP-soil) of the 9 pilot farms in '93. In comparison to the farm-specific reference years '87-'89, these EEPs were reduced by factors of 10^6, 3 and 5, respectively. On average, the lowest EEP is achieved by farms 2, 3 and 9 and the highest by farms 4 and 7.

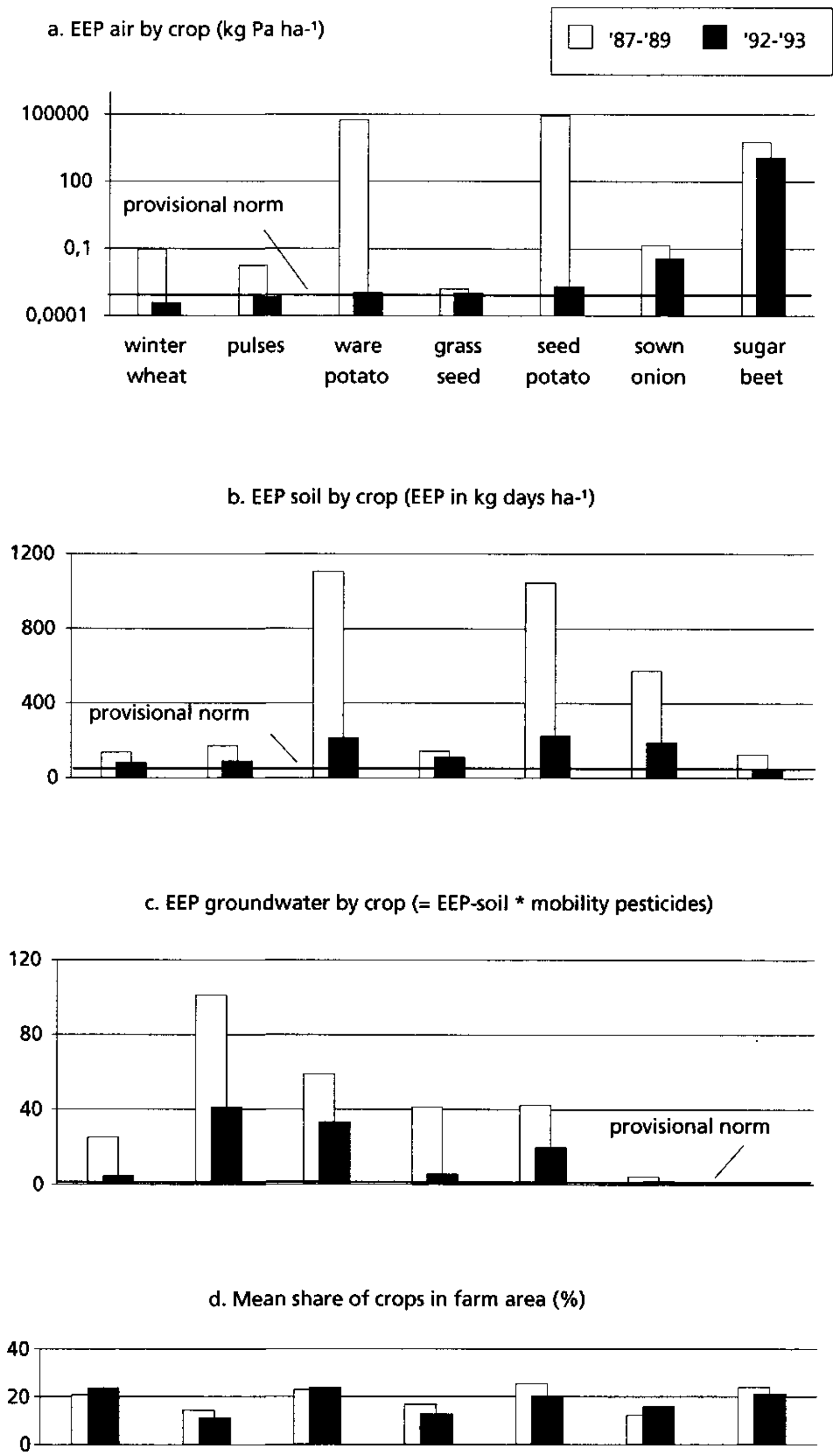


Figure 4.9. Environment Exposure to Pesticides (EEP) by crop for air (a), soil (b) and groundwater (c), and mean share of crops in farm area (d), crops ranked by increasing EEP-air.

The main cause of the drastic decline of EEP air is that dichloropropene (DCP), a soil fumigant used to control potato cyst nematodes, has been replaced by non-chemical measures. This compound is extremely volatile and used in a huge dosage (80-110 kg active ingredient per ha). At crop level the replacement of DCP causes a drastic decline in EEP air of potato (Fig 4.9). The high average EEP in sugarbeet is caused by one application of DCP on one farm in '92 to control beet cyst nematodes. The decline in EEP air in winter wheat ('92-'93) and sown onions reflects the decreasing use in active ingredient (effect of ICP). In pulses the herbicide dinoseb was only used during '87-'89. Considering the mean share of crops in the farm area, a further reduction in EEP air should be achieved through ICP (reduction in the amount of active ingredient used) and EEPS in seed potato, sugar beet and sown onion (herbicides) (Fig. 4.9). A provisional norm of 10^{-3} has been set for EEP air, based on the results of the Nagele farm.
The EEP soil is mainly determined by the nematicide dichloropropene, the fungicides used in potatoes and onions and the herbicide pendimethalin in onions (Fig. 4.9). See EEP air for the nematicide use (potatoes). In onions, the decrease in EEP is a result of replacing the soil herbicide pendimethalin by contact herbicides and of the drastic reduction in fungicide use (ICP). A further reduction in EEP soil should be achieved through ICP and EEPS in potatoes and onions (fungicides) (Fig. 4.9). A provisional norm of 50 has been set for EEP soil, based on the results of the Nagele farm.

The EEP groundwater is dominated by fungicides in potatoes and the herbicide bentazon in grass seed, winter wheat and pulses (Fig. 4.9). The lower EEP in seed potatoes reflects the smaller amount of active ingredient used (shorter growing season). In '92 and '93 these compounds were gradually replaced by the new compound fluazinam, to the benefit of the EEP. The decreasing EEP in grass seed, winter wheat and pulses is a result of decreased use of bentazon (EEPS). A further reduction in EEP groundwater should be achieved through ICP and EEPS in potatoes (fungicides) and pulses (herbicides) (Fig. 4.9). A provisional norm of 1 has been set for EEP groundwater, based on the results of the Nagele farm.

The basis for the reduction in EEP is ICP. However, the beneficial effect of EEPS can be enormous as is apparent from the foregoing, especially on EEP air. Furthermore, we expect that judicious EEPS will improve the beneficial effect even further. ICP is ready for use, effective, generally well accepted and manageable. We expect that EEPS can also be made ready for use by farmers and that it will prove to be very helpful for reducing the EEP.

(6) FARM STRUCTURE OPTIMISATION

FSO is the finalising method for achieving desired results in Net Surplus (NS) and Energy Efficiency (EE), if the current amounts of land, labour or capital goods of the pilot farms fail to do so with the agronomically and ecologically optimised prototype IAFS. The 9 pilot farms are not yet at this stage, and therefore, FSO has not been used. However, the results of initial testing with NS indicate that FSO is indispensable.

8.3 Conclusions

As part of a larger project, the theoretical prototype of IAFS was laid out in nine variants in the central clay area in collaboration with the pilot farms. Only three of the six innovative methods have been designed and laid out for testing: MCR, INM and ICP. Although all three methods were ready for use and effective, INM was neither fully accepted nor well managed by the farmers, with major shortfalls between desired and achieved results in NAR/NDW as a result.
EIM was not laid out for testing because of lack of research capacity. EEPS was designed after the project period, but was tested a posteriori with EEP, to get ready for use. It appeared to be effective and is considered to be of major importance for reducing EEP.
FSO was not used, since the four-year project period proved to be too short to achieve the major objectives fully. However, an initial test with NS enabled farm strategies to establish the desired results to be identified. The results underlined that FSO is indispensable.

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9 Focus on testing an EAFS prototype in pilot project NL 2

Research team: P. Vereijken, H. Kloen and R. Visser

9.1 Interactive prototyping with pilot farmers

In pilot project Flevoland (NL 2) the entire methodical way of designing, testing and improving an EAFS prototype is being covered (steps 1-4, see Section 1.2). This is being done, to avoid agro-ecological, agronomic and economic distortions of prototyping on an experimental farm and to save time and money, because prototyping on an experimental farm always requires continuation of testing and improving on pilot farms (see Section 10.4 of Progress Report 1).

Fig. 5.1 shows how the research team of NL 2 is prototyping in interaction with pilot farms. Prototyping on pilot farms has major advantages over prototyping on an experimental farm:

- The new objectives of the prototype are integrated with the current objectives of a group of farms. Only in this way do the new objectives become economically acceptable in various farm situations.
- The new methods of the prototype are integrated with the current methods of a group of farms. Only in this way do the new methods become practically manageable in various farm situations.
- The new methods of the prototype are tested and improved in cohesion with the management of a group of farm. Only in this way do the new methods become practically effective in various farm situations.

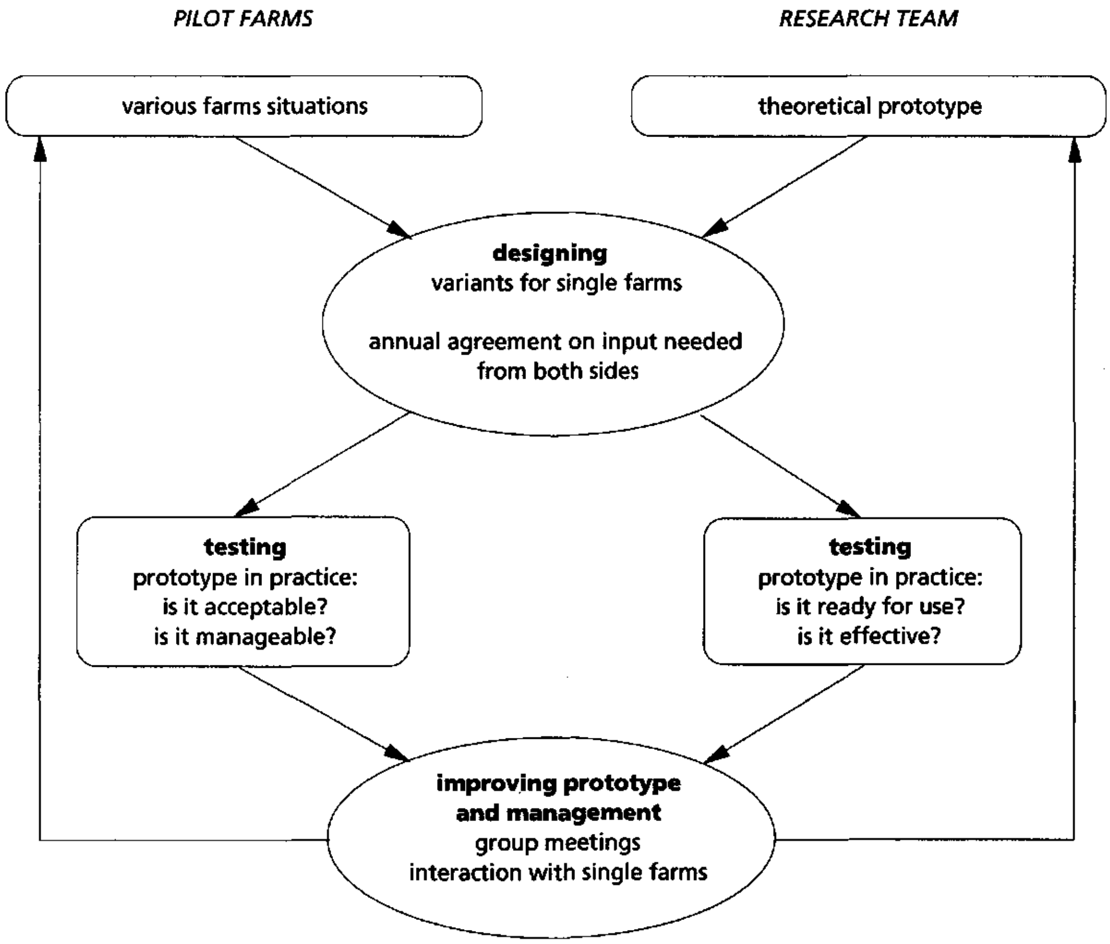


Figure 5.1. Interactive prototyping: designing, testing and improving a prototype by interaction of pilot farms and research team

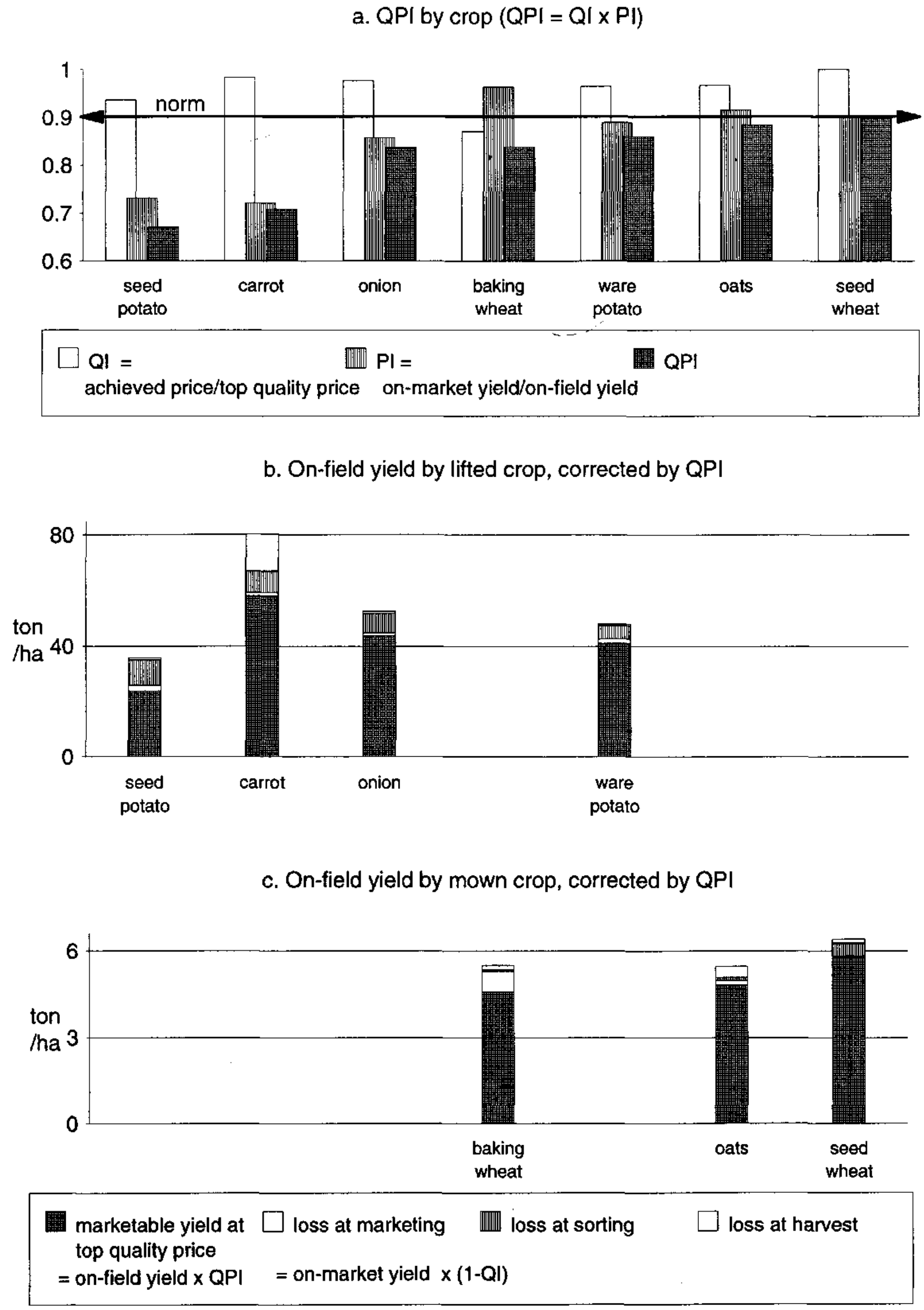


Figure 5.2. Quality Production of major crops, overall the pilot group, in 1993 (mean of crops on ≥ 5 fields)

In NL 2 we collaborate with 10 pilot farms (see Identity Card Part 5 in Chapter 7). The farms have been selected according to the following criteria:

- The farm is sufficient in size, providing employment for a full time farmer , at least.
- All the fields are adjacent, yielding an agro-ecological whole as a prerequisite for an agro-ecological identity.
- The farmer is willing to achieve more in quality production and care for environment, nature and landscape than is currently demanded by the government or the trade label.
- The farmer is willing to subscribe to an agreement of cooperation specifying the input needed for the project.

9.2 Results of testing

In line with the format for testing in Section 6.2, this chapter focuses on testing the prototype EAFS on pilot farms. Initial results of 1992-1994 are presented in the order of the 4 major methods needed to achieve the objectives, as transformed and quantified in a set of 14 multi-objective parameters (see theoretical prototype of NL 2 in Fig. 2.2.4, Chapter 4).

(1) MULTIFUNCTIONAL CROP ROTATION (MCR)

MCR is the major method to achieve desired results in Quality Production Indices (QPI $product^{-1}$), Net Surplus (NS) and Soil Cover Index (SCI). The MCR variants of the 10 pilot farms have been designed and laid out following the demands made of MCRs of EAFS, as specified in Subsection 3.2.1 for the temporal dimension and in Section 7.3 for the spatial dimension.

Fig. 5.2 presents the QPIs of the major crops in 1993 throughout the pilot group (yields of 1994 are still being marketed). Four crops show a wide shortfall between achieved and desired results (=norm). In seed potato the major causes of losses are the rejected oversized tubers and tubers infested with Rhizoctonia solani. In carrot the major causes of losses are the failure of the lifting machinery to harvest carrots with too old and too weak foliage and the rejected malformed and too small carrots. In onion the major causes of losses are the rejected bulbs that are rotten because of pre-harvest water stress, or are undersized. In baking wheat the major cause of loss is marketing below the top quality price because the protein content is too low .

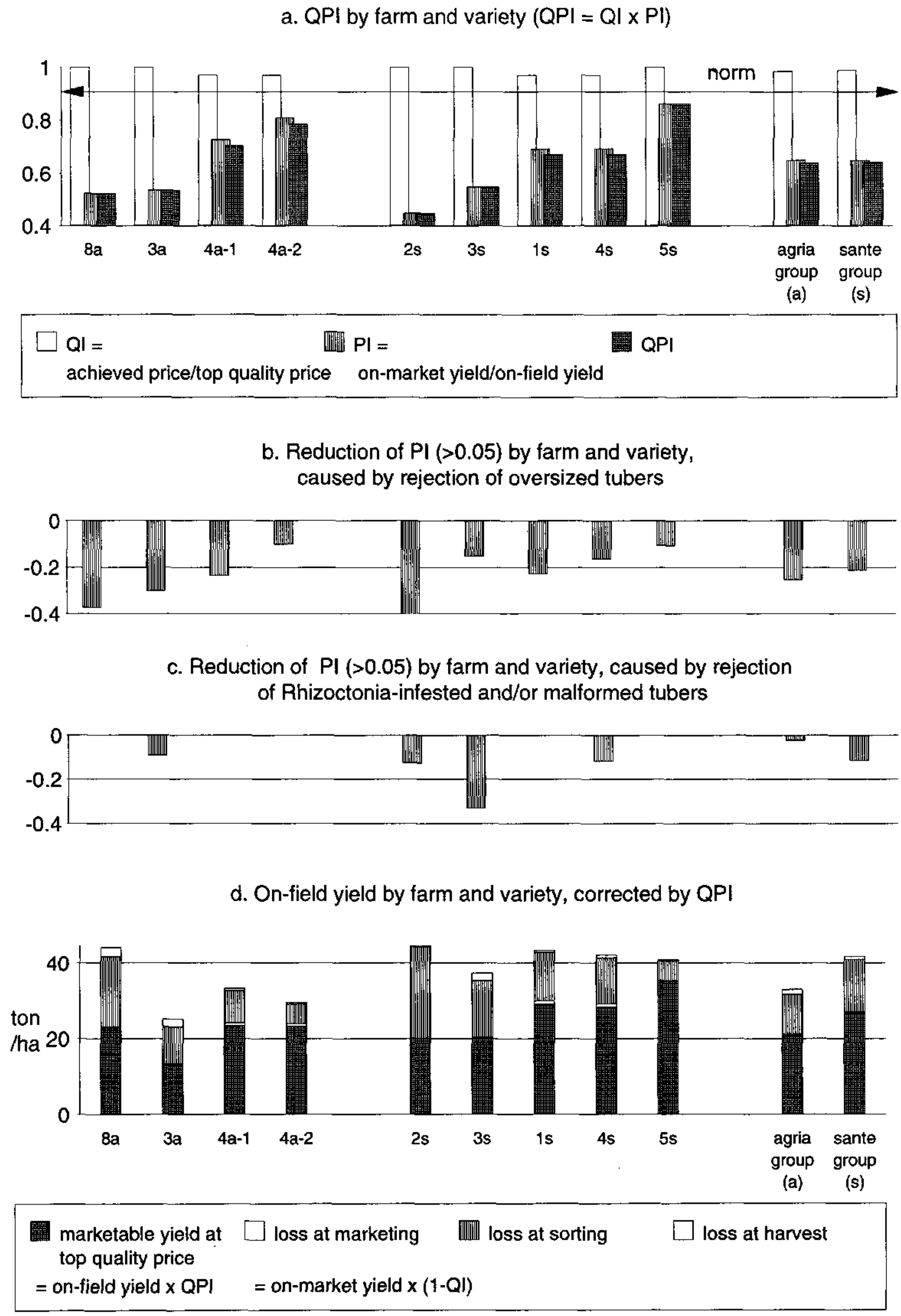


Figure 5.3. Quality Production of two varieties of seed potato, grown on 6 pilot farms in 1993

Fig. 5.3a presents the QPIs of seed potato, grown on 6 of the 10 pilot farms in 1993. The QPIs of the two major varieties Agria and Santé are listed separately. There appears to be a large variation between the farms. Farms 2, 3 and 8 are far below the desired result (=norm), whereas farms 4 (Agria) and 5 (Santé) are only slightly below it. From Fig. 5.3b and 5.3c it appears that rejection of oversized tubers is a more important cause of losses than rejection of Rhizoctonia-infested and malformed tubers. The latter is more important in Santé than in Agria. From Fig. 5.3.d it appears that farms 4 and 5 achieve the highest marketable yield at top quality price, due to their high QPI. The initial results of testing with QPI show that the sometimes wide shortfalls between desired and achieved results tend to be caused by insufficient management (notably too late harvesting) rather than by insufficient MCR or ENM (N supply of wheat). However, top quality production calls for the improvement of both management and farming system!

NS has not yet been used in testing. It is in explained in (4) Farm Structure Optimisation.

Fig. 5.4a presents the SCI of the 10 pilot farms in 1994. The mean of the group is low because most farms are on sandy clay soils. Consequently, they plough late in the autumn and leave the fields fallow until spring. Only farms 5, 4 and 1 have predominantly sandy soils and retain the soil cover on most fields until ploughing in early spring. Therefore, these 3 farms have the highest SCIs. Though autumn ploughing is needed, SCI can be improved to benefit soil fertility and fauna in the crucial wet period from December to April (Fig. 5.4b). To do this, fields must be ploughed early in autumn and subsequently a green manure crop must be sown. This green manure crop should develop during the autumn and die down during winter, covering the soil with a thin layer of dead foliage which should not impede seedbed preparation and sowing or planting in spring. Based on this strategy, SCI = 0.6 is considered an achievable and therefore reasonable provisional norm.

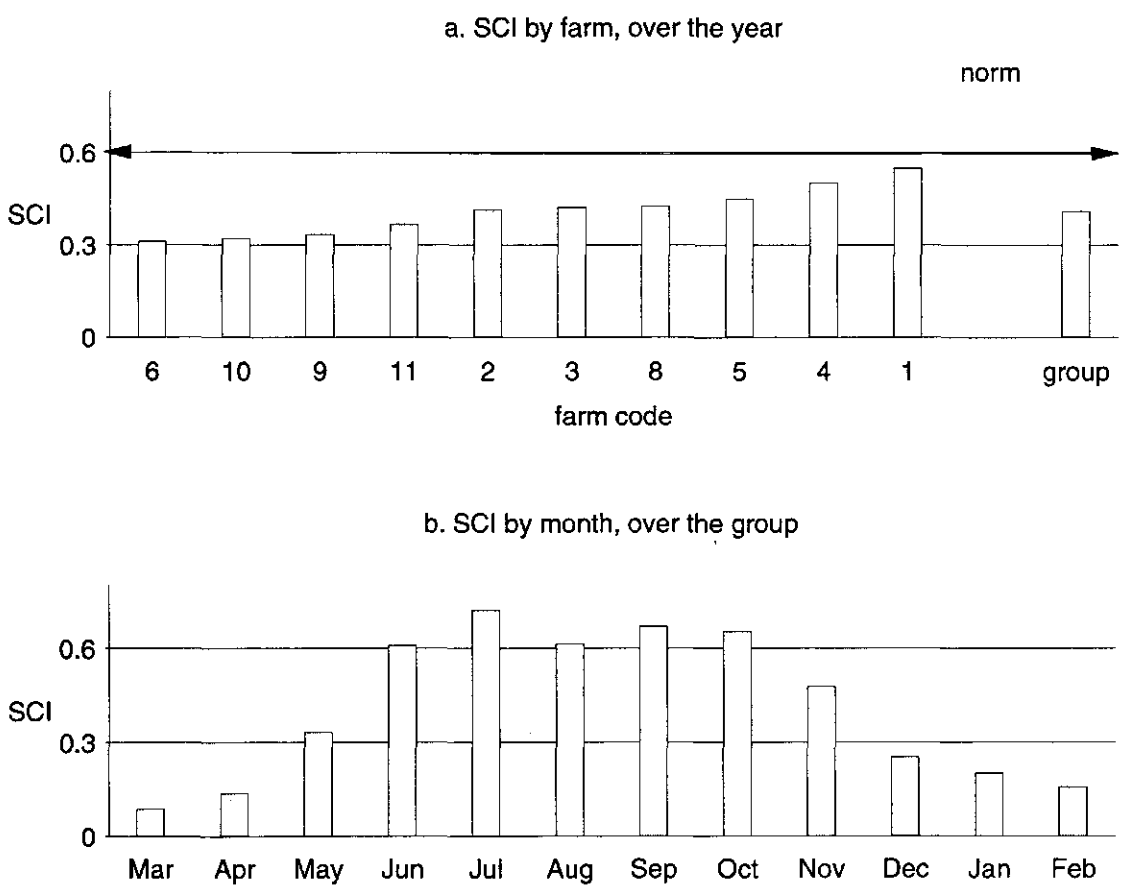
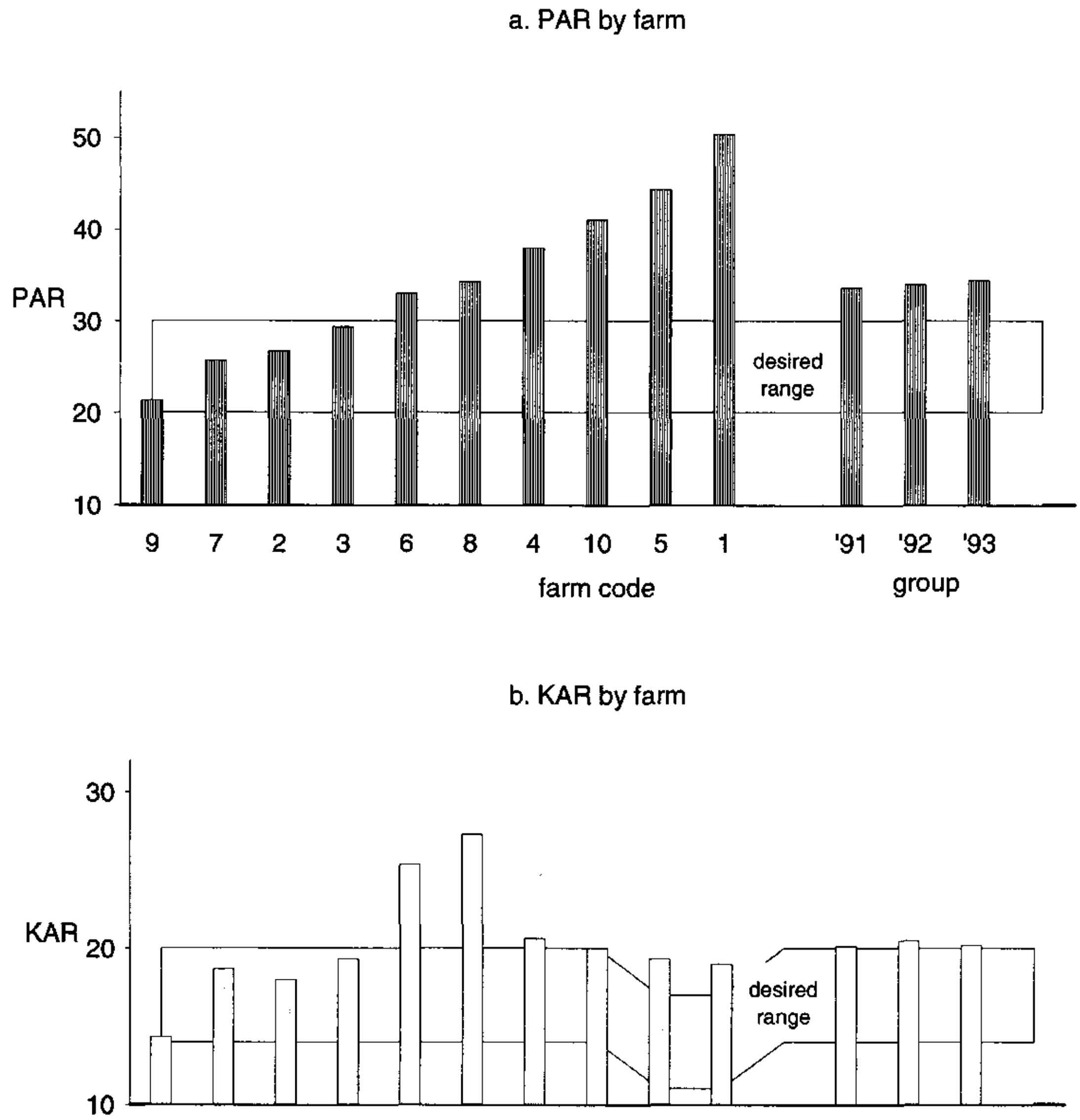


Figure 5.4. Soil Cover Index (SCI) of the 10 pilot farms in 1994



Desired ranges correspond with ranges called 'agronomically sufficient' by the advisory service. Beyond these ranges we assume risks of exceeding norms for P and K in shallow waters are ecologically inacceptable. The range for K varies with soil type.

a. PAR = mg P2O5 / l soil, 1:60 extraction with water (Pw count)

b. KAR = mg K2O / 100 g of air-dry soil, 1:10 extraction with 0.1 n HCl (K count)

Figure 5.5. P and K Available soil Reserves (PAR and KAR; both ranked by increasing PAR) of the 10 pilot farms in 1993

(2) ECOLOGICAL NUTRIENT MANAGEMENT (ENM)

ENM is the major method to achieve desired results in P and K Available Reserves (P/KAR), P and K Annual Balances (P/KAB), N Available Reserves (NAR) and N Drainage Water (NDW). The ENM variants of the 10 pilot farms are characterised by norms for PAB and KAB, to bridge possible shortfalls between achieved and desired PAR and KAR. If achieved results exceed desired results by 1-10 units, P/KAB should be ≤ 1. If achieved results exceed desired results by more than 10 units, P/KAB should be ≤ 0.5. Ideally, P/KAB = 0 (so, P/K-input = 0) may reduce excessive P/KAR most rapidly. However, it is not acceptable to ecological farmers, because it implies no use of manure at all.

Fig. 5.5 presents the PAR and KAR of the 10 pilot farms in 1993. Farms 6, 8 and 4 exceed the desired range of PAR by less than 10 units and farms 10, 5 and 1 exceed it by more than 10 units. Farms also exceed the desired range of KAR by less than 10 units, except for farm 10. Farms 5 and 1 should meet a lower range of KAR, because their rather sandy soils are prone to leaching of K.

Fig. 5.6 presents the PAB and KAB of the 10 pilot farms in 1994, and the norms to be achieved considering possible shortfalls between desired and achieved PAR and KAR in 1993. Farms 6 and 8 succeed in achieving the desired PAB and KAB. Farm 4 is less successful. Farms 10, 5 and 1 cannot achieve the rather ambitious PAB. However, they achieve a PAB less than 1, so PAR will be lowered, though less fast than desired. Farm 5 did not achieve KAB deliberately, because of concern about a lack of K for the lifted crops. Apart from this single case, it can be concluded that ENM is generally acceptable and manageable considering P and K. However, in the case of very excessive PAR, farms find it difficult to accept legumes as a major source of N supply instead of manure. The reason is that legumes for feed are unprofitable and legumes for food such as peas and beans for canning are scarcely marketable. Nevertheless, the gradual decline in PAB over the group indicates the increasing acceptance of the need to deplete excessive PAR.

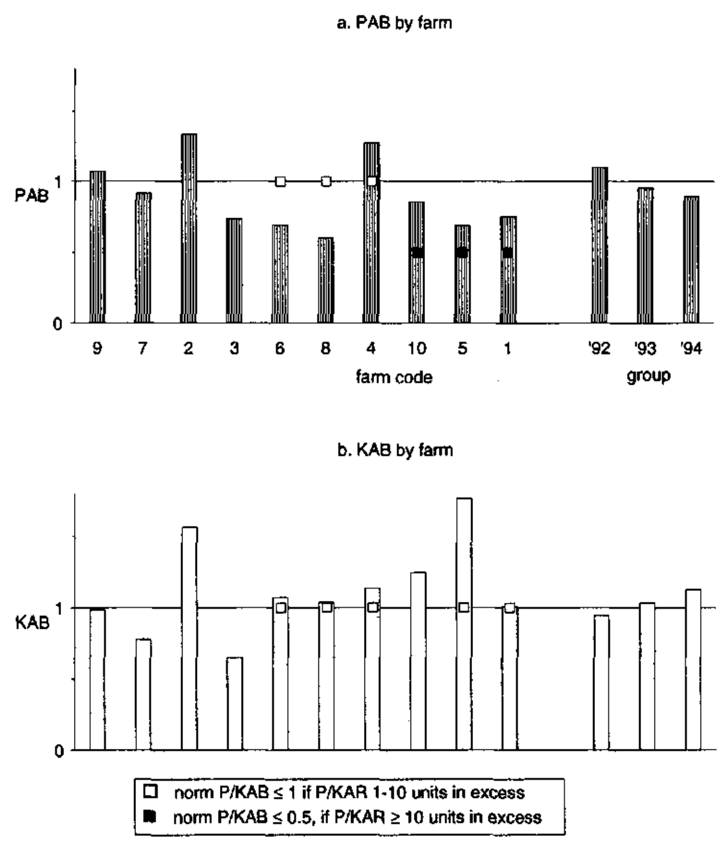
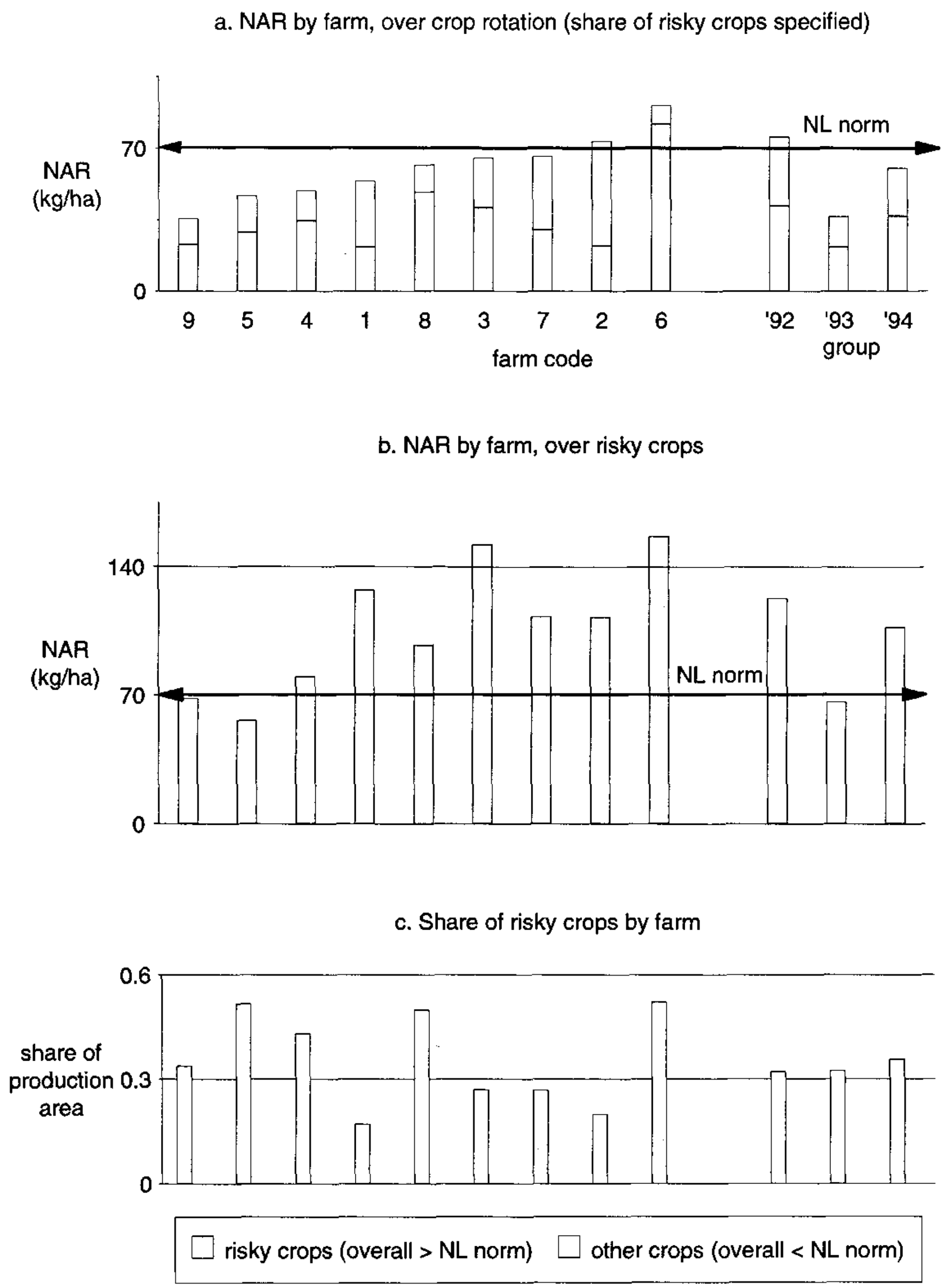


Figure 5.6. P and K Annual Balances (P/KAB, both ranked by increasing PAR) of the 10 pilot farms in 1994



NAR (kg/ha nitrate and ammonium N) is based on mixed soil samples from 20 probes by crop, 0-100 cm at start of the leaching period. NAR over crop rotation is the mean of crops, weighted for their area. NAR over risky crops is the mean of risky crops, weighted for their area.

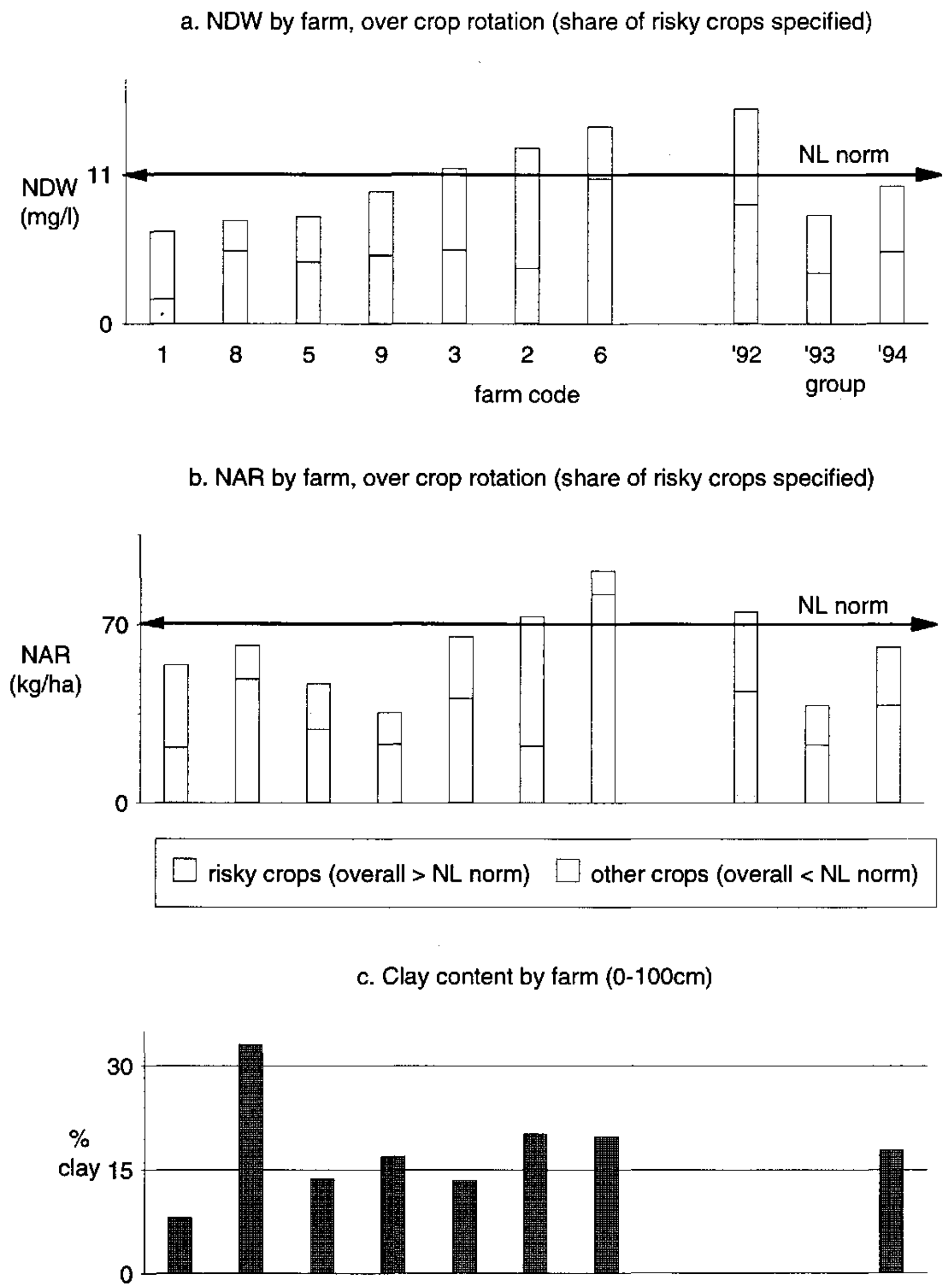
Figure 5.7. N Available soil Reserves (NAR) of 9 pilot farms in 1994, related to NAR and share of risky crops

Considering N, ENM is acceptable but not easily manageable. The reason is that N is supplied from various organic sources (manure, crop residues, legumes), whose net N availability is not easily predictable. Only by repeated testing and improving, can desired amounts of N be made available to single crops, ensuring both quality production and ecologically acceptable N leaching.

Fig. 5.7 presents the NAR of 9 pilot farms in 1994. Farm 2 slightly exceeds the provisional NL norm and farm 6 clearly exceeds it. This norm we consider as a desired result, since it is assumed to comply well with the norm of 11 mg l^{-1} nitrate N in Drainage Water (NDW). (In the Netherlands, the EU norm for drinking water (11 mg l^{-1} nitrate N) is also applied to shallow groundwater and consequently to drainage water at 2 m below the soil surface). From Fig. 5.7a it appears that more than half the NAR over the group is based on the share of 4 crops that mostly exceed the norm, namely potato, onion, celeriac and pulses.

From Figs. 5.7b and 5.7c it appears that the differences in NAR over the crop rotation (Fig. 5.7a) are based more on differences in NAR of these risky crops than on their share of the production area per farm. In addition, it appears that the excessive NAR of farm 6 is based on a combination of high NAR and high share of the risky crops.

Over the group, the desired result was achieved in 1994, because less manure was applied to potato and more to wheat (to improve its QPI). The results achieved in 1993 should be considered as an artifact. The leaching period started in August, when most crops were still growing. Consequently, the NAR assessed at harvest was an underestimate.



NDW (mg/l nitrate-N) is based on mixed samples from 3 drains by crop, taken once every two months during the period of precipitation surplus. NDW by crop is the mean of two-monthly samples, weighted for their share of precipation surplus. NDW overall crop rotation is the mean of crops, weighted for their area.

Figure 5.8. Nitrate leaching (NDW) of 7 pilot farms in 1994, related to NAR and clay content

Fig. 5.8 presents the NDW of 7 pilot farms in 1994. Farm 3 slightly exceeds the NL norm and farms 2 and 6 clearly exceed it. From Fig. 5.8b it appears that NDW complies with NAR fairly well, per farm and over the group. The major deviation is farm 8, which has a lower NDW than expected. From Fig. 5.8c it appears that this farm has a much higher clay content than the others, which explains why less N has been leached from NAR.

In addition to clay content, the organic matter content and SCI are co-factors in the relation between NAR and NDW. As a result, NDW cannot easily be replaced by NAR. Another reason for maintaining both parameters is that NDW is also strongly influenced by the size of the precipitation surplus, contrary to NAR. For example, in 1993 and 1994 the precipitation surplus was more than twice the long-term average! So, from the fact that both in 1993 and in 1994 the desired result of NDW was achieved, it is premature to conclude that ENM does not need further improvement.

(3) ECOLOGICAL INFRASTRUCTURE MANAGEMENT (EIM)

EIM is the major method to achieve desired results in Ecological Infrastructure (EI), Plant Species Diversity (PSD) and local parameters of flora: Plant Species Distribution (PSDN) and Flower Density (FD). Besides, EIM is the major method to achieve desired results in Bird Species Diversity (BSD), a local parameter which has not yet been elaborated. The EIM variants of the pilot farms are based on the demands of EIM as specified in Subsection 3.2.4 and take into account the specific situation of each farm.

Fig. 5.9 presents EI of the 10 pilot farms in 1994. Only farms 5 and 9 have achieved the norm of 5 % of the production area, so far. The gradually shrinking shortfall between achieved and desired results over the group clearly shows the reluctant acceptance of the norm, because it implies that some 2 % of the production area is permanently set-aside as buffer strips along the ditch banks. This set-aside is not compensated for, at first. Nevertheless, all farms have agreed to achieve the norm in 1995, which implies that each ditch bank is buffered against erosion and runoff of nutrients. In addition, the buffer strips make the ditch banks accessible for mowing and removing the hay during the growing season.

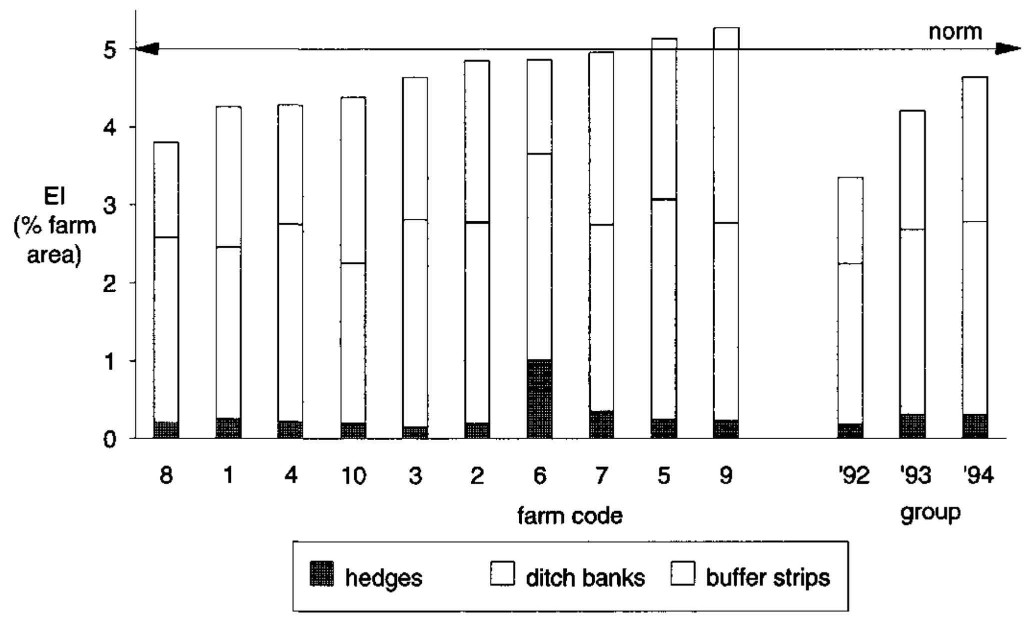


Figure 5.9. Layout of Ecological Infrastructure (EI) of the 10 pilot farms in 1994

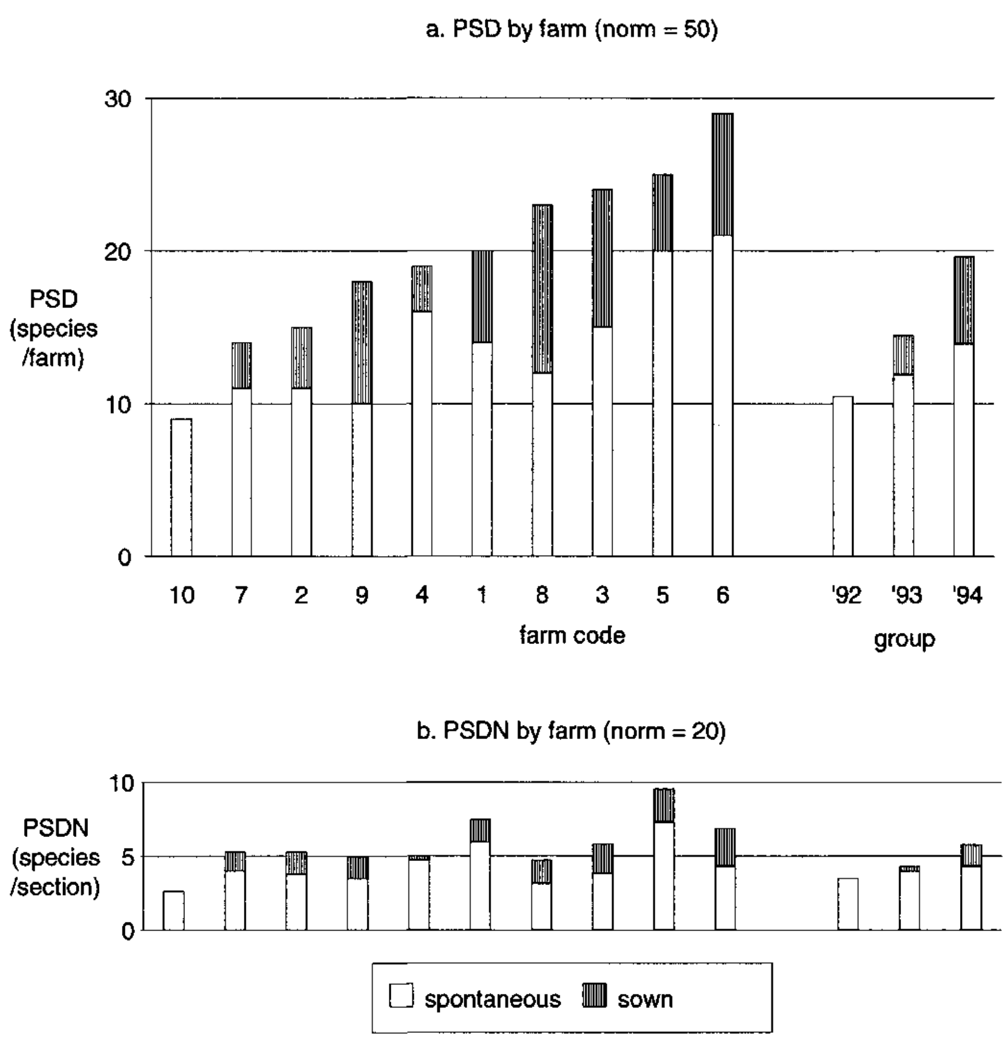


Figure 5.10. Plant Species Diversity (PSD) and Plant Species Distribution (PSDN) in ditch banks of the 10 pilot farms in 1994 (only target species with flowers attractive to people and insects are considered)

Fig. 5.10 presents PSD and PSDN in the EI of the 10 pilot farms in 1994. All farms have large shortfalls between desired and achieved results. However, considering the results for the whole group (1992-1994) the sowing of target species, and a consistent management of course, are proving effective in gradually reducing the shortfalls.

Fig. 5.11 presents the FD of the 10 pilot farms in 1994. This parameter is of primary importance to the continuity in time and space for entomofauna and recreation. Again, all farms still have wide shortfalls between desired and achieved results. To bridge these shortfalls, the sowing of target species will be focused on species with the potential to maintain FD ≥ 1 for a month, at least (major target species).

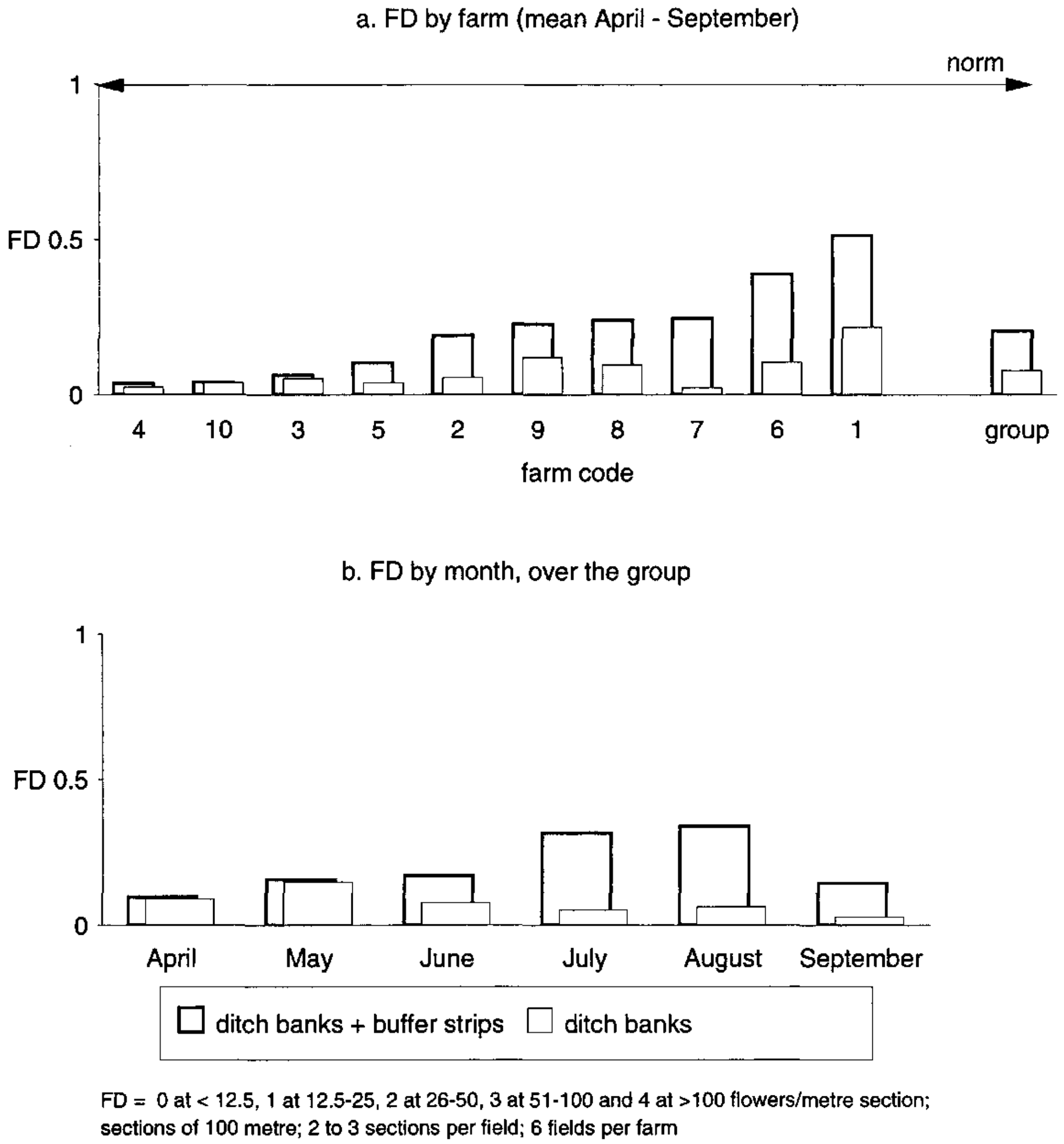


Figure 5.11. Flower Density (FD) in the Ecological Infrastructure of the 10 pilot farms in 1994

(4) FARM STRUCTURE OPTIMISATION (FSO)

FSO in the major method to achieve the desired result in Net Surplus (NS), if current amounts of land, labour and capital goods of pilot farms were to fail to do so with the agronomically and ecologically optimised prototype EAFS.

From the definition of FSO it can be concluded that testing on NS is irrelevant, as long as prototype variants and management are still being optimised. In 1996, most farms will have completed a full cycle of the 6-course MCR. We assume that most of the desired results of agronomic and ecological parameters will have been achieved by that time. Therefore, NS will be tested from 1997 on. By 2000 a mean NS over 4 years can be established for each farm-specific variant of the prototype. This is considered to be a reliable base for judging the economic feasibility of the 10 variants and for establishing the farm structure needed for the desired NS.

9.3 Initial conclusions

After a first year of designing a theoretical prototype including 10 farms variants in interaction with the pilot farmers, the prototype EAFS has been laid out three times for testing and improving (1992-1994). The three innovative methods (MCR, ENM and EIM), which are the major elements of the prototype, have generally appeared to be acceptable and manageable. However, both the prototype and the management need further improvement, in view of the initial results of testing.

Major shortfalls have to be made good between desired and achieved results especially in QPIs of various products, SCI, NDW and various parameters of flora in the Ecological Infrastructure. From 1996 on (after a first cycle of the 6-course MCR), the prototype variants will be tested on NS. This will show to what extent FSO is needed to make good a possible shortfall between desired and achieved NS.

10 Conclusions and recommendations

The following conclusions and recommendations have been drawn up in the light of the results of this second year of concerted action.

10.1 Need to increase research capacity

Sixteen creative leaders of pilot projects have been chosen to attend the second workshop, July 1994 at Wageningen. Only DE 1, DE 3, DK 2 and NL 2 can fulfil all criteria (Section 1.4, Table 1). However, it is reasonable to consider the criteria as future milestones, because prototyping of farming systems is still in its infancy. Therefore, another 5 pilot projects have been selected to describe their state-of-the-art in this second report. They also have at least 1 scientist year in prototyping (number of pilot farms * scientist years $farm^{-1} \geq 1$). In addition they have a research leader who is at least 40 % involved in the project and whose main activity is designing.

Considering the overall insufficient to minimal research capacity, all teams are strongly recommended to increase their research capacity. From our experience in pilot project NL 2, a minimum sized project of 10 pilot farms should ideally have a team of 3 fulltimers: a senior researcher (creative leader), a junior researcher (to be groomed as potential leader!) and a scientific assistant. In addition, senior research leaders are strongly recommended to delegate a junior researcher to the workshops, if the junior has more creative input.

10.2 Designing a theoretical prototype and methods in this context

Designing I/EAFS implies 3 initial steps on a methodical way of prototyping:

(1) making a hierarchy of general and specific objectives (prototype's identity card Part 1);
(2) transforming the major (10) objectives into multi-objective parameters to quantify them and establishing the multi-objective methods needed to achieve the quantified objectives (prototype's identity card Part 2).
(3) designing a theoretical prototype by linking parameters to methods and designing the methods in this context until they are ready for initial use (prototype's identity card Part 3).

Steps (1) and (2) were studied at the first workshop in 1993. The methodology and the state-of-the-art of most ongoing projects was presented in the first progress report. The state-of-the-art of 4 incoming pilot projects (DE 3, PL 1, B 1 and DK 2) is presented in this second report (Chapter 2).

Step (3) was studied at the second workshop in 1994. The methodology is presented in this second report, using an updated European shortlist of parameters and methods (Chapter 3). The state-of-the art of the 9 selected pilot projects is also presented in this report (Chapter 4). Using their theoretical prototype, the 9 teams involved clearly show which are the major and the minor methods to achieve the desired result in any parameter and in which order and context the methods will be designed. However, most of the theoretical prototypes have been drawn up while a programme of on-farm research is already in progress!

Considering the overall tendency to stick to comparative research, teams with ongoing projects or projects in preparation are strongly recommended to design a theoretical prototype and use this as the base for their programme of on-farm research.

10.3 Designing a Multifunctional Crop Rotation (MCR)

Following a format for designing an MCR based on a set of multifunctional demands (Subsection 3.2.1.), the teams of the 9 selected pilot projects each present an MCR variant of a representative pilot farm (Chapter 5). As the central method and the first to be designed, MCR is an appropriate Part 4 of the prototype's identity card, after the theoretical prototype as Part 3.

Because of the central role of MCR, the state-of-the-art in designing MCR is considered in more detail, based on the set of multifunctional demands (Section 5.3.). Only PL 1 has succeeded in designing an MCR fulfilling all demands. Most teams have not yet succeeded in designing an MCR with sufficient soil cover (SCI), as a major preventive measure against erosion by wind or water. Neither have most teams succeeded in sufficiently diversifying their MCR by limiting the share species^{-1}, as a major preventive measure against weeds and soilborne pests and diseases (already explained in Chapter 7 of Progress Report 1). In particular, the teams of DK 2, F 1 and IRL 1 have built in high risks, because their MCRs also have too high a share group^{-1} of phytopathologically related crop species. Except for NL 1 and NL 2, all teams have succeeded in designing an MCR with a balance between crops that degrade soil structure (by compaction at harvest) and crops that restore soil structure (by intensive rooting). In addition, all teams have succeeded in designing an MCR with minimum need of N input, largely compensating for N offtake by products by counting on biological N fixation and efficient N transfer from residues of crops.

In most pilot projects there are still many more fields than rotation blocks, comparing the range in production area farm^{-1} to the range in mean field size farm^{-1} (Sections 7.1-7.2). Apparently, most teams have not yet designed and laid out an appropriate MCR variant on most of their farms. Therefore, it is concluded that most teams still have sufficient scope to improve both the design and the layout of the prototype variants, before proceeding to step (4) of the methodical way, which is testing and improving the prototype on-farm!

Considering the state-of-the-art in designing an MCR, all teams are recommended not to follow the path of least resistance by adopting the current rotations of the pilot farms, which are often too short (cereal-dominated) and provide for too little soil cover. On the contrary, teams are recommended to only design MCR variants that meet all multifunctional demands, to provide any pilot farm with a well-balanced 'team' of crops with a minimum need for inputs that are polluting and based on fossil energy (nutrients, pesticides, machinery and fuel) to maintain soil fertility and crop vitality as a base for quality production.

10.4 Testing a prototype on-farm

After the 3 initial steps of designing, the methodical way of prototyping I/EAFS continues 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.

The methodology of testing was discussed at the second workshop and is elaborated in this report, in particular for the parameters of the European shortlist (Chapter 6). The state-of-the art in testing is that in most ongoing projects it is not consistent with the 3 initial steps of designing.

Because most ongoing pilot projects are not following the methodical way of prototyping from the outset, teams are strongly recommended to revise ongoing testing programmes and make them consistent with the initial 3 steps of designing. This implies that testing with parameters which do not occur in the theoretical prototypes should be abandoned. Otherwise, parameters occurring in the theoretical prototype and not yet used in testing, should be made ready for use by assessing which results are desired and how they can be quantified in practice. Major revision of the ongoing testing programme may be embarrassing and painful for your team, but it is always better than proceeding along the path of comparative research and ending up with a report on an inconsistent and incomplete prototype.

Testing a prototype implies, that you lay it out on an experimental farm or on a group of pilot farms and that you ascertain if the achieved results correspond with the desired results, as quantified in your set of parameters. To be effective and achieve the desired results, I/EAFS prototypes need an agro-ecological layout. Such a layout is based on the concept that I/EAFS should be an agro-ecological whole consisting of a 'team' of steadily interacting and rotating crops, together with their accompanying (beneficial or harmful) flora and fauna.

Only by having the farming system as an agro-ecological whole:
- can the prototype achieve sufficient agro-ecological identity in a turbulent and distorting environment, dominated by monocultures and short rotations with a chronic imbalance between beneficial and harmful flora and fauna and chronic use of pesticides to compensate for this.
- can the prototype achieve desired results in multi-objective parameters which directly depend on an agro-ecological identity, such as Ecological Infrastructure requiring sufficient spatial continuity (for flora, fauna and recreation), and Exposure of Environment to Pesticides and Quality Production, both requiring sufficient support from beneficial flora and fauna.
- can the prototype achieve desired results in multi-objective parameters, which indirectly depend on an agro-ecological whole, insofar as it supports a management which is effective and efficient in timing and input of labour and energy. In principle, all parameters, including Net Surplus and Energy Efficiency, are concerned.

From the concept of a farm as an agro-ecological whole, a set of 7 agro-ecological criteria has been drawn up to characterise the layouts of the 9 selected pilot projects (Part 5 of their prototype's identity card) and subsequently to evaluate them (Chapter 7). The state-of-the-art in laying out prototypes is that most layouts seriously fall short of meeting the 7 agro-ecological criteria. In 1994, only some agro-ecologically valid layouts were present in DE 3, IRL 1 and NL 2. After minor revision, some could also be present in B 1, F 1, NL 1 and PL 1. However, most pilot projects need major revision to achieve agro-ecologically valid layouts of all prototype variants, because many of the pilot farms have one or more fields not adjacent to the others and therefore their prototype variants cannot be laid out as an agro-ecological whole, which is a prerequisite for an agro-ecological identity.

Considering the overall tendency of farmers to scatter their fields and of researchers to split their plots, teams with ongoing projects or projects in preparation are strongly recommended to layout their prototypes as an agro-ecological whole. Depending on the value you attach to the criterion of field adjacency, there are various options for revising the layout of your prototype variants. The most consistent is to select only those pilot farms whose fields are all adjacent (permanent grassland included). Another consistent solution is to layout the prototype only on the part of the farm with adjacent fields, so to exclude non-adjacent fields. A compromise would be to include 1 or 2 non-adjacent fields if they can be connected to the other fields by the ecological infrastructure.

From the state-of-the-art in testing their prototypes of IAFS and EAFS on pilot farms (Chapters 8 and 9) presented by the teams of NL 1 and NL 2, it appears that significant progress has been made, though various parameters still show considerable shortfalls between achieved and desired results.

From the third year of concerted action, teams with ongoing projects on experimental farms or pilot farms are recommended to present their state-of-the-art in on-farm testing in line with their theoretical prototypes and the format for testing (Chapter 6).

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DE 1
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DE 3
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IRL 1
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NL 1
Wijnands, F., P. van Asperen, G.J. van Dongen, S. Janssens., J. Schröder & K. van Bon, 1995.
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NL 2
Vereijken, P., 1992.
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Annex I

Programme of Concerted Action AIR3-CT920755

Working group on Integrated Arable Farming Systems in EU and associated countries

1. Objectives

The general objective is to come to a representative research network on Integrated Arable Farming Systems (IAFS), involving all 12 EU member-countries and essentially contributing to a sustainable development of European agriculture, based on a common methodology and an effective dissemination of the results throughout the Union.

Specific objectives are:

(A) 3 workshops on methodology and layout of new research projects, resulting in a manual on IAFS research (1993-1995);
(B) 4 workshops on progress of ongoing research projects, resulting in 4 progress reports (1993-1996).

2. Expertise and role of participants

The first initiative towards European cooperation in the design and development of IAFS was taken in 1986 by institutes in UK, DE, NL and F. They were inspired by promising results from the first two EU experimental farms in IAFS, namely Lautenbach (DE) and Nagele (NL). The outcome was a first report on the potential and limits of IAFS, presented as a comprehensive elaboration of Integrated Pest Management (Vereijken et al., 1986). Subsequently, experimental farms were started in Long Ashton (UK), Boigneville (F), Foulum, (DK) and Florence (I). The layout and initial results of these farms and some farms from EU-associated countries (A, CH) were presented in a second report (Vereijken & Royle Eds, 1989). The EU institutes involved in this first wave of IAFS research projects joined forces in a CAMAR project in 1990, which was scheduled to be finalized at the beginning of the current concerted action, early 1993. For this concerted action a large group of newcomers from all EU countries is being assembled around the small core of experienced participants (see annex 2). The participants must be leaders in the design, development and evaluation of prototype IAFS. Only 2-3 participants are being accepted per country, to maintain an effectively operating research network. Annual workshops are organized in turn by the experienced participants, to present their research projects and to have them critically but constructively evaluated, for the benefit of the prototypes to be developed in that region and elsewhere. The expertise of these participants is highlighted in subannex 1, with references.

There are three kinds of roles in this action:

- The coordinator (AB-DLO-NL, participant X_1) who will coordinate, arrange workshops, conduct inquiries and write reports.
- Participants, which also have extensive experience with IAFS such as PAGV (NL), FIPP (DE), and LARS (UK) (participants X_2-X_4)will jointly organise workshops and report in detail on their research projects.
- The other participants will input to the inquiries and workshops on methodology and results and will thus contribute to the manual and progress reports. As well, they will act as focal points within the scientific and farming communities in their countries for the flow of information on IAFS. The participants from non-member countries will have the same role but will receive no funding.

3. Results and evaluation criteria

(A) a manual on a commonly agreed methodology for IAFS research and a representative and interactive European network of IAFS research projects laid out and executed according to this manual;

(B) 4 progress reports presenting the participants and the state-of-the-art of their research projects, including a detailed presentation of the research projects of the main European centres and a critical review of the results for the major target groups (practitioners, policymakers and researchers).
The manual and the progress reports may be considered as hard evaluation criteria.

4. Benefits

For CAP: the coming available of concrete results from IAFS in major European regions, with a more balanced approach to the societal interests involved (food supply, employment/basic income, profit, environment, nature/landscape, health/well-being) compared to the current farming systems.

For agricultural research: a shift in activities from monodisciplinary research to interdisciplinary farming systems research, including interaction with pilot groups of farmers.

5. Work Plan of the concerted action

(A) Evaluation, improvement and standardisation of methodology in I/EAFS research

This task involves an inventory of the current methods followed by the members, based on an inquiry; 3 workshops on methodology and layout of new research projects and ultimately the publication of a manual on IAFS methodology covering three chapters:
I Prototyping on experimental farms.
II Evaluation and optimisation on pilot farms.
III Dissemination by groups or networks of pilot farms.

		time	*participant*
(A1)	*Prototyping on experimental (and pilot) farms*		
	- inventory by inquiry	1993/1	X_1, All
	- draft chapter I	1993/2	X_1,
	- workshop (Wageningen, first ½ week) to evaluate and standardise	1993/3	X_1, All
	- final chapter I	1994/4	X_1
(A2)	*Evaluation/optimisation on pilot (and experimental) farms*		
	- inventory by inquiry	1994/1	X_1, All
	- draft chapter II	1994/2	X_1
	- workshop (Wageningen, first ½ week) to evaluate and standardise	1994/3	X_1, All
	- final chapter II	1995/4	X_1
(A3)	*Dissemination by pilot groups or networks*		
	- inventory by inquiry	1996/1	X_4, All
	- draft chapter III	1996/2	X_4
	- workshop (Stuttgart or another centre, first ½ week) to evaluate and standardise	1996/3	X_4, All
	- final chapter III	1996/4	X_4,
	- publication and distribution of manual	1997/1	X_1, All

(B) Annual elaboration and dissemination of the results in the expanding European network of I/EAFS research projects

This task involves 4 annual inventories, 4 workshops and 4 progress reports on the state of the art and main results from ongoing research. At the workshops, the draft report based on the inventory will be evaluated and the local experiment will be considered in detail, based on a detailed description of the state of the art and main results. As a result, the progress report will contain a general view of the ongoing research, with special emphasis on the experiment visited that year. Workshops 1, 2 and 4 will be combined with the 3 workshops of task A, to save time and money.

		time	*participant*
(B1)	*First progress report*		
	- inventory by inquiry	1993/1	X_1, All
	- draft report	1993/2	X_1, X_2
	- workshop (Wageningen, second ½ week) focus on prototyping (exp. farms)	1993/3	X_2, X_1, All
	- publication first report	1994/1	X_1, X_2
(B2)	*Second progress report*		
	- inventory by inquiry	1994/1	X_1, All
	- draft report	1994/2	X_1, X_2
	- workshop (Wageningen, second ½ week) focus on evaluation/optimisation (pilot farms)	1994/3	X_2, X_1, All
	- publication second report	1995/1	X_1, X_2
(B3)	*Third progress report*		
	- inventory by inquiry	1995/1	X_1, All
	- draft report	1995/2	X_1, X_3
	- workshop (Long Ashton or another centre, 3 days) focus on prototyping, evaluation/ optimisation (exp. farms and pilot farms)	1995/3	X_3, X_1, All
	- publication third report	1996/1	X_1, X_3
(B4)	Fourth progress report		
	- inventory by inquiry	1996/1	X_1, All
	- draft report	1996/2	X_1, X_4
	- workshop (Stuttgart or another centre, second ½ week) focus on dissemination (pilot groups)	1996/3	X_4, All
	- publication fourth report	1997/1	X_1, X_4

Coordination

Overall coordination, including the writing of the manual, the editing of the 4 progress reports and the organisation of 2 methodology workshops will be done by Vereijken (X_1). The organisation of the 4 workshops will be done by Vereijken (X_1) and Wijnands (X_2) (first 2 workshops), Jordan (X_3) (third?) and El Titi (X_4) (fourth?) respectively.

Communication

Communication within the network of I/EAFS researchers will be by correspondence, workshops and (if possible) electronic mail.

Dissemination

Dissemination of methodology and results will be assured by all participants who will act as national focal points and by way of 1 publication on methodology and 4 publications on the state of art. 1000 Copies of each publication will be printed and be distributed through the network of participants and EC-DG VI.

Subannex I

The methodical steps taken by the European IAFS research network to elaborate, evaluate and introduce Integrated Arable Farming Systems.

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1. Collect or develop the following components of integrated farming systems in a comprehensive and consistent way.
   1.1 environmentally safe methods of maintaining soil fertility
   1.2 varieties with broad resistance, sufficient productivity and high quality
   1.3 biological and physical methods of crop protection with chemicals as last resort, as far as allowed
   1.4 equipment, machines and buildings for a technically optimum management
   1.5 cropping systems aimed at quality and profitability
2. Compose and develop prototype systems on regional experimental farms.
   For example in Germany: Lautenbach (FIPP) and in UK: Long Ashton exp. farm (LARS). For example in the Netherlands: Nagele in the central clay district, Veendam in the peaty sand district (1986) and Vredepeel in the light sand district (PAGV). These 3 exp. farms cover the need to develop prototype systems for specific soil types in The Netherlands in a reasonable way.
3. Introduce and test the prototype systems on a small scale (for example FIPP in Germany and AB-DLO/PAGV in the Netherlands).
   3.1 regional formation of pilot groups for planned conversion from conventional to integrated farming
   3.2 monitoring and evaluation of technical, economic and environmental progress is monitored and evaluated (feed back to steps 1 + 2)
   3.3 optimising major input/output relations, to obtain generally applicable cropping and farming systems
4. Introduce integrated production systems on a large scale via extension and education
   4.1 manuals and courses for extension specialists and teachers
   4.2 appropriate teaching in agricultural schools
   4.3 courses and study groups for farmers
   4.4 appropriate cropping manuals and view-data

References

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Vereijken, P. & D.J. Royle (Eds.), 1989. Current status of research on integrated arable farming systems in Western Europe. IOBC/WPRS Bulletin 1989/XII/5, Wageningen, 76 pp.

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

EU countries	Participants workshop Wageningen 1994		Projects type	name	code
BELGIUM **(B)**	ir. Vincent van Bol	Université de Louvain Lab. d'Ecologie des Prairies Place Croix du Sud 2, (bte 5) 1348 Louvain-La-Neuve Fax no. 32-10472428	EAFS 8 pilot farms	Mid-Belgium	B 1
DENMARK **(DK)**	Dr Erik Steen Kristensen (replacing Dr Ib Sillebak Kristensen)	Research Centre Foulum Nat. Institute Animal Science Postboks 39 8830 Tjele Fax no. 45-89991300	EAFS 19 pilot farms	National Network	DK 2
FRANCE **(F)**	Dr Françoise Ansay	ITCF 10, rue Dieudonné Costes 28024 Chartres Fax no. 33-37244677	IAFS 8 pilot. farms	Ferté-Vidame	F 1
	Dr Philippe Girardin	INRA B.P. 507 68021 Colmar Cedex Fax no. 33-89724933	IAFS 16 pilot farms (in prep.)	Rhénane	F 3
GERMANY **(DE)**	Dr Hans Peter Wieland (replacing Dr Adel El Titi)	State Inst. for Plant Protection Reinsburgstrasse 107 7197 Stuttgart 1 Fax no. 49-7116152268	IAFS 15 pilot farms	Baden-Württemberg	DE 1
	Dr Franz Gröblinghoff (replacing Dr Petra Zerhusen-Blecher)	University of Paderborn P.O. Box 1465 59474 Soest Fax no. 49-2921378200	IAFS 10 pilot farms	Nordrhein Westfalen	DE 3
GREECE **(GR)**	Dr Kiriaki Kalburtji	University of Thessaloniki Faculty of Agriculture Lab. Ecology and Env. Protection 54006 Thessaloniki Fax no. 30-31471795	EAFS (in prep.)	Kerkini	GR 1
IRELAND **(IRL)**	Dr Finnain S. Mac-Naeidhe	Johnstown Castle Research Centre - Wexford Fax no. 353-5342213	EAFS 10 pilot farms	Southeast and Midwest	IRL 1
ITALY **(I)**	Prof.dr Giuseppe Zerbi (replacing Dr Gemini delle Vedove)	University of Udine Dept. of Plant Prod. and Agrotechnology Via delle Scienze, 208, 33100 Udine Fax no. 39-432558603	I/EAFS 2/2 pilot farms (in prep.)	Northeast	I 2
ITALY **(I)**	Dr Carlo Malavolta (replacing Dr Giampaolo Sarno)	C.E.R.A.S. Emilia Levante, 18 40026 Imola (BO) Fax no. 39-542609230	IAFS 3 pilot farms (in prep.)	Emilia-Romagna	I 3

continued

NETHERLANDS **(NL)**	Ir Frank Wijnands	Exp. Station of Arable Farming P.O. Box 430 8200 AK Lelystad Fax no. 31-320030479	IAFS 38 pilot farms	National network	NL 1
	Dr Pieter Vereijken	Research Institute for Agrobiology and Soil Fertility (AB-DLO) P.O. Box 14 6700 AA Wageningen Fax no. 31-837075952	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
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.)	-	ES 2
UNITED KINGDOM **(UK)**	Dr Paul Farmer (replacing Dr Vic Jordan)	Long Ashton Research Station Long Ashton Bristol BS18 9AF Fax no. 44- 1275 394007	IAFS 1 exp. farm (2 pilot farms)	LIFE (Southwest England)	UK
	Dr Sue Ogilvy	ADAS-High Mowthorpe Duggleby, Malton Y 017 8BP North Yorkshire Fax no. 44- 1944 738434	IAFS 6 exp. farms	LINK	UK

contin

Countries outside EU

FINLAND **(FIN)**	Dr Tapio Poutala	University of Helsinki Dep. of Plant Production PL 27 Viikki 00014 Helsinki Fax no. 358-0 708 5463	IAFS 1 exp. farm	Suitia	FIN 1
POLAND **(PL)**	Dr Edward Majewski	FDPA UL. Czerniakowska 73/79 00-718 Warsaw Fax no. 48-26179613	IAFS 15 pilot farms	Mazovia	PL 1
	Dr Marian Krol (replacing Dr Irena Duer)	Institute of Soil Science and Plant Cult. 24-100 Pulawy Fax no. 48-831 4547	5 IAFS and 6 EAFS pilot farms (in prep.)	Bialystok	PL 2
SLOVAKIA **(SL)**	Dr Karol Kovác	Res. Inst. Plant Production Bratislavská 122 921 68 Piešt'any Slovakia Fax no. 42-83826306	EAFS 5 pilot farms	Slovakia	SL 1
SWEDEN **(S)**	Dr Carl-Anders Helander	Agricultural Society P.O. Box 124 532 22 Skara Fax no. 46-51118631	I/EAFS 1 exp. farm	Logården	S 1
SWITZERLAND **(CH)**	Ir Oswald Perler	Ministery of Agriculture Mattenhofstr 5 3000 Bern Fax no. 41-313222634	I/EAFS 165 pilot farms (in prep.)	National Network	CH2