Research Station for Arable Farming and Field Production of Vegetables

The information model for crop protection in arable farming

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CONTENTS

SUMMARY

This report is a follow up of the PAGV report nr. 133: Information modelling for arable farming. Both reports are part of a European project 'cooperative development of decision support software using agricultural information models' within the EC CAMAR programme. Whereas in the previous report the general information model for arable farming has been described, this report focuses on certain business areas referring to crop protection more in detail.

The information model for 'crop protection in arable farming' is based on the farmer's decision-making process related to crop protection and therefor only information and decisions relevant to him are incorporated.
The information model is a reference model, because it is representative of every type of arable farm. Within the information model, the field of attention is limited by only considering measures aimed at the control of damage caused by diseases, pests and weeds. Damage caused by abiotic factors such as over-fertilisation, frost, hail or wind have not been incorporated in the model.

An information model is divided into two parts. The first part, which is the process model, describes the important functions of the farm and the processes belonging to these functions. When dividing it up into functions and processes, account was taken of the management cycle of the farm (planning, implementation and evaluation) and of the most important products and production resources.
The second part, the data model, describes the data used or created by these processes. The link between data- and process model is made with data flows.

The information model for 'crop protection in arable farming' can serve as starting point for the following activities at an international level:

- to standardize concepts, algorithms and decision rules concerning crop protection;
- to synchronize research activities for crop protection;

- cooperative development of Decision Support Systems concerning crop protection.

Looking at the results of these projects, information modelling has proved to be a good tool for the development of consistent Decision Support Systems.

1. INTRODUCTION

There is a great deal of interest internationally in the approach and method chosen by the Netherlands in the field of Decision Support Development (DSS). In the late eighties the Dutch Ministry of agriculture has initiated some pilot activities to stimulate the use of Information Technology in agriculture. The financing of IT demonstration projects, the foundation of so called branch organizations on IT for farmers and the development of branch oriented and inter-branch oriented information models were the key activities of this Stimulation Programme for Information Technology.

In an information model the activities taken place on the farm are described as a hierarchy of functions and processes in the so called process model whereas the data related to these processes are structured and described in a data model.
According to the Information Engineering method by James Martin Strategy a general arable farming information model has been developed.
Later, several business areas of the general model have been detailed into elementary processes which has led to the so called detailed 'Arable farming information model' (IMOT; SIVAK, 1990). This information model is intended as a crop independent reference model for arable farming.

The information model can serve as a basic starting point within projects for the development of products such as:

- definitions/messages for the interchange of information between the farmer and organizations (e.g. accountants, consultants) and the annual adjustment of standard messages for financial and economic purposes;
- an interface for data interchange between Crop Management Systems and registration programs, and an interface between Crop Management Systems and board computers for tractors;
- an operational Farm Management System (BEA) at farm level which is used by advisors;
- several Decision Support Systems (DSS) as part of the integrated farm

management system e.g. (Meijer & Kamp, 1991):

- the operational system (crop management system) for Sugar Beet (BETA) which is being commercialized by an organization newly set up in 1992;
- a operational system for the cereals Winter Wheat and Barley (CERA), which has been intensively tested by end-users (the farmers), CERA is also commercialized in 1992;
- a system for Cauliflower and Brussel Sprouts (KOBAS) which will be developed and tested in 1993;
- a prototype DSS for the control of potato root eelworm disease (TERRA).

On the basis of the results of these project, information modelling has proved to be a good tool for harmonizing concepts, algorithms and decision rules.

The information modelling approach has proven to be a successful methodology in the field of DSS developments. Existing international contacts led to the approval of an European project - 'cooperative development of decision support software using agricultural information models'. This project forms part of the EC CAMAR programme (Competitiveness of Agriculture and Management of Agricultural Resources).

The following organizations take part in the project:

- Department of Agriculture and Rural Development (DLG) in Germany, contact person K. Schlösser;
- Justus-Liebig-University of Giessen in Germany, contact person F. Kuhlmann;
- ACTA in France, contact person G. Waksman;
- INRA in France, contact person J. Attonaty;
- ITCF in France, contact person, G. Lemaitre;
- AGPM in France, contact person, D. Bloc;
- ADAS in the United Kingdom, contact person I. Houseman;
- Instituto Nacional de Investigaciones Agrarias in Spain, contact person J.L.G. Andujar;

- the Research Station for Arable Farming and Field Production of Vegetables (PAGV) in the Netherlands, contact person B.J.M. Meijer.

Within the framework of this project, the Dutch 'General Arable Farming Information Model' has been translated into English to serve as a basis for the development of a European Information Model. The next step after the development of the Dutch 'General Information Model for Arable Farming' was to detail the defined business areas into elementary processes. This detailed 'Arable Farming' information model (IMOT;SIVAK,1990) is intended as a crop-independent reference model.

The detailed information model for arable farming (IMOT) provides insight into the farmer's decision-making process. A general description is available in English and is entitled 'Information modelling for arable farming' PAGV report nr. 133 by A.J. Scheepens.

The standards set in IMOT can also be used to attune standards at an international level. Together with the other participants in the above-mentioned EC project, we have decided to give crop protection first priority for standardization. The first step is to make the information contained in IMOT accessible to the other participants. The results are presented in this report.

The area of crop protection is given first priority because new pest, disease and weed control management strategies will increase in importance as a result of the deteriorating income-expenditure ratio and the constant tightening of regulations concerning the use of chemicals in agriculture.
Within this context, an information model for arable farming can provide:

- better understanding of the interaction between different pest and disease control decisions;
- a starting point for the attunement at an international level of regulations, concepts and decision rules concerning crop protection measures;
- it can be used as a starting point for further international collaboration concerning the development of costly, knowledge-intensive systems.

This report can be seen as an extraction of the 'detailed information model for arable farming' (IMOT), concerning decision-making in the field of protecting crops against pests, diseases and weeds.

The basic starting points, the relationship with IMOT and conclusions which have been drawn from the information analysis, are described in text form and illustrated by means of simple diagrams in chapter 2. In order to make the model accessible to everyone, it has only been described in general terms.
The description of all business areas, processes and entity types incorporated in the model can be found in appendices C, D and E. Appendix A explains the Information Engineering methodology used in accordance with the Agricultural Information Modelling Approach (LIA); appendix B concerns the use of Information Engineering Workbench (IEW) in accordance with the LIA approach.

For the complete information model for crop protection, please refer to the model included in the Information Engineering Workbench (IEW), which is available at the Research Station for Arable Farming and Field Production of Vegetables (PAGV).

2. DESCRIPTION OF THE INFORMATION MODEL FOR CROP PROTECTION

2.1 Definition

According to Heitefuss (1989), crop protection may be defined as follows:
"Crop protection is the entire range of measures to prevent damage and yield reduction of useful plants by using all relevant scientific knowledge in an ecological and economically suitable way".

Within the information model, the field of attention is further limited by only considering measures aimed at the control of damage caused by diseases, pests and weeds. Damage caused by abiotic factors such as over-fertilisation, frost, hail or wind has not been incorporated in the model.

Critical success factors which have to be complied with in order to achieve this objective are:

- planning an effective strategy for operational protection measures is of vital importance;
- Choices have to be made within the plan such as:
  - whether the protection should be chemical or mechanical;
  - whether to take preventive or curative measures. Examples of preventive measures are: effective crop rotation systems and the choice of a variety resistant to the disease or pest;
- throughout all stages of the production process, strict control (by means of observation) of diseases, pests and weeds is of vital importance so as to ensure that effective measures can be taken in time;
- prediction of the population development for diseases or pests gives the farmer more support for his decision regarding whether or not to take timely protection measures;
- there are strict regulations for the use of chemical protection agents which

should be followed to the letter by the farmer. The farmer should therefore be fully up-to-date with current regulations;

- in addition, in order to be able to take the most effective and economically profitable decision, the farmer should be aware of the actual costs and benefits of a measure;
- any control of a disease or pest should be attuned to other cropping measures and should be carried out at the right moment. The crop protection plan, for example, should be attuned to the fertilisation plan.

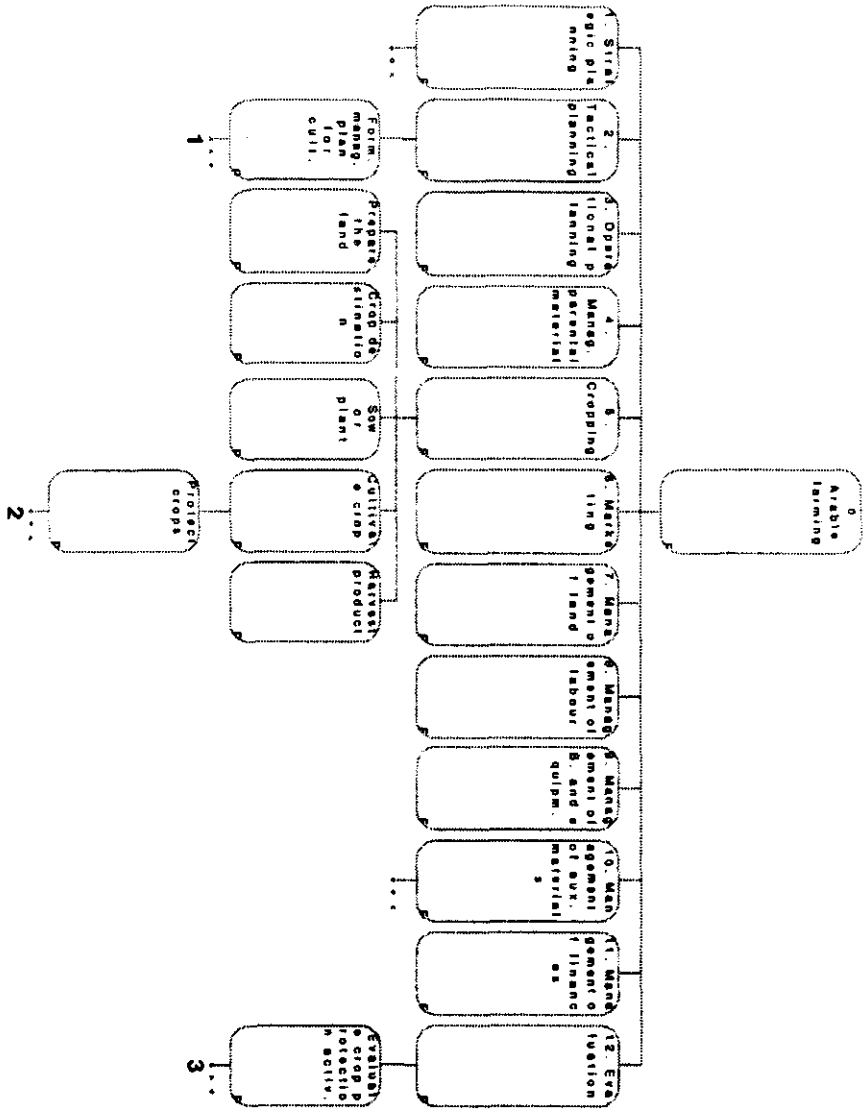
On the basis of these critical success factors, the field of attention has been defined and a number of different sections or business areas have been incorporated in the crop protection model (see appendix C and figure 2). A short description of the used methodology can be found in appendix A. More information is included in the previous mentioned PAGV-report nr. 133.

Only the processes and data which support the decision-making process of a farmer in relation to crop protection have been incorporated. In addition, all information (including information formalized outside the farm) which is relevant to the implementation of these activities has been documented. Information has also been incorporated from external organizations playing a role in these activities.

In the 'detailed information model for arable farming', the area of crop protection has been divided between several different functions (see figure 1) and has not been identified as a separate information area or business area. In other words in IMOT, in accordance with the definition of a business area, crop protection is not described as a relatively independent and internally cohesive cluster of activities and information use. If we consider crop protection in this model as a separate cluster, a number of entity types, functions and processes will be grouped differently in relation to each other. An example is the function **observation** in IMOT. Observation is not a separate function in the information model for crop protection, but is subdivided into a number of processes which form part of the operational process **Protect crops**. The reason is

that observation is a critical success factor with regard to the choice of the best measure at the most suitable time and is consequently very closely related to the implementation of crop protection measures.

Figure 1. Functional decomposition diagram for 'arable farming'.
The processes below (1) are detailed in figure 3, the processes below (2 in figure 4 and the process below (3) detailed in figure 6.



2.1.1 The crop protection model's link with IMOT

Crop protection can be seen as a section or business area of IMOT whereby the processes relating to crop protection and relevant data from IMOT are used as a basic starting point. The model for IMOT is described on the basis of the management cycle. Activities can be subdivided into three categories which together form a complete management cycle:

- planning;
- implementation;
- evaluation.

Within the crop protection processes, we can distinguish the same cycle. The crop protection processes can therefore be seen as processes of the following IMOT functions:

- Function **1. Strategic planning**: the business policy for the coming years determines the content of the crop protection plan at a tactical and operational level. The chosen farming system (e.g. non-use of chemical agents, integrated farming system or conventional farming system) largely determines the preconditions for decisions at a tactical and operational level;
- Function **2. Tactical planning**: at a tactical level, the production plan based on the **farming system** is crystallised further. The production plan is determined for the duration of one or more rotation cycles. The **parasite and weed control plan** also forms part of the production plan;
- Function **3. Operational planning** and Function **5. Cropping**: on operational level the variety choice and the process **protect crops** is further detailed within the crop protection model;
- Function **12. Evaluation**: the process **Evaluate crop protection** evaluates the results in comparison with a **weed and parasite protection plan** or from specific crop protection measures.

2.1.2 Subdivision of the crop protection model into individual business areas

Just as crop protection can be distinguished from IMOT as a business area, we can also subdivide crop protection itself into different business areas. These individual

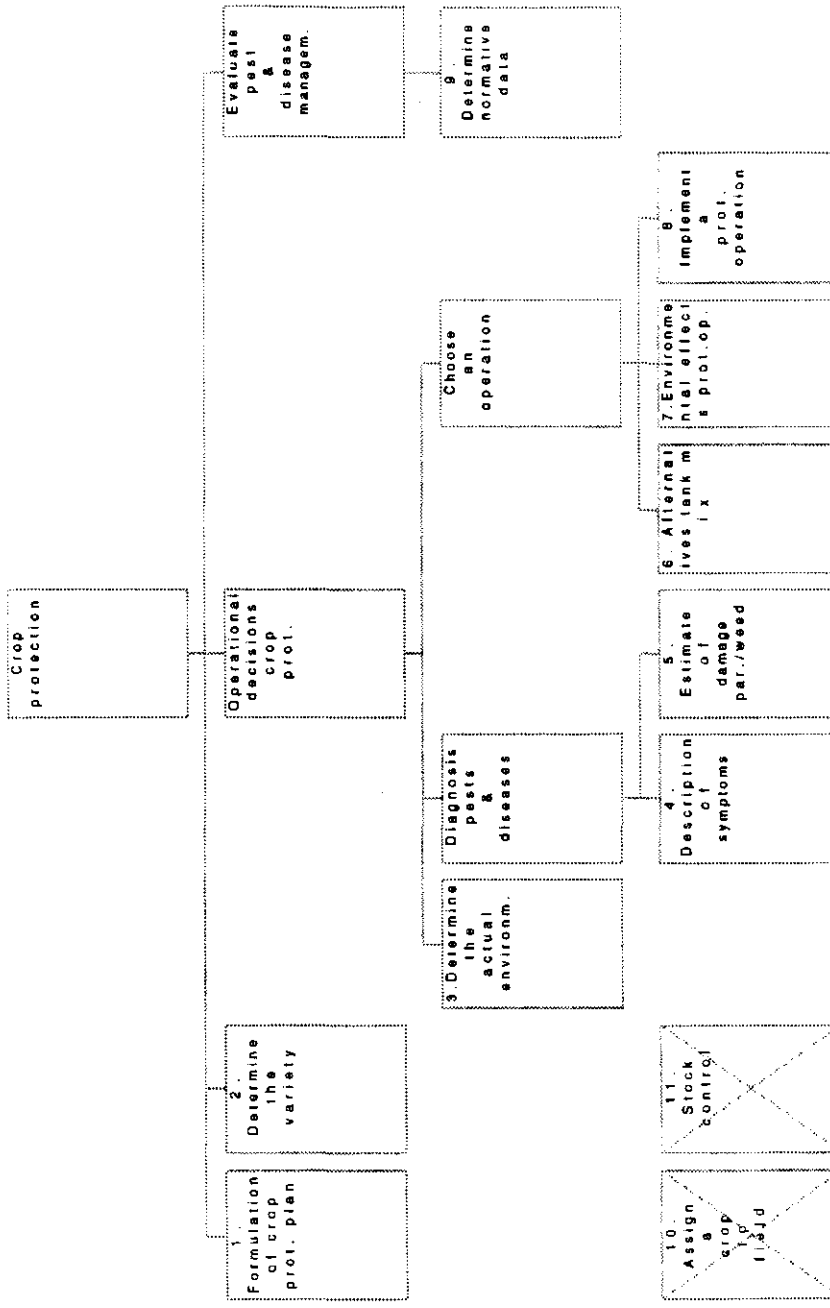
business areas are clearly defined sub-sections of the model which can be further analysed as separate clusters.

Using the affinity analysis from the Information Engineering Workbench (IEW), similar processes and entity types can be grouped on the basis of analogous associations. An analogous association exists, for example, if two processes make use of the same entity type. An example is the process **Match the description** which can create both an entity of the type **Actual description weed symptoms** and the type **Actual description parasite symptoms.**
This option is used within the crop protection model to distinguish clearly defined business areas which can be further analysed individually.

Making use of this option in IEW, the following business areas can be distinguished in crop protection (figure 2):

1. Formulation of a crop protection plan;
2. Determine the production possibilities;
3. Determine the actual environment;
4. Descriptions of symptoms;
5. Estimate damage parasite/weed;
6. Alternative tank mix;
7. Environmental impact of a protection operation;
8. Implement an operation;
9. Assessment of normative data;
10. Assign a crop to a certain field;
11. Stock control.

Figure 2. The decomposition of the business area crop protection into sub-sections or business areas which can be analysed seperately. The CRUD matrix (figure 15) shows the interaction between those subject areas. The numbered subject areas are described in Appendix C.



The decomposition of the crop protection model into these business areas is illustrated by figure 2 and 16. Figure 2 shows the mutual relationship and difference in detailing between different business areas.

The business areas **Assign a crop to a field** and **Stock control** do not form part of the crop protection model, but are so relevant to the implementation of crop protection measures that they are described in connection with the crop protection model.

The descriptions of the different business areas and the processes and entity types per business area can be found in Appendix C.

In the following sections, the model is dealt with from the point of view of the processes. The data model has been created by means of analysis from the point of view of processes and data flows between the different processes. This approach clearly shows which data are important and which not when taking decisions.

2.2 The Process model

A number of main functions can be distinguished in IMOT, namely planning, operational activities and evaluation. The following processes are detailed further in the crop protection model:

- the process **Formulate a management plan for cultivation** included in function **2. Tactical planning** (figure 3);
- the process **Cultivate crop** which forms part of function **5. Cropping** has been detailed to include operational activities in the field of crop protection which form part of the process **Protect crops** (figure 4 and 5);
- function **12. Evaluation** has been detailed with the process **Evaluate crop protection** activities (figure 6).

2.2.1 Formulate a management plan for cultivation

The process **Formulate a management plan for cultivation** comprises sub-processes which are of importance when planning crop protection activities (figure 3). Processes with a close relationship with crop protection and consequently

incorporated in the model are **Divide the cultivation** area and **Determine the crop rotation plan**. The two processes help to determine the content of the entity types **weed and parasite control plan**. These plans cover all other cropping cycles. Attunement of the choice of variety has been incorporated in this model as part of function **3. Operational planning**.
In the process **Formulate a parasite/weed control plan**, a decision is taken to plan protection measures against a specific weed in a specific crop in order to prevent damage to a following crop.

2.2.2 Protect crops

The process **protect crops** forms part of function **5. Cropping** from IMOT and covers all operational activities relating to crop protection on the arable farm.

The process is subdivided into the processes **Plan crop protection measures** (figure 4) and **Implement crop protection operations** (figure 5).

In the process **Plan crop protection measures**, the probability that a disease, pest or weed attacks the plant is first determined by means of the process **Determine the probability of a parasite/weed**. In order to be able to estimate this probability, the crop and weather conditions need to be determined. If these conditions are such that a parasite could be expected in the crop, an observation is planned. figure 9 illustrates the different data flows between the different sub-processes of **Determine the probability of a parasite or weed**. The content of the different data flows can be referred to in appendix D (process model).
On the basis of the incoming flow **planned observation**, a decision is taken to make an observation whereby the observed symptoms are described and compared with normative symptoms of known diseases or pests for the crop concerned. The infestation pressure is also determined (figure 10).
On the basis of the infestation pressure and crop development, the epidemiological growth is estimated which can then be used to ascertain the expected damage to the product in a qualitative and quantitative sense. The data flow diagram of the process **Prognosis of the potential damage** illustrates the relationship between the data

required to calculate the expected damage (figure 11).

Within the process **Implement crop protection measures**, it is first necessary to decide on the best possible protection operation (sub-process: **Decide about crop protection**). This decision is made on the basis of the following information (figure 13):

- the flow **estimated damage parasite/weed** and **identified parasite/weed** as a result of the process **Plan crop protection measures**;
- the conditions such as the **actual weather** and **crop condition**;
- the availability of **equipment** and **crop protection agents** (stock);
- information needed to determine the cost and benefits such as: the expected yield, price of the crop and price of the crop protection agent;
- **protection threshold** determined by the process **Evaluation crop protection measures**;
- **environmental effects** of such an operation;
- restrictions in force regarding soil properties and water catchment area and restrictions resulting from the **farming system**.

On the basis of the crop, restrictions imposed by the **farming system** (e.g. non-use of chemical protection agents) and restrictions with respect to the soil and water catchment area, a choice of agents which can be used is then made from the table of crop protection agents (= process **Restrict number of protection agents**) (figures 5 and 13).
On the basis of the identified parasites and the permitted protection agents, combinations are then determined for a **tank mix**. In the case of each tank mix, a suitable **operation** is sought, depending on the available **equipment**.
By driving through the crop with the spraying equipment, it can cause damage to the crop. This damage is estimated in the process **Estimate damage protection operation** (figures 5 and 13).

Given the permitted and available **crop protection agents**, the damage caused by a parasite or weed, the damage to the crop caused by an operation and

environmental effects, it is then necessary to choose the most suitable protection operation (figure 14).

When choosing an economically optimum **operation**, two decision procedures can be used:

1 the use of a fixed **protection threshold**. Operations which exceed this threshold are cost-effective. As a starting point for this decision rule, use is made of the infestation pressure or the number of insects observed or number of leaves infected etc. (Process: **Use the protection threshold**). The fixed protection threshold is a normative factor which is established on the basis of the relationship between the number of weeds, diseases or pests and the expected financial damage. This relationship is based on an average of several years and regions. The consequence is that differences in the yield level, differences in price and the efficacy of crop protection agents are not considered. It is, however, possible to attune the crop protection threshold to measures to be carried out for other crops in the cropping plan;

2 the use of a cost/benefit analysis (Process: **Analyse cost/benefits**). The calculation of the costs is based on the following information:

- the estimated drop in yield of the crop if no protection is carried out;
- damage to the crop caused by implementation of a crop protection measure;
- the price of the **crop protection agents** which form part of the **tank mix**;
- if required the cost of labour (at contract work rate) and costs of mechanisation can be included in the calculation.

Where benefits are concerned, account is taken of the following:

- a indicator number for the efficacy of a crop protection operation. When determining the efficacy of a operation, the efficacy of individual crop protection agents on the pests, diseases or weeds to be controlled is taken into consideration;
- the estimate of the damage which may be caused by the combined disease(s), pest(s) or weed(s) which have been observed. The expected damage is related to the expected yield;

- the physical damage is converted into the a figure for financial damage on the basis of the **product** price per kg.

By using information more specifically related to the plot in question, this last decision procedure will result in advice which is better suited to the situation. One disadvantage, however, is that much more information is necessary before the advice stage can be reached. In particular, calculation of the infestation pressure and an estimate of the damage caused require a great deal of research.
Within the decision procedure a choice is made between the type of operation. Operation types are for example: spraying the whole field, spraying only rows or hoeing.
In addition to a financial evaluation of **crop protection agents**, damage to the environment is also taken into consideration when choosing an **operation**. Likewise the availability of an agent.
A date and the **equipment** needed for the protection operation are then determined. Once the need for crop protection has been established, it is usual for the tank mix and necessary equipment to be prepared for implementation of the protection operation.
When a protection operation has been carried out, a new observation can be considered depending on the normative data concerning the duration of effectiveness of the agents used in the tank mix. The cycle within the process **protect crops** can then be restarted.

2.2.3 Evaluate crop protection activities

The process **Evaluate crop protection activities** forms part of function **12. Evaluation** (figures 1 and 6). An important sub-process is to **determine the normative data** which are important as input for the process **protect crops**. The normative data are based on average values established by research based on different farm situations and a number of years. With the observed results of implemented operations and observation of the surrounding conditions in the process Protect crops, the normative data specific to the farm can be adjusted (figure 15).

Depending on the **parasite and weed control plan** drawn up by the process **Formulate the crop protection program** (figure 3) and the **farming system**, the observation and operation criteria can be established (Process: **Determine the observation criteria** and **Determine the operation criteria**).
In addition, conditions around the farm are determined which might be of importance to internal decisions concerning crop protection (Process: **Observe circumstances around the farm**).

2.3 The data model

In the data model (figure 17) there is a description of information which the farmer wishes to retain for crop protection. Part of this information comes from external agents, e.g. Plant Protection Service, extension service or research. This information is classified in the model as external normative data.
In addition we have normative data, specifically applicable to the farm in question, which is produced by the farmer's own evaluation process (Process: **determine the normative data**).

On the basis of the business areas, the data model is subdivided into different subject areas (see appendix C).
There is also current information available which is created or changed within the farm (see CRUD matrix; figure 15).

2.4 Diagrams

Figure 3. Process decomposition of **Formulate management plan for cultivation**. This figure is an extension of figure 1: part (1).

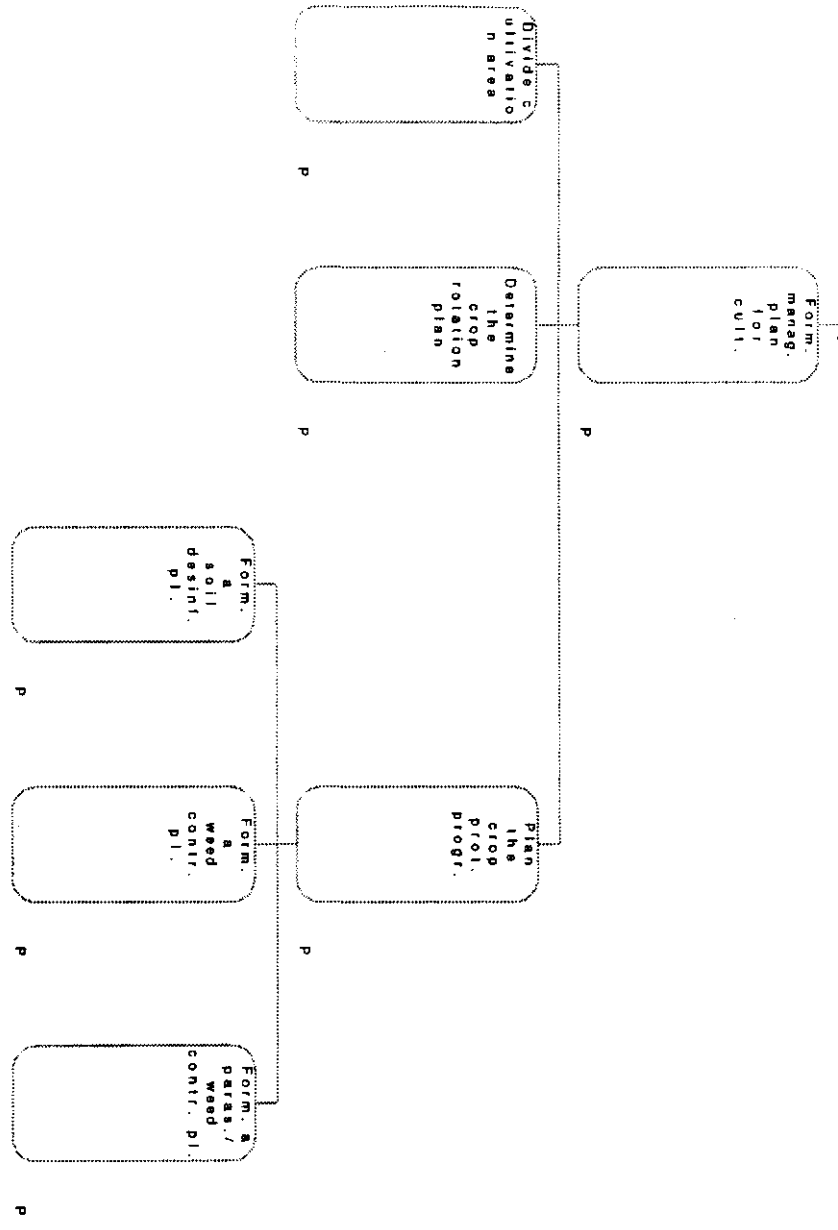


Figure 4. Process decomposition of **Protect Crops** and **Plan crop protection measures**. This figure is an extension of figure 1: part (2)

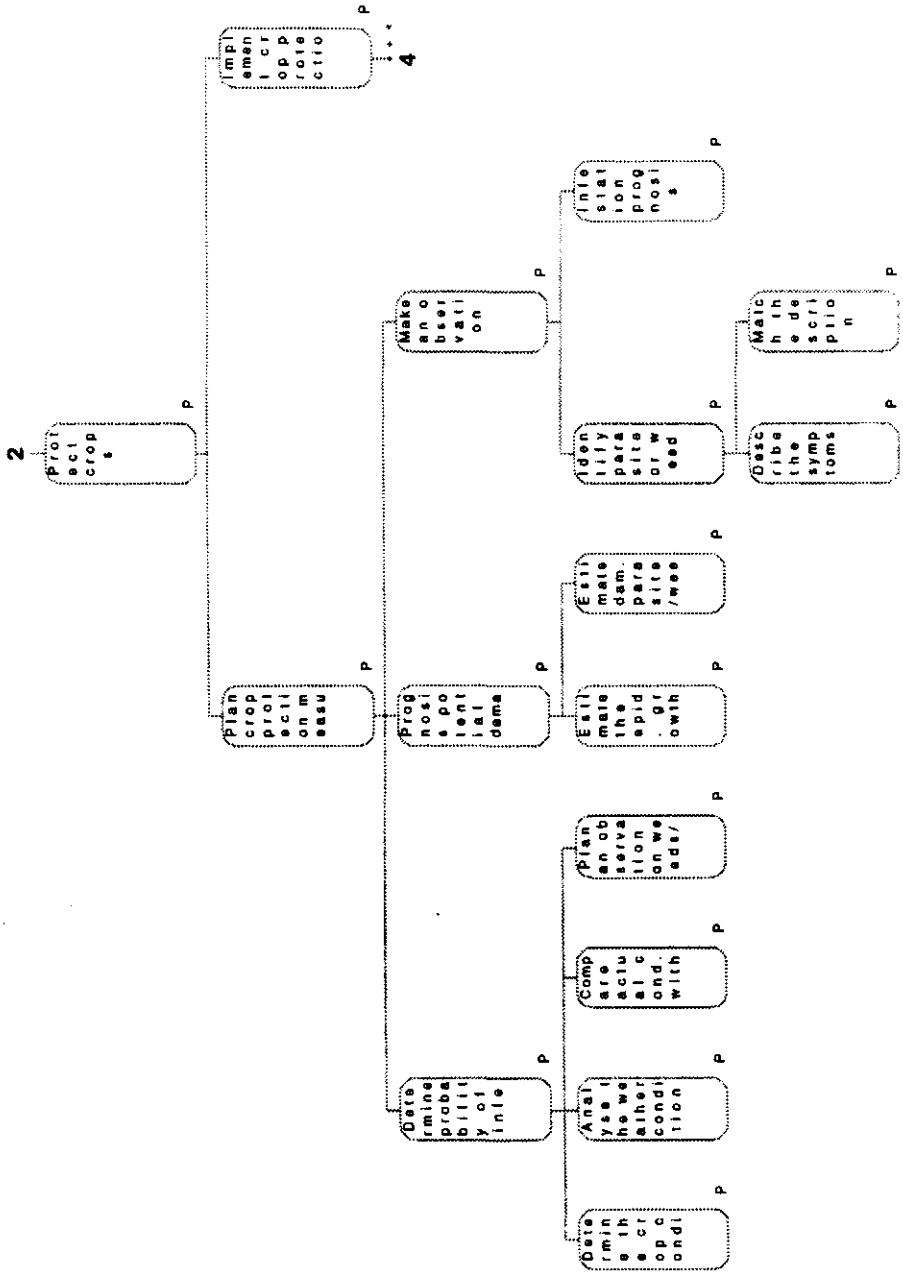


Figure 5. Process decomposition of **Implement crop protection measures**. This figure is an extension of figure 4: part (4).

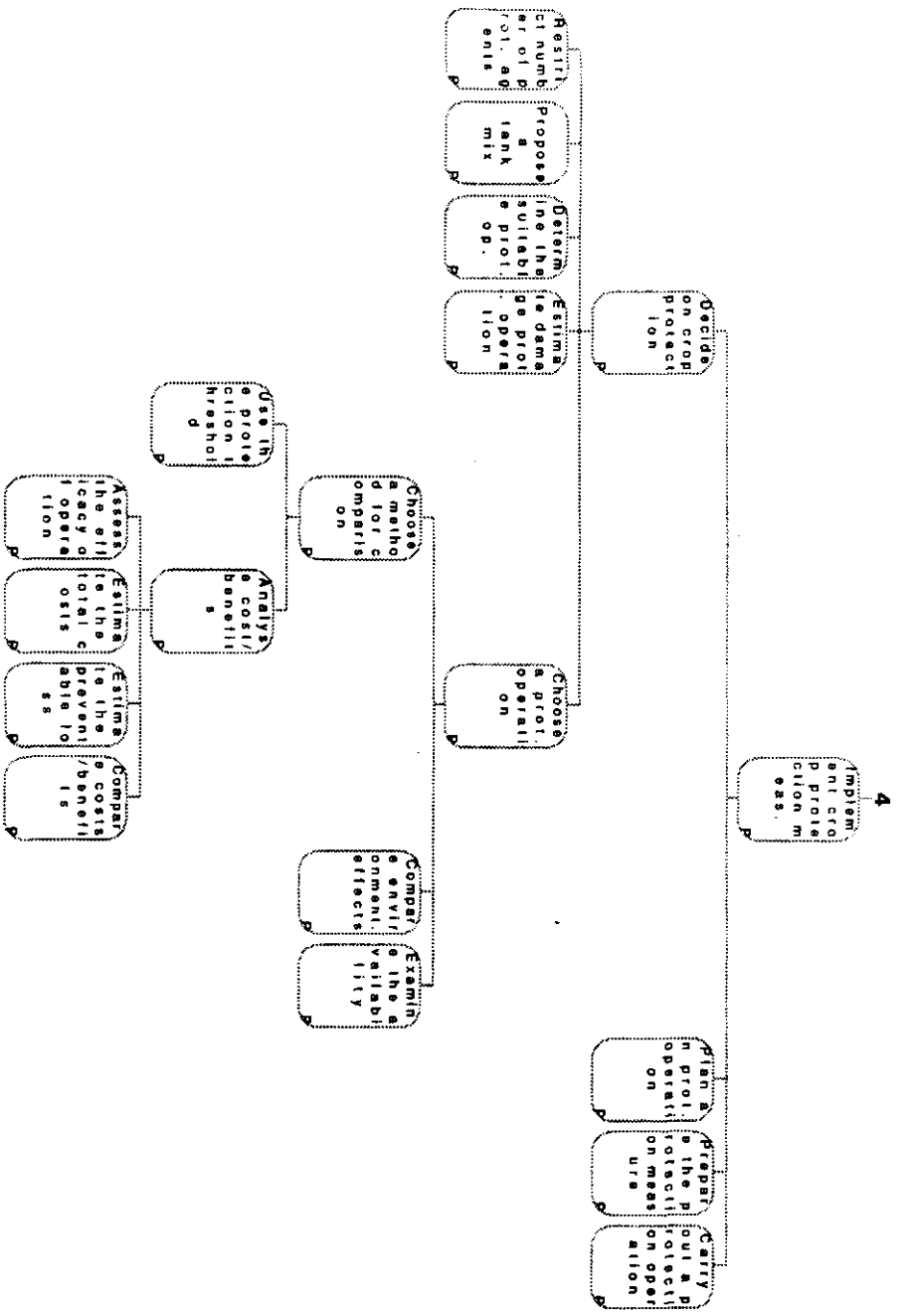


Figure 6. Process decomposition of **Evaluate crop protection**. This figure is an extension of figure 1: part (3).

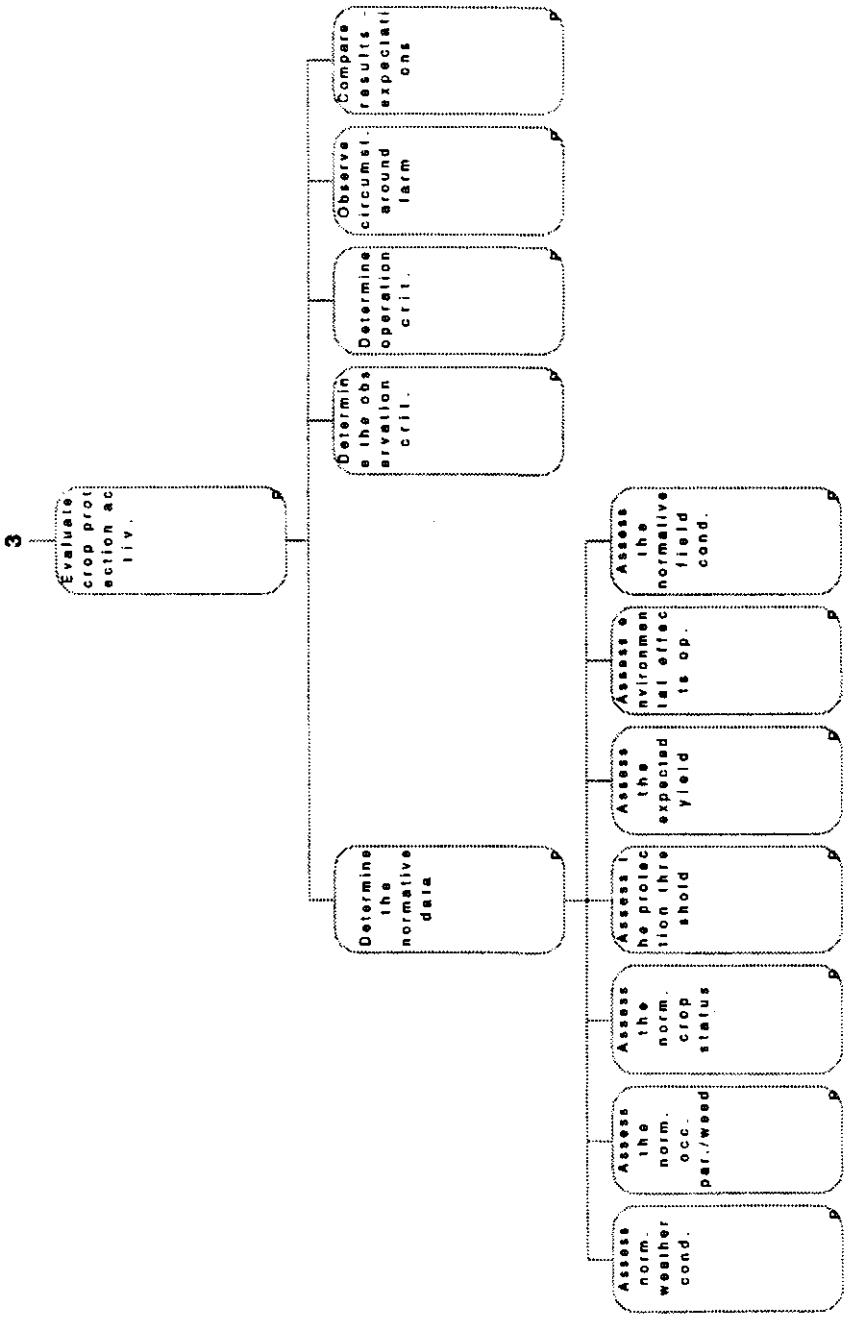


Figure 7. Data Flow diagram: **Protect Crops** with the sub-processes **Plan crop protection measures** and **Implement crop protection measures.**

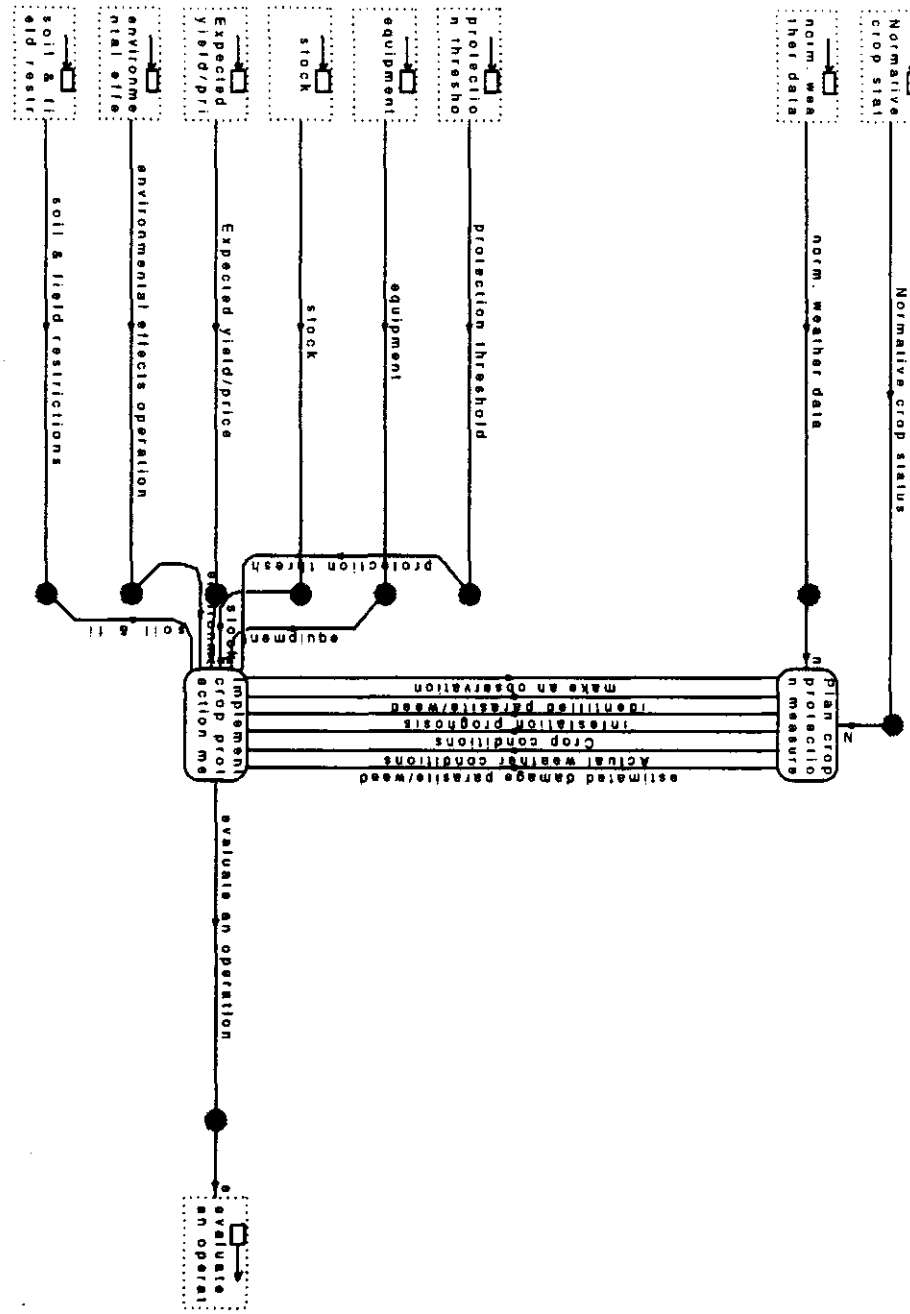


Figure 8. Data Flow diagram: **Plan crop protection measures** with the sub processes **Determine probability of infestation, Make an observation** and **Prognosis of the potential damage.**

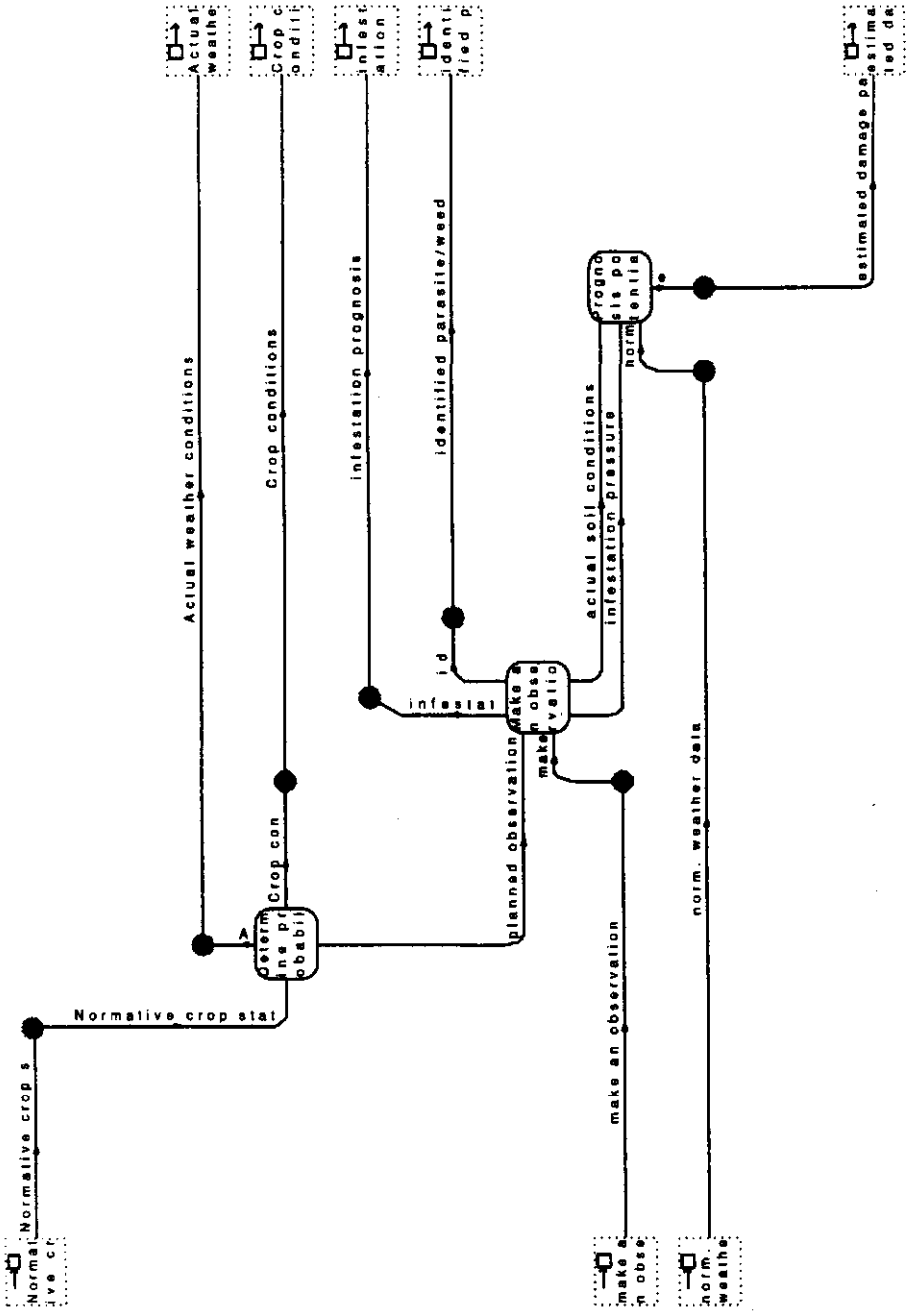


Figure 9. Data Flow diagram: **Determine probability of infestation** with the sub-processes **Determine the crop conditions, Analyze the weather conditions, Compare the actual conditions with historical conditions** and **Plan an observation.**

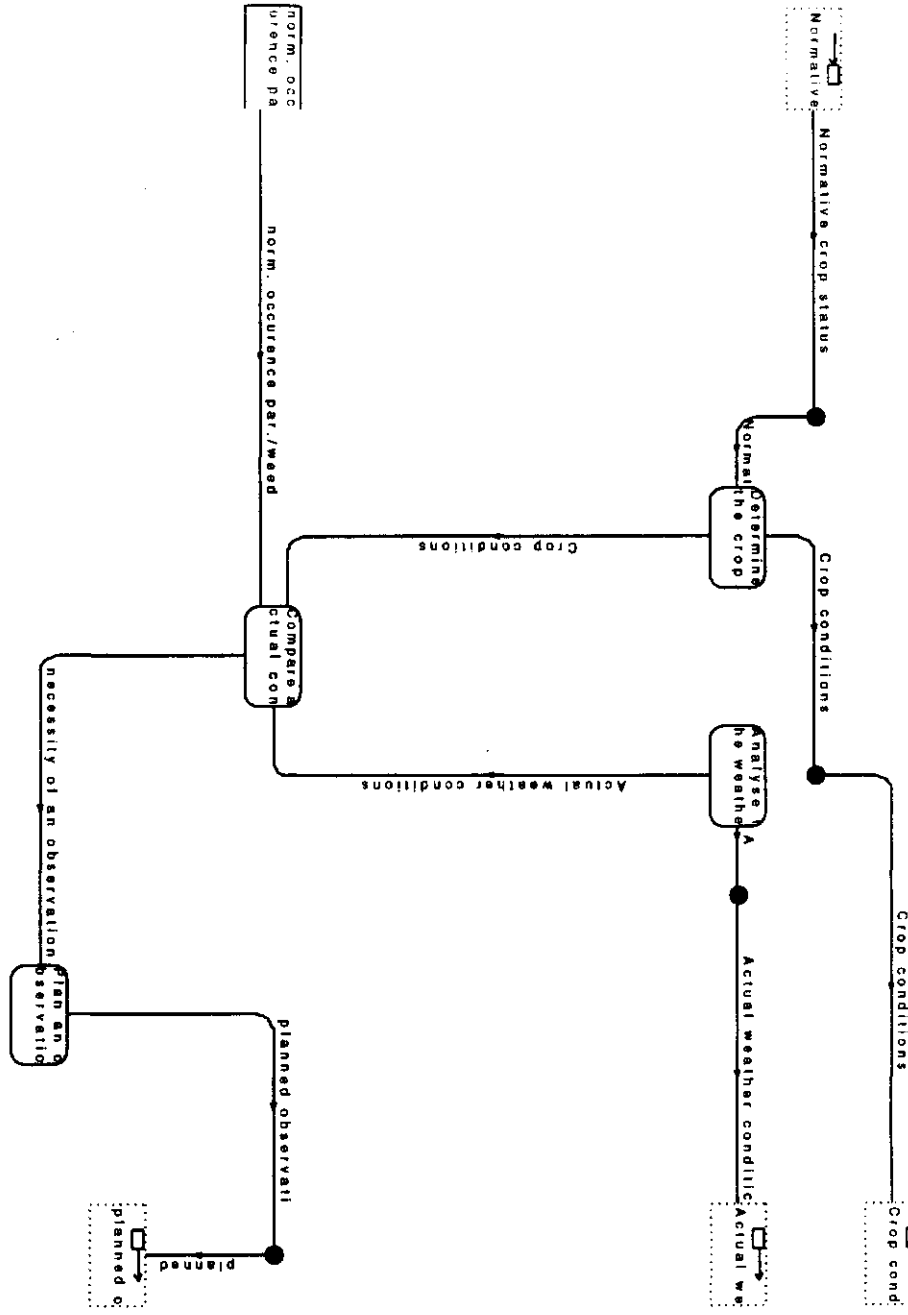


Figure 10. Data Flow diagram: **Make an observation** with the sub-processes **Identify parasite or weed** and **Infestation prognosis**.

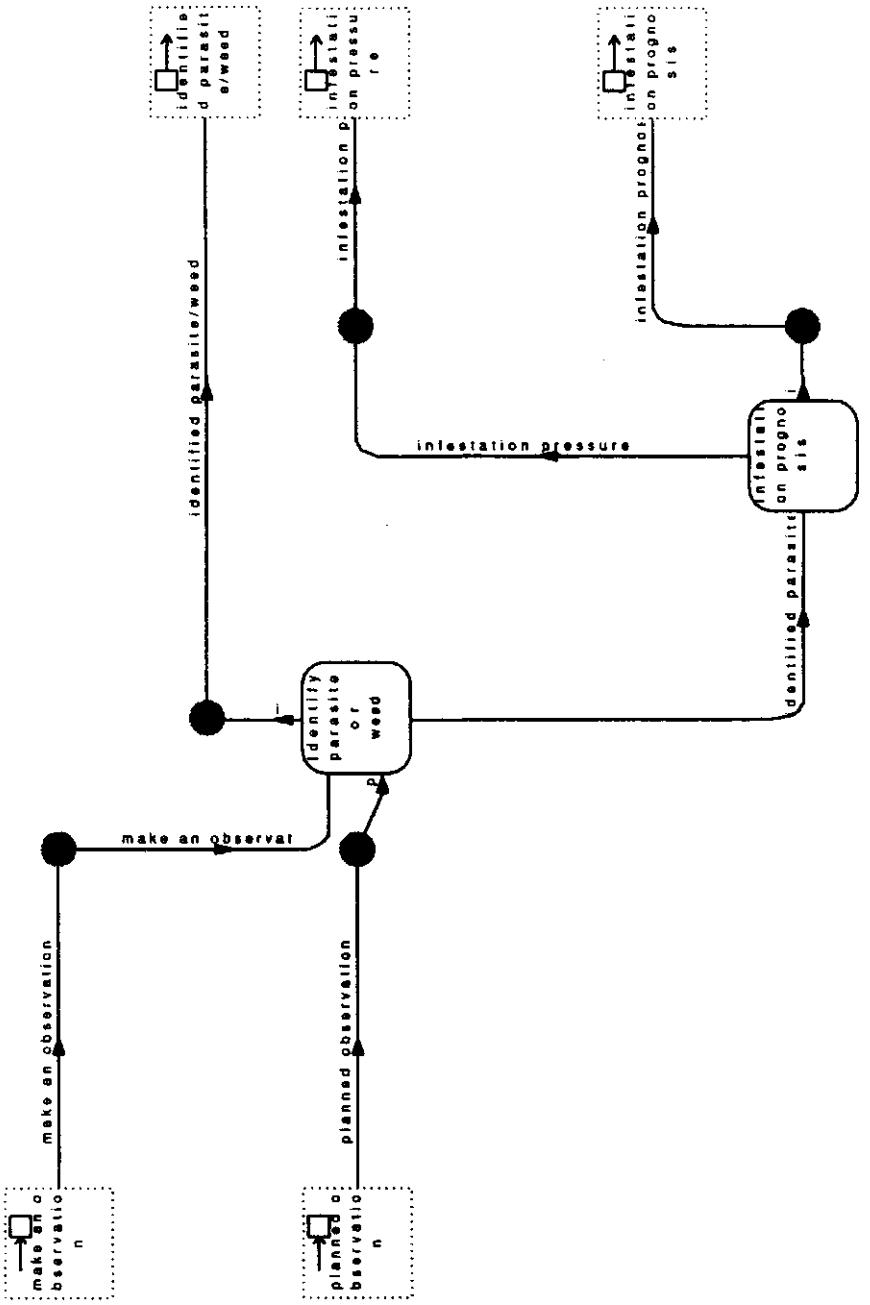


Figure 11. Data Flow diagram: **Prognosis of the potential damage** with the sub-processes **Estimate the epidemical growth** and **Estimate damage parasite/weed**.

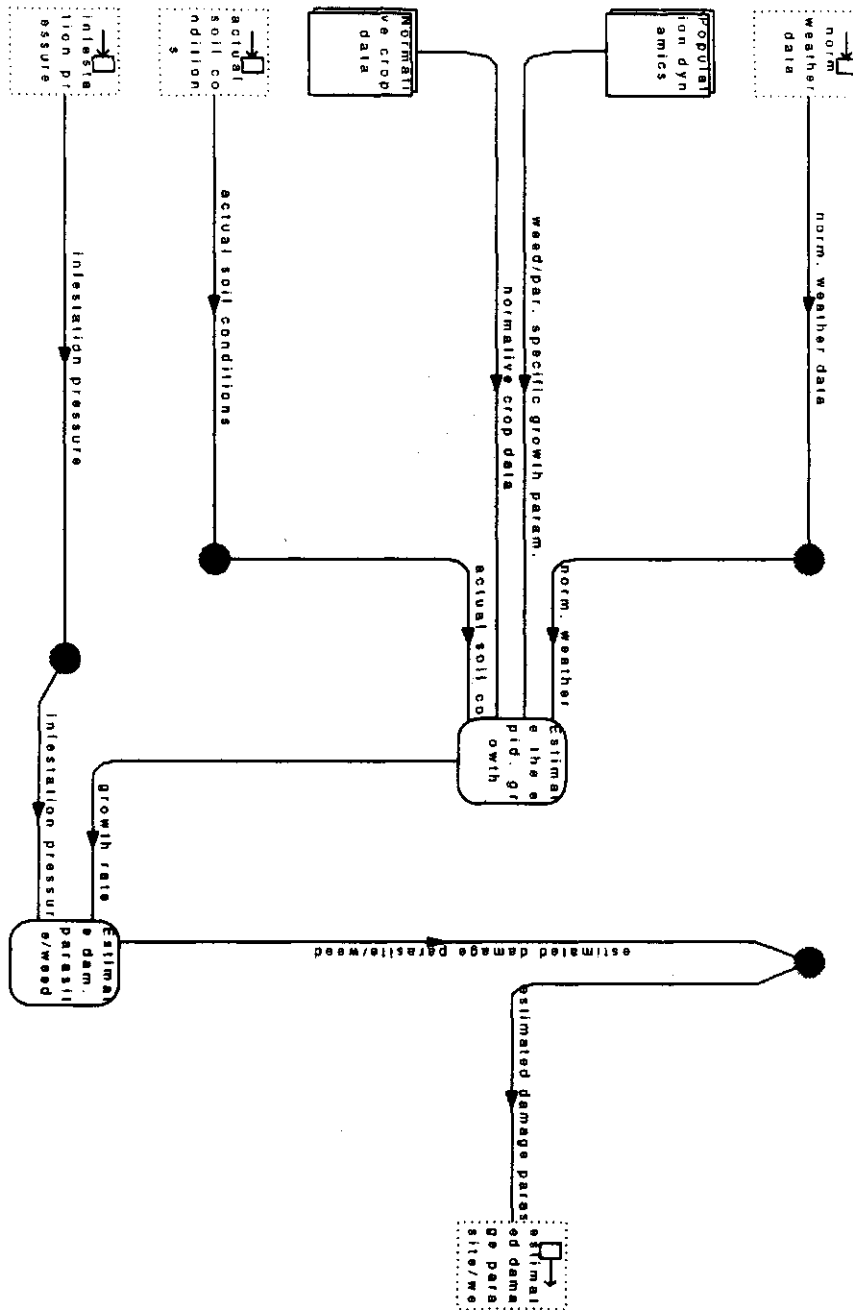


Figure 12. Data Flow diagram: **Implement crop protection measures** with the sub-processes **Decide about crop protection**, **Plan protection operation** and **Prepare the protection operation** and **Carry out the operation**

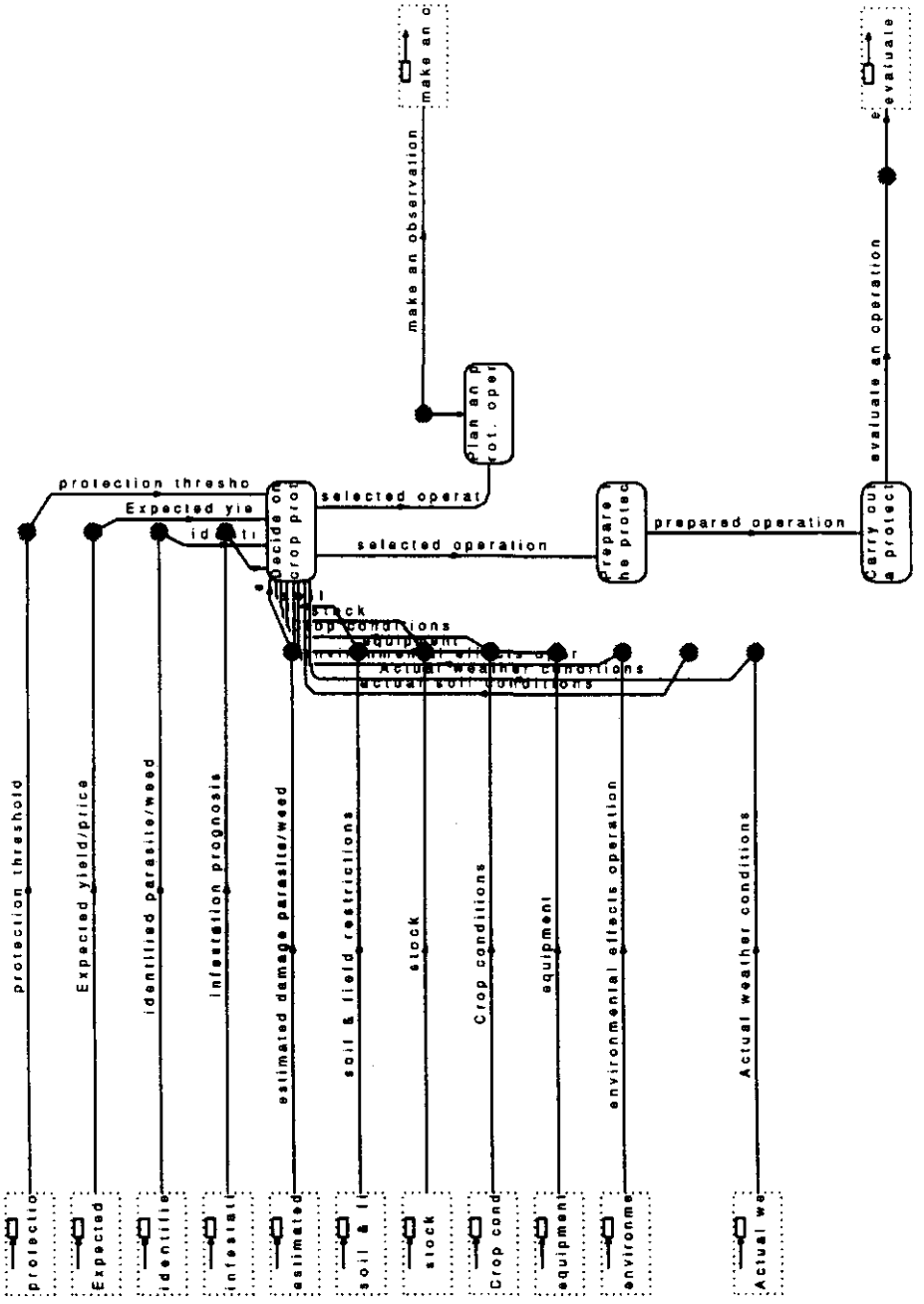


Figure 13. Data Flow diagram: **Decide on crop protection** with the sub-processes **Restrict the number of Protection agents**, **Propose a tank mix**, **Determine the suitable protection agents**, **Estimate the damage protection operation** and **Choose a protection operation**.

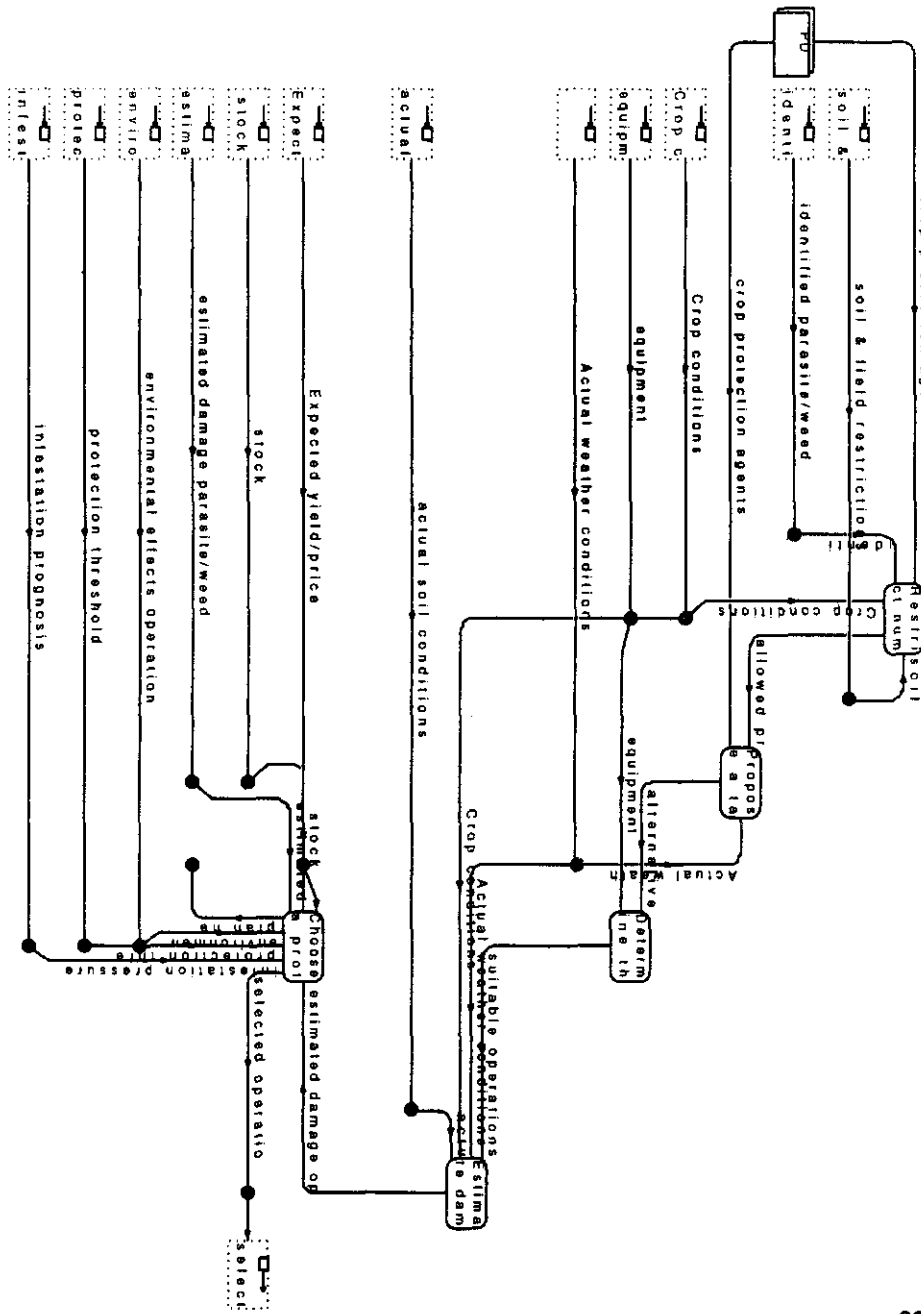


Figure 14. Data flow diagram: **Choose a protection operation** with the sub-processes **Choose a method a method for comparison, Compare environmental effects, Examine the availability.**

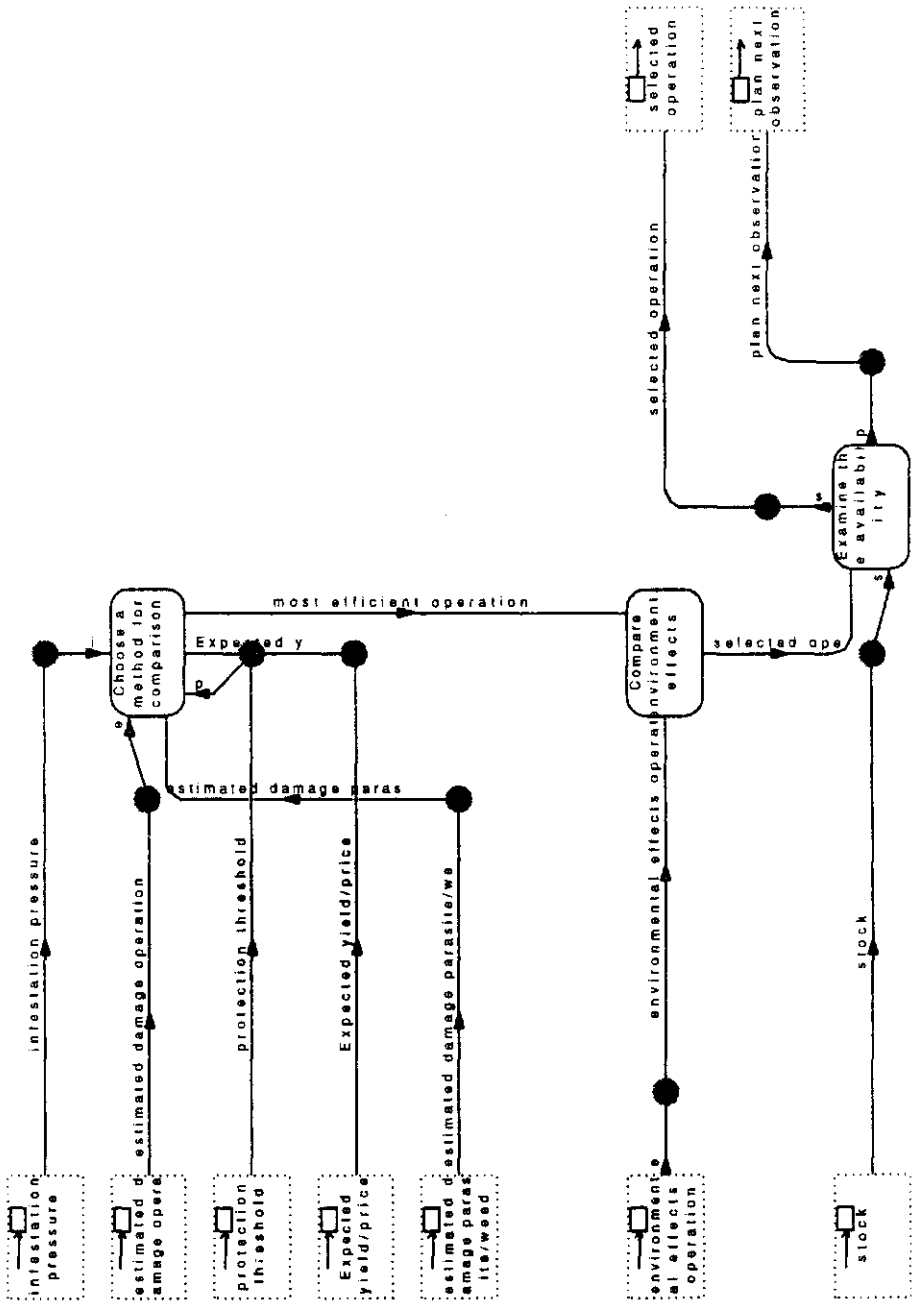


Figure 15. Data flow diagram: **Determine the normative data** with the sub-processes **Assess the normative weather conditions**, **Assess the normative occurrence parsite/weed**, **Assess the normative crop status**, **Assess the protection threshold**, **Assess the expected yield**, **Assess the environmental effects** and **Assess the normative field conditions**.

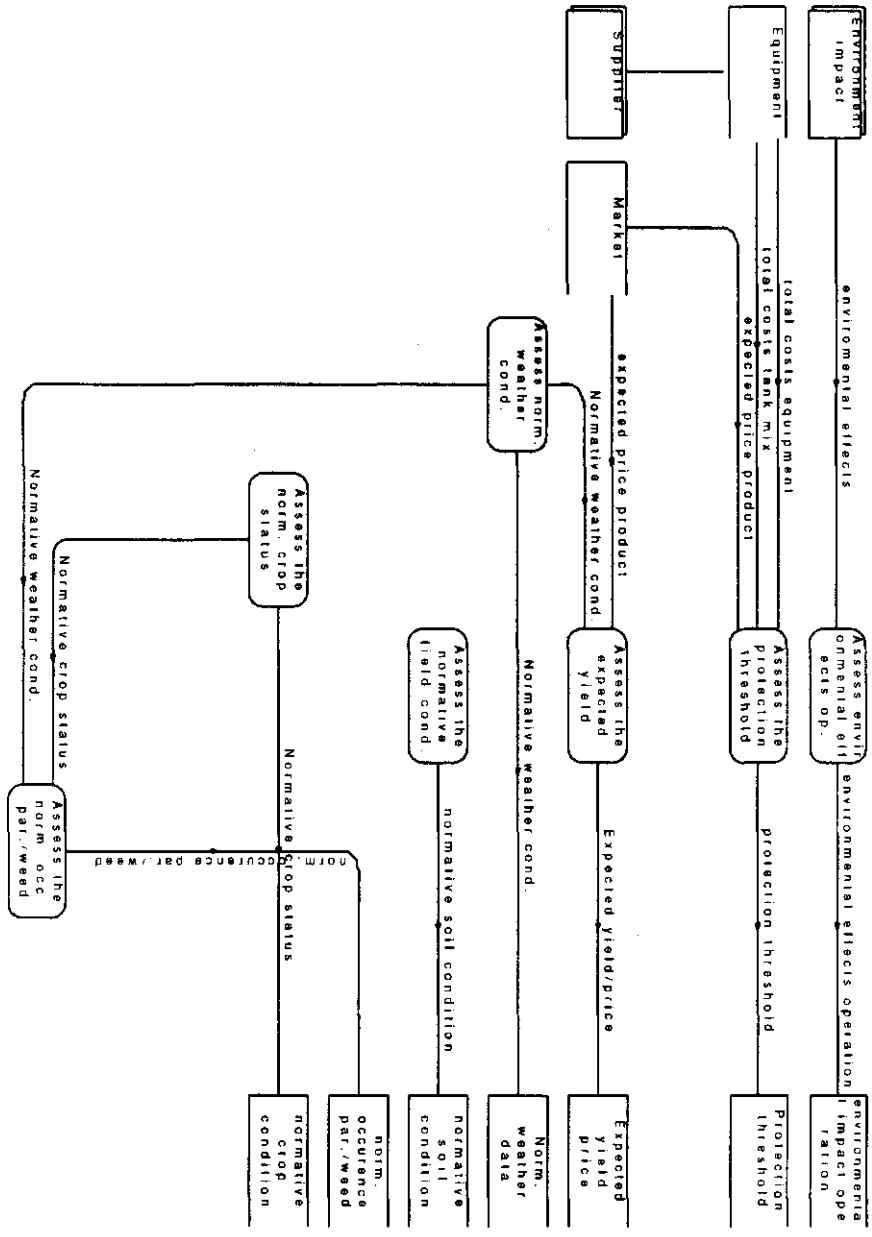


Figure 16. Crud matrix: interaction between data and process model

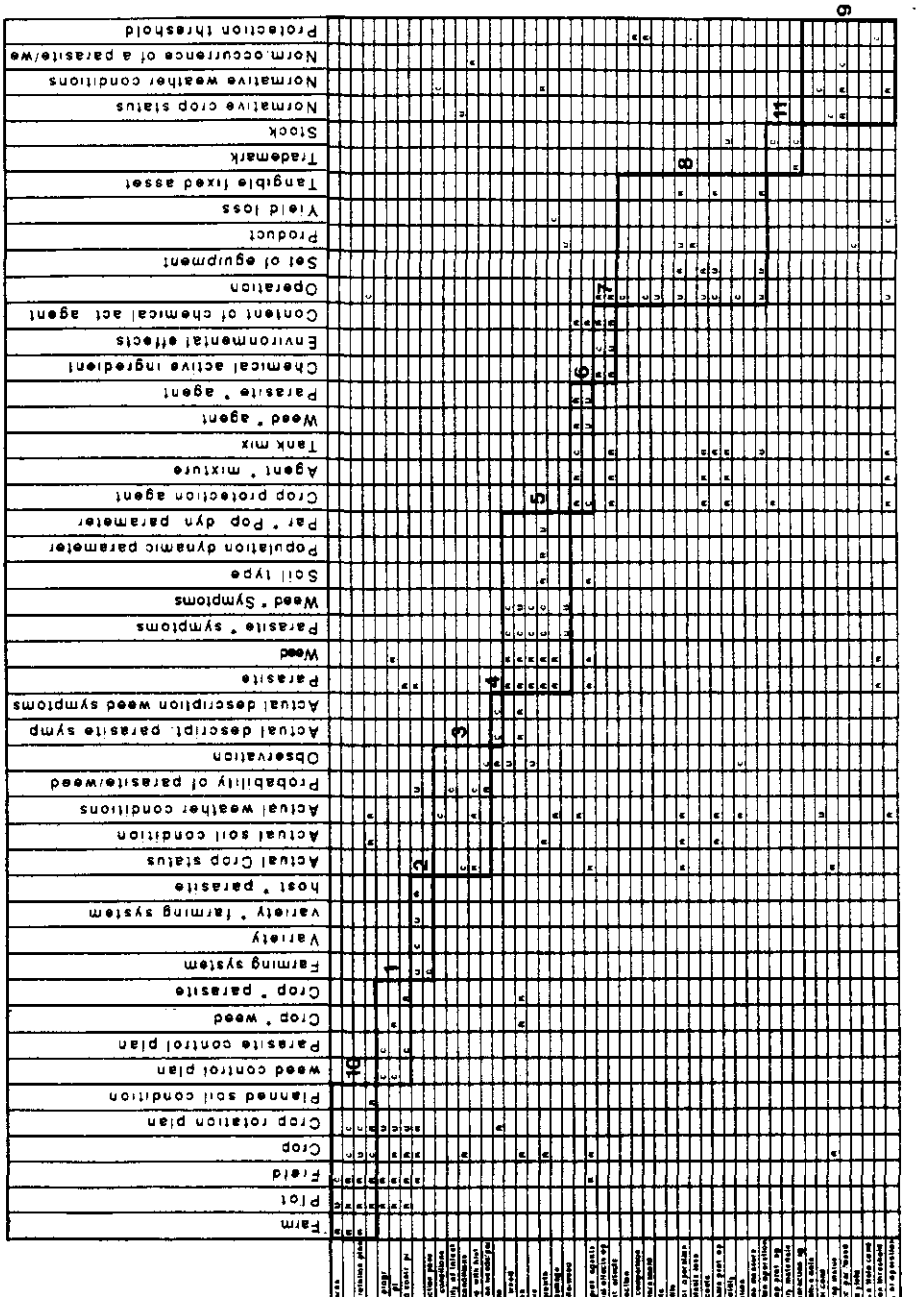


Figure 17A. The entity relationship diagram for the subject areas: **10. Assign a crop to a field, 1. Formulate crop. prot. plan** and **2. Determine the variety**

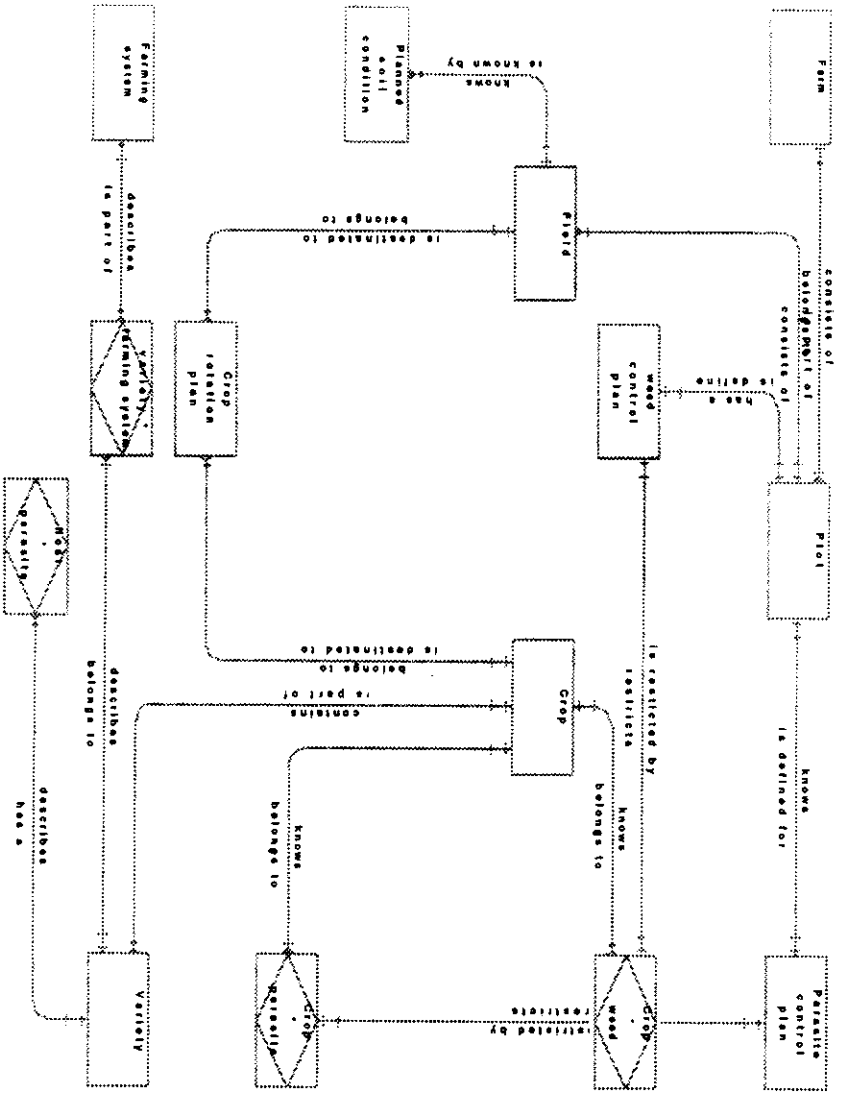


Figure 17B. The entity relationship diagram for the subject areas: **3. Determine the actual environment, 4. Description of symptoms, 5. Estimate damage parasite/weed** and **6. Alternatives tank mix**

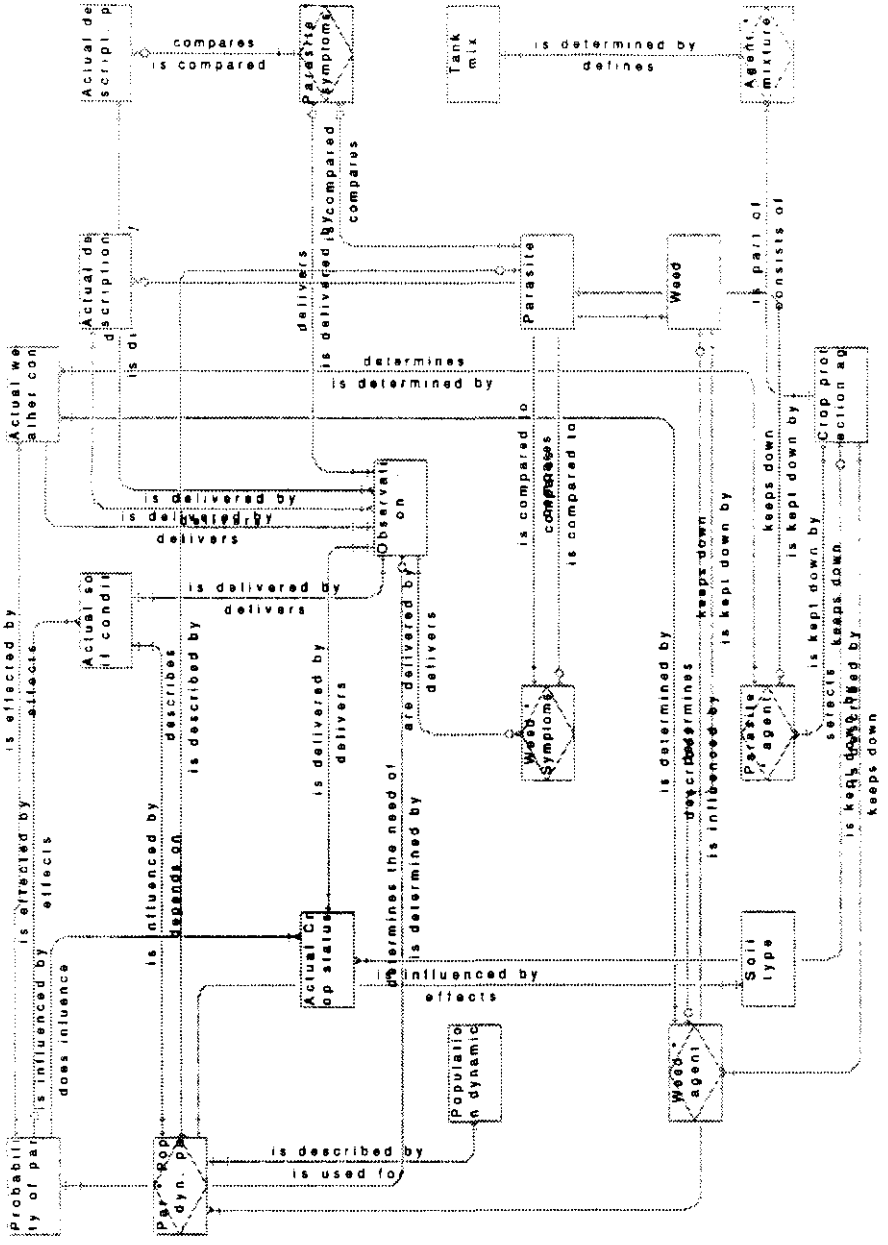
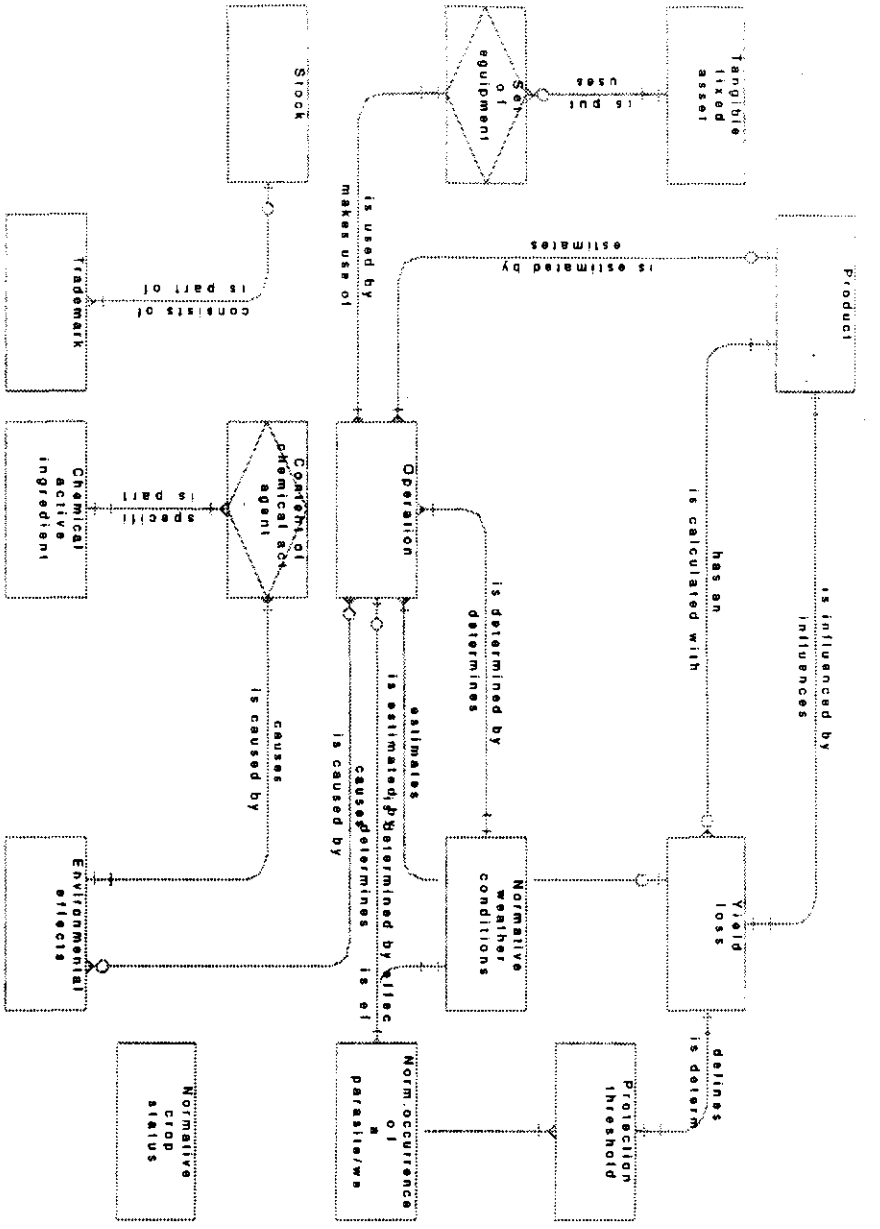


Figure 17C. The entity relationship diagram for the subject areas: **7. Environmental effects prot. op, 8. Implement a prot. operation, 9. Determine normative data, 10. Assign a crop to a field** and **11. Stock control**



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Appendix A Methodology and technique

A1 Introduction

A good information system is characterized by interrelated subsystems. On the basis of this, programs can be developed in which the subprograms are coordinated with each other and the data interchangeable. Furthermore, new functional specifications must be easy to integrate into the system. A good information system should provide an up-to-date picture of the part of the current situation relevant to the business or organization. It is therefore very important to have a structured approach and method.

The method which is used for the development of information systems in arable farming and market gardening is based on Information Engineering.
Information Engineering is supported by James Martin Strategies and represents a cohesive aggregate of methods, techniques and tools which can be used to create information systems for a business or organization. The separate parts of the method are constantly attuned to the information needs and priorities of the business or organization.

An important basic principle of this method is that the development should take place in accordance with a 'top-down' approach. This means that products to be supplied become on the one hand increasingly detailed and on the other hand cover an increasingly narrow area.

The method used is briefly described below using examples from the detailed model of the cluster 'Crop Protection'.

A2 Method

In the information model, the activities and decisions which take place on an arable farm are illustrated by means of charts. All data playing a role in these activities are also incorporated. The activities are to be found in the **process model**; the data relating to these activities and which have to be saved are described in the **data model**.
The relationship between the different functions, processes and external organizations is graphically illustrated in a **data flow diagram**.

Appendix F includes a summary of the concepts and symbols used.

A2.1 The process model

All the activities of a farm are described in a **process model**. The relationship between the processes is shown by means of information flows, both within the farm and with external organizations.

Functions and processes

In the **information model**, functions and processes are separated. A **function** is a main activity of a business, with a more or less continuous nature.

A **process** is a part of a function, the implementation of which is demonstrable and which has a clear starting point and end. When making the detailed information model, processes are further elaborated into elementary processes. A process is usually indicated by a verb. An elementary process is the smallest possible activity which is carried out as a whole and which is relevant to the management of the farm from the point of view of the supply of information. This means that new information is generated by an elementary process, or existing information is changed.

Within the function **Management auxiliary materials** there is for example a separation between the processes **Purchase of auxiliary material** and **Stock control of auxiliary material**. Grouping the activities within the farm consecutively

in functions and processes gives rise to the process decomposition diagram (see figures 1,3 and 4).

A process requires a **process description**. This states what the process consists of, what information is necessary for the process to run smoothly and what information is subsequently made available as a result of the process. Information necessary for carrying out a process are indicated within destination flows. Information supplied by a process are indicated with source flows. A link is made here between process and data models because the information flows between processes consist of entity types and attributes. Figure 18 shows the detailing of the process description for the process **Describe the symptoms**.

Process: **Describe the symptoms**

Definition

Describe the characteristics of a spot, weed or insect detected in the cultivated crop.

Is source of:
- Data Flow: symptoms
  Entity type: Actual description weed symptoms
    Attributes: Name
    Description of symptom
  Entity type: Actual descript. parasite symp.
    Attributes: Name
    Description of symptom

Is Destination of:
- Data Flow: planned observation
  Entity type: Observation
    Attributes: Status (plan., impl., carr.out)
    planned date
- Data Flow: crop destination
  Entity type: Crop rotation plan
  Entity type: Crop
  Entity type: Field
  Relations: Field is destinated to Crop rotation plan
  Crop belongs to Crop rotation plan

Figure 18. Example of a Process description: **Describe the symptoms**, a process of the Function **5. Cropping**

A2.2 The data model

A data model describes the activities in a company concerning which information has to be recorded. This information is generated by the processes of the process model or comes from an external agent. A data model concerns information (entity types and attributes) which are kept for a longer or shorter period of time. It may on the

one hand concern basic information (including actual weather and crop information) which either originates from outside the farm or is 'measured' on the farm. On the other hand, it may concern information which is generated by a process and is then required for the implementation of other processes.
The purpose of making a data model is to define and classify data and indicate their inter-relationships.

The following concepts play a role here: entity type, entities, attributes and relationships.

Entity types
An entity type is a group of objects (entities) relevant to a business and concerning which information is needed. These entities may concern physical objects (machine) or events (supply) or theoretical concepts (growth stage). An entity type is described by data which provide usable information concerning that object. These data are called attributes. Entity types are defined from the point of view of information systems. An entity is an occurrence of an entity type. For example: an entity of the entity type operation is spraying a crop protection agent using the row sprayer.

Entity type: **Field**

Definition: A continuous piece of land, considered to be homogeneous by the farmer with regard to soil type, production capacity, crop rotation plan, history and other requirements of the farmer. Different crops are usually grown consecutively in a field.

Relationship:

is part of	Plot
is destined to	Crop rotation plan
is described by	Soil type
knows	Actual soil condition
knows	Planned soil condition
restricts	Crop protection agent

Attributes:

- Field code
- Description
- location of field
- shape of field
- length
- Width
- Water catchment area (Y/N)
- location
- area

Figure 19. Example of a Entity type description

The general 'arable farming' information model includes the entity type **Field** (see figure 19). This entity type concerns all possible fields which fall under this common description. An entity of the entity type field is for example a field referred to as 'the back field'. This entity has for example code 21 and as a further description: 'the back field'.

It is possible for an entity type to be subdivided into not only common characteristics of the entity main type but also extra information characteristics. The entity main type

operation can be subdivided into the entity subtypes **observation**.

Attributes

Attributes are the properties of an entity type. One of these unique properties (or a combination (concatenation) of several) forms a unique identification of an entity type. This is also known as the key and is indicated in the data model by id. For example: (the entity type **field** is uniquely identified by the attribute **field code**.)

Relationships

A relationship shows a link between entity types and is of importance from the point of view of the supply of information. All entity types and the relevant relationships are illustrated in the entity relationship diagram.

There are different types of relationships:

a) *Cardinality;*

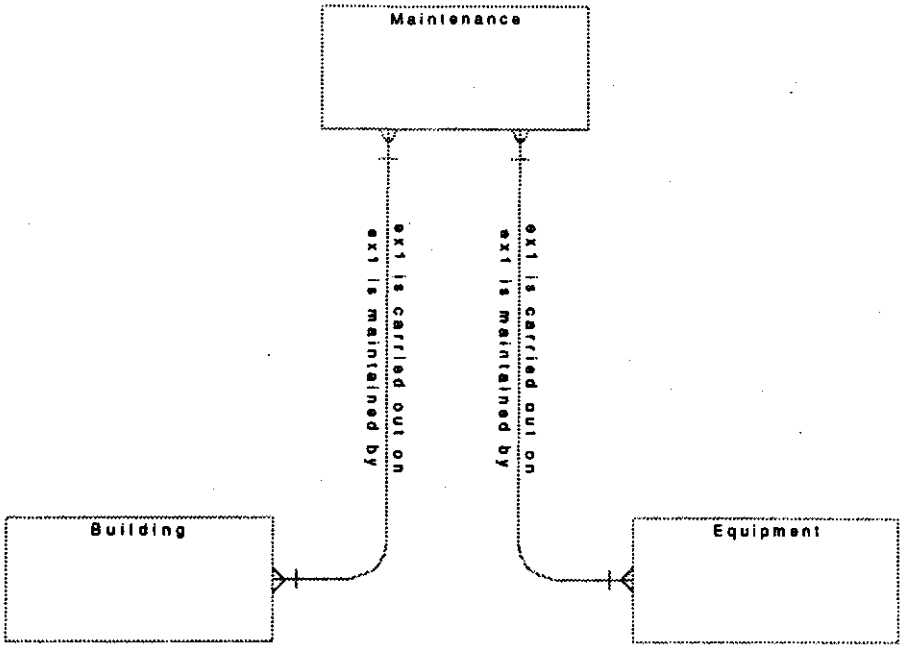
The chart below shows on the one hand that one tractor, once bought, requires a quantity of petrol one or more times. This is indicated by a 'crow's-foot' alongside an entity type which occurs more than once. On the other hand, a quantity of petrol always goes to one tractor; this is indicated by the small lines at right angles to the relationship.

Cardinality shows whether an entity of entity type A has a link with one or more entities of entity type B within one specific relationship. There are three possible cardinalities:

* one-to-one (1:1) : man married with wife;
* one-or-more(1:n) : farm has one or more employees;
* many-to-many (m:n) : teacher knows subject;

b) *Exclusivity;*

If two (or more) relationships are exclusive, this means that an entity of the entity type can only occur in one of the relationships at the same time.



The above chart shows that maintenance is carried out on a building or equipment. Maintenance cannot contain machine and building data simultaneously. A relationship of this nature is indicated in the model by putting the abbreviation 'ex' in front of the name of the relationship.

c) *Optionality;*

The optionality of a relationship indicates that a relationship can occur, but does not necessarily have to be present.

The above chart shows on the one hand that a piece of equipment, once bought, is repaired zero, one or more times. In reverse, a repair in this chart always relates to one piece of equipment. This is graphically illustrated by a 'O' on the side of the entity type which may or may not occur (is optional).

It is also possible for both entity types to participate optionally in the relationship. This is indicated by placing an 'O' on both sides in the relationship.

Keys

Keys provide unique identification of one entity of an entity type. An entity type has one or more keys. For example: in a warehouse all articles will be furnished with an article code with a number of characteristics of the relevant article. The article code forms the key. In this way, one entity distinguishes itself another entity. The value of the keys for each entity should always be known. In the information model keys are indicated with the aid of key attributes.

Interpretation of the data model chart

In an entity relationship diagram relationships can be read in two directions. For this reason, for the sake of clarity words have been placed by the relationships. These should be read clockwise together with the names of the entity types.

The relationship '**service** is carried out for **equipment**' indicates that a service concerns a **equipment**. Conversely **equipment** can have a relation with **service** (the relationship '**equipment** undergoes a **service**').

A3 Interaction between process and data models

The process and data models must be fully attuned to each other. Entity types should be used with each defined process. These data may be generated by other processes. The data may also be supplied by external information sources. Within the model each defined process must create at least one entity type and use at least one entity type. If this is not the case, the model would be incorrect or incomplete. Information would then be created which is apparently not used in decisions or information is required which is never created. The relationship between processes and data is illustrated in a matrix showing which entity types are created or used per process, the so-called CRUD matrix (see figure 16).

The information flows for the underlying processes are given per function in **data flow diagrams**. The connecting lines between the processes show the input or output of a process and concern information. The double lined boxes indicate external agents which either provide or use information. "This model does not describe how these organizations produce information or what they do with it."

Interpretation of the data model chart

A dataflow diagram displays the processes, data stores, external agents, junctions and dataflows of one level of decomposition of a process. The process described by a data flow diagram is the topic of the diagram. The processes displayed in the diagram are the children of the topic process (see figure 6).

An external agent is an object which receives or sends data but does not form part of the specific business area model. External agents for the crop protection model are, for example, suppliers of crop protection agents or other relevant sources of information such as the information service.

A4 The phasing used and the products which should be produced per phase

In the method used by the agricultural sector in The Netherlands, the development stage of information systems is divided into the following phases:

1. formulation of a general information model;
2. formulation of a detailed information model;
3. formulation of system specifications;
4. determination of research requirements;
5. formulation of a technical design;
6. construction of the system;
7. implementation and maintenance;

ad 1) *formulation of a general information model*

The following 'products' are relevant:

- function and functional decomposition of the farm;
- data model of the company (entity types and relationships);
- matrix of processes versus entity types and business areas of processes and data.

The level of detail of the general information model is such that decisions can be taken about definition in information areas and about priorities for further analysis and development.

ad 2) *formulation of a detailed information model*

The general model is given more detail. In order to do this, the general model is split up into clusters: relatively homogeneous sections within which many relationships exist and with few relationships with other sections. This detailing provides better insight into the information which is important for company decisions.

The following products are generated during this phase:

- functional decomposition to elementary processes;
- detailed data model (entity types, relationships and attributes and their

descriptions);

- data flow diagrams.

ad 3)*formulation of system specifications*

The following products are relevant for this phase:

- logical database design;
- description of procedures of the information system;
- layout of screens, sequence of screens;
- layout of reports;
- data flow diagrams;
- access diagrams.

ad 4) Phase 4 shows in which sections of a company there is still insufficient knowledge available to be able to develop information models and systems.

ad 5) In phase 5 the technical design of the system is formulated.

Appendix B The use of the Information Engineering Workbench

Use has been made of the Information Engineering Workbench (IEW) for the development of the model for Crop protection.
Reasons which justify the use of a case tool are:

- improvement of the quality of the system which has been developed due to the fact that all kinds of consistency controls are supported by the workbench;
- the use of the reference 'the detailed information model for arable farming' (IMOT) and the re-use of parts of related models is simplified;
- an increase in productivity due to the back-up provided with diagrams and automatic production of reports.

The Information Engineering Workbench is built up of modules. Each module supports a development stage within the IE methodology.
For the development of the crop protection information model, use has been made of the Planning Workstation with which a process composition, a data model and subdivision of the model into business areas can be achieved. The relationships between entity types and processes can be illustrated in a CRUD matrix (figure 16). On the basis of these association matrices it is possible, with the help of the affinity analysis option in IEW, to divide the model into related sections, the so-called business areas.
With the aid of the second module (Analysis Workstation), the identified business areas are analysed with the help of process decomposition, the entity type relation diagram and data flow diagrams. The data flow diagrams are a good way of safeguarding the consistency of the model. When a process within a data flow diagram is detailed in a data flow diagram at a lower level, IEW checks whether the source and destination flows of a process go to an external agent or another process.

In addition to the Planning and Analysis Workstation which supports the information analysis, IEW comprises the Design and Construction Workstations which support

technical implementation and the construction of the system respectively.
Within the Design and Construction Workstations, the information model can be converted into a physical design.

Appendix C Description of business areas

Business area: **1. Formulate crop prot. plan**

Definition: Formulate a parasite and weed control plan taking into account several cultivation years.

	Crop * parasite	Crop * weed	Parasite control plan	weed control plan
Plan the crop prot. progr.	C	C		
Form. a weed contr. pl.	C		R	
Form. a paras./weed contr. pl.		C		R

Figure 20: Crud matrix for the subject area: **1. Formulate crop prot. plan**

Business area: **2. Determine the variety**

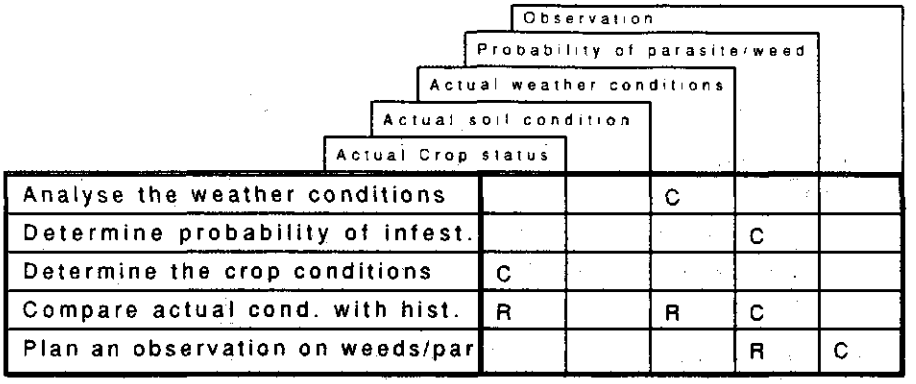
Definition: Determine which variety will be cropped, taking into account the expected parasites and the applied farming system.

	host * parasite	variety * farming system	Variety	Farming system
Choose a variety	U	C	U	R
Determine the production poss.	C			

Figure 21: Crud matrix for the subject area: **2. Determine the variety**

Business area: **3.Determine the actual environm.**

Definition: Determine the environmental conditions important for crop, parasite and weed development.

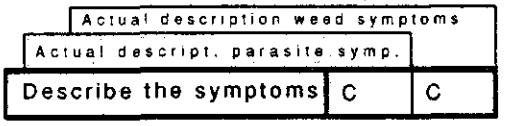


	Actual Crop status	Actual soil condition	Actual weather conditions	Probability of parasite/weed	Observation
Analyse the weather conditions			C		
Determine probability of infest.				C	
Determine the crop conditions	C				
Compare actual cond. with hist.	R		R	C	
Plan an observation on weeds/par				R	C

Figure 22: Crud matrix for the subject area: **3.Determine the actual environm.**

Business area: 4. Description of symptoms

Definition: Description of symptoms caused by parasites or weeds. These symptoms are obtained by an observation.

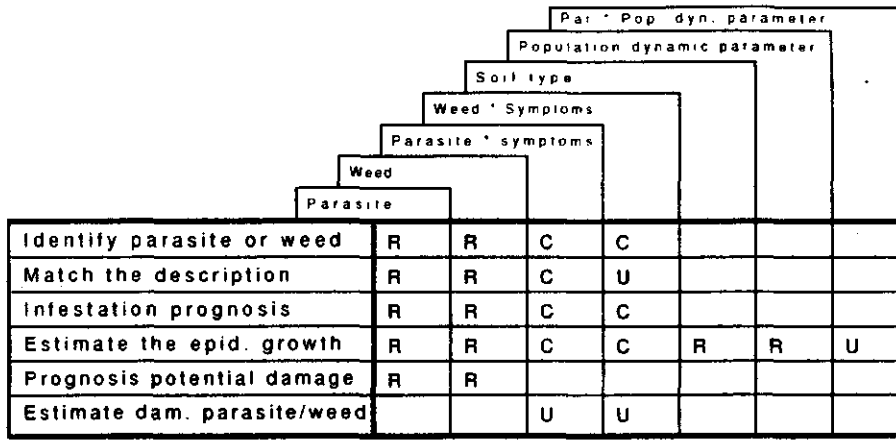


	Actual descript. parasite symp.	Actual description weed symptoms
Describe the symptoms	C	C

Figure 23: Crud matrix for the subject area: **4. Description of symptoms**

Business area: 5. Estimate damage parasite/weed

Definition: Estimate the damage caused by an identified parasite or weed.



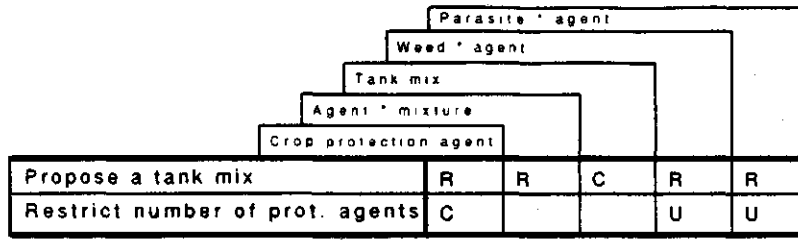
Identify parasite or weed	R	R	C	C			
Match the description	R	R	C	U			
Infestation prognosis	R	R	C	C			
Estimate the epid. growth	R	R	C	C	R	R	U
Prognosis potential damage	R	R					
Estimate dam. parasite/weed			U	U			

Figure 24: Crud matrix for the subject area: **5. Estimate damage parasite/weed**

Business area: **6. Alternatives tank mix**

Definition: Propose different alternatives for a tank mix taking into account restrictions for e.g.:

- soil condition
- water catchment area:
- efficacy of operations including the efficacy of tank mixes



Propose a tank mix	R	R	C	R	R
Restrict number of prot. agents	C			U	U

Figure 25: Crud matrix for the subject area: **6. Alternatives tank mix**

Business area: **7.Environmental effects prot.op.**

Definition: The environmental effects as result of carrying out a protection operation.

	Chemical active ingredient	Environmental effects	Content of chemical act. agent
Assess environmental effects op.	R	C	R
Compare environment. effects	R	U	R

Figure 26: Crud matrix for the subject area: **7.Environmental effects prot.op.**

Business area: **8. Implement a prot. operation**

Definition: Decide which, prepare and carry out a protection operation.

	Operation	Set of equipment	Product	Yield loss		Tangible fixed asset
Decide on crop protection	C					
Choose a method for comparison						
Use the protection threshold	C					
Analyse cost/benefits	U					
Compare costs/benefits						
Estimate damage prot. operation	U	R	U			R
Estimate the preventable loss			R			
Estimate the total costs	U	R				
Determine the suitable prot. op.	C	U				R
Examine the availability						
Plan an prot. operation	C					
Prepare the protection measure						
Carry out a protection operation	U	U				R

Figure 27: Crud matrix for the subject area: **8. Implement a prot. operation**

Business area: **9. Determine normative data**

Definition: Determine the farm properties taking into account average date over

several years, regions and farms.

	Normative crop status	Normative weather conditions	Norm.occurrence of a parasite/we	Protection threshold
Assess norm. weather cond.		C		
Assess the norm. crop status	C			
Assess the norm. occ. par./weed	R	R	C	
Assess the expected yield				
Assess the normative field cond.				
Assess the protection threshold				C
Assess the efficacy of operation		R		

Figure 28: Crud matrix for the subject area: **9. Determine normative data**

Business area: **10. Assign a crop to a field**

Definition: Divide the farm into one or more plots and fields., and destine a crop to a certain field.

	Farm	Plot	Field	Crop	Crop rotation plan	Planned soil condition
Divide cultivation area	R	U	C			
Crop destination	R	R	R	C	C	
Determine the crop rotation plan	R	R	R	U	C	
Sow or plant		R	R	C	R	R

Figure 29: Crud matrix for the subject area: **10. Assign a crop to a field**

Business area: **11. Stock control**

Definition: The purchase and stock control of auxiliary materials.

	Stock	
	Trademark	
Stock control of crop prot. ag.		C
Purchase of auxiliary materials		
Purchase of crop protection ag.	R	C

Figure 30: Crud matrix for the subject area: **11. Stock control**

Appendix D Description of the process model

Process: Analyse cost/benefits

Definition: Calculate for each crop protection operation how much of the total loss can be prevented and the total costs related to the operation.

Is source of:

- Data Flow: most efficient operation

Entity type: Operation

Attributes:

name

status (planned,prep, carr. out)

expected total costs

expected total benefits

Is Destination of:

- Data Flow: estimated damage parasite/weed

Entity type: Product

Attributes:

description of product

status (planned,harvested,store)

Yield capacity

Expected yield loss

- Data Flow: estimated damage operation
- Data Flow: Actual weather conditions

Entity type: Actual weather conditions

Attributes:

date of measurement

time of measurement

temperature

vaporization

relative humidity

global radiation

dew point

figure for rainfall

Period of registration

- Data Flow: efficacy tank mix

Entity type: Crop protection agent

Attributes:

Name of crop protection agent

efficacy

Content of chemical act. agent

Relations: Crop protection agent contains Content of chemical act. agent

- Data Flow: efficacy of an operation
- Data Flow: alternatives for a tank mix

Entity type: Tank mix

Attributes:

Name of tank mix

Status (prop., prep., sprayed)

- Data Flow: Crop conditions

Entity type: Actual Crop status

Attributes:

development stage

Entity type: Crop

Attributes:

Crop code

Name

Relations: Actual Crop status describes the status of a Crop

Process: **Analyse the weather conditions**

Definition: Determine the weather conditions at the actual moment.

Is source of:

- Data Flow: Actual weather conditions

Entity type: Actual weather conditions

Attributes:

date of measurement

time of measurement

temperature

vaporization

relative humidity

global radiation

dew point

figure for rainfall

Period of registration

Process: **Assess environmental effects op.**

Definition: Assess the environmental effects of an operation.

Is source of:

- Data Flow: environmental effects op.

Entity type: Environmental effects

Attributes:

Risk for persistence

Risk for eluviation

Toxicity to warm-blooded org.

Toxicity to non-target org.

Entity type: Operation

Attributes:

name

type of operation

Is Destination of

- Data Flow: enviromental effects

Entity type: Chemical active ingredient

Attributes:

Chemical formula

Solubility in water

Chemical category

Mode of action

Toxicity

Entity type: Content of chemical act. agent

Attributes:

content

Relations: Environmental effects is caused by Operation

dimension

Relations: Environmental effects assessment is caused by Content of chemical act. agent

Chemical active ingredient is part of Content of chemical act. agent

Process: **Assess norm. weather cond.**

Definition

Assess the normative weather conditions which can be expected during a specific season.

Is source of:

- Data Flow: Normative weather cond.

Process: **Assess the efficacy of operation**

Definition

Assess the efficacy of an operation concerning the control of a pest or disease.

Is source of:

- Data Flow: efficacy of an operation

Entity type: Operation

Attributes:

name

status (planned,prep, carr. out)

Is Destination of:

- Data Flow: actual soil condition

Entity type: Actual soil condition

- Data Flow: Actual weather conditions

Entity type: Actual weather conditions

Attributes:

date of measurement

time of measurement

temperature

vaporization

relative humidity

global radiation

dew point

figure for rainfall

Period of registration

- Data Flow: Crop conditions

Entity type: Actual Crop status

Attributes:

development stage

Entity type: Crop

Attributes:

Crop code

Name

Relations: Actual Crop status describes the status of a Crop

- Data Flow: efficacy tank mix

Entity type: Crop protection agent

Attributes:

Name of crop protection agent

efficacy

Content of chemical act. agent

Relations: Crop protection agent contains Content of chemical act. agent

- Data Flow: alternatives for a tank mix

Entity type: Tank mix

Attributes:

Name of tank mix

Status (prop., prep., sprayed)

Process: **Assess the expected yield**

Definition: Assess the expected yield and price taking into account the yield of previous years.

Is source of:

- Data Flow: Expected yield/price

Entity type: Product

Attributes:

status (planned,harvested,store)

expected price

Yield capacity

Is Destination of:

- Data Flow: expected price product

Entity type: Product

Attributes:

description of product

expected price

- Data Flow: Normative weather cond.

Process: **Assess the norm. crop status**

Definition

Assess the crop status which can be expected at a certain moment taking into account the development of the crop previous years.

Is source of:

- Data Flow: Normative crop status

Entity type: Normative crop status

Attributes:

Expected field emergence

Expected field damage

Development stage

- Data Flow: Normative crop status

Entity type: Normative crop status

Attributes:

Expected field emergence

Expected field damage

Development stage

Process: **Assess the norm. occ. par./weed**

Definition Assess the chance of occurrence of a parasite or weed under normative conditions.

Is source of:

- Data Flow: norm. occurence par./weed

Entity type: Norm.occurrence of a parasite/we

Attributes:

expected occurrence

Is Destination of:

- Data Flow: Normative crop status

Entity type: Normative crop status

Attributes:

Expected field emergence

Expected field damage

Development stage

- Data Flow: Normative weather cond.

Process: **Assess the normative field cond.**

Definition: Assess the field conditions specific to the farm.

Is source of:

- Data Flow: normative soil condition

Process: **Assess the protection threshold**

Definition: If the normative threshold is exceeded an operation for crop protection should be carried out taking into account costs and benefits.

Is source of:

- Data Flow: protection threshold

Entity type: Protection threshold

Attributes:

limit weed density

unit

Is Destination of:

- Data Flow: expected price product

Entity type: Product

Attributes:

description of product

expected price

- Data Flow: total costs tank mix

Entity type: Tank mix

Attributes:

active ingredient

Name of tank mix

Status (prop., prep., sprayed)

Agent * mixture

Entity type: Crop protection agent

Attributes:

Name of crop protection agent

average price (guild./kg)

Content of chemical act. agent

Relations: Agent * mixture defines Tank mix

Crop protection agent is part of Agent * mixture

Crop protection agent contains Content of chemical act. agent

- Data Flow: total costs equipment

Entity type: Operation

Entity type: Set of equipment

Entity type: Tangible fixed asset

Relations: Set of equipment is used by Operation

Tangible fixed asset is put on Set of equipment

Process: Carry out a protection operation

Definition: Carry out a protection operation according to the proposed procedure.

Is source of:

- Data Flow: evaluate an operation

Entity type: Operation

Attributes:

name

type of operation

date of starting

date of ending

time of beginning

time of ending

main task period

speed of working

price or required labour

total price of required equipm.

usage of tank mix

Entity type: Tank mix

Attributes:

Is Destination of:

- Data Flow: prepared operation

Entity type: Operation

Attributes:

name

status (planned,prep, carr. out)

active ingredient
Name of tank mix
Status (prop., prep., sprayed)

Entity type: Crop protection agent

Attributes:

Name of crop protection agent
average price (guild./kg)
Agent * mixture
Content of chemical act. agent

Relations:

Tank mix is used by Operation
Agent * mixture defines Tank mix
Crop protection agent is part of Agent * mixture
Crop protection agent contains Content of chemical act. agent

Process: **Choose a method for comparison**

Definition: Choose a method to compare different protection operations with respect to their efficiency, using either a protection threshold or a cost/benefit analysis.

Is source of:

- Data Flow: most efficient operation

Entity type: Operation

Attributes:

name
status (planned,prep, carr. out)
expected total costs
expected total benefits

Is Destination of:

- Data Flow: estimated damage operation

- Data Flow: estimated damage parasite/weed

Entity type: Product

Attributes:

description of product
status (planned,harvested,store)
Yield capacity
Expected yield loss

- Data Flow: infestation pressure

Entity type: Weed * Symptoms

Attributes:

Figure for infestation pressure
Status (expect,estimat.,count.)

Entity type: Parasite * symptoms

Attributes:

Figure for infestation pressure
Status (expect.,detect.,count.)

- Data Flow: protection threshold

Entity type: Protection threshold

Attributes:

limit weed density
unit

- Data Flow: Expected yield/price

Entity type: Product

Attributes:

status (planned,harvested,store)

expected price

Yield capacity

Process: **Choose a prot. operation**

Definition: Choose the optimal protection operation from all suitable protection operations. Important considerations are:

- the loss of yield which could be prevented by the application of a crop protection operation;
- the costs of the application. (e.g. cost of pesticides, wheelings, labour and machine costs).

Process: **Compare actual cond. with hist.**

Definition: Compare the crop conditions (e.g. stage) and the weather conditions with historical weather and cropping data in context with associated date of the appearance of certain parasites or weeds.

Is source of:

- Data Flow: necessity of an observation

Is Destination of:

- Data Flow: norm. occurence par./weed

  Entity type: Norm.occurrence of a parasite/we

  Attributes:

  expected occurrence

- Data Flow: Crop conditions

  Entity type: Actual Crop status

  Attributes:

  development stage

  Entity type: Crop

  Attributes:

  Crop code

  Name

  Relations: Actual Crop status describes the status of a Crop

- Data Flow: Actual weather conditions

  Entity type: Actual weather conditions

  Attributes:

  date of measurement

  time of measurement

temperature
vaporization
relative humidity
global radiation
dew point
figure for rainfall
Period of registration

Process: **Compare costs/benefits**

Definition: Compare the costs and benefits for each operation

Is source of:
- Data Flow: most efficient operation
  Entity type: Operation
  Attributes:
  name
  status (planned,prep, carr. out)
  expected total costs
  expected total benefits

Is Destination of:
- Data Flow: figure for total costs
  Entity type: Operation
  Attributes:
  name
  expected total costs
- Data Flow: total benefits of an operation
  Entity type: Product
  Attributes:
  description of product
  status (planned,harvested,store)
  expected price
  preventable yield loss
- Data Flow: Expected yield/price
  Entity type: Product
  Attributes:
  status (planned,harvested,store)
  expected price
  Yield capacity

Process: **Compare environment. effects**

Definition: Take into account the environmental effects of different operations for choosing the most optimal operation.

Is source of:
- Data Flow: selected operation
  Entity type: Operation
  Attributes:
  name
  status (planned,prep, carr. out)

Is Destination of:
- Data Flow: most efficient operation
  Entity type: Operation
  Attributes:
  name
  status (planned,prep, carr. out)
  expected total costs

expected total benefits

- Data Flow: environmental effects op.

Entity type: Environmental effects assessment

Attributes:

Risk for persistence

Risk for eluviation

Toxicity to warm-blooded org.

Toxicity to non-target org.

Entity type: Operation

Attributes:

name

type of operation

Relations: Environmental effects assessment is caused by Operation

Process: **Compare results - expectations**

Definition: Compare the actual results of plant protection measures with their expected results based on normative data. If there is inconsistency the normative data should be adjusted.

Process: **Crop destination**

Definition: Assign a crop to a certain field.

Process: **Cultivate crop**

Definition: All operational cultivation operations.

Is source of:

- Data Flow: selected operation

Entity type: Operation

Attributes:

name

status (planned,prep, carr. out)

- Data Flow: selected operation

Is Destination of:

- Data Flow: protection threshold

Entity type: Protection threshold

Attributes:

limit weed density

unit

- Data Flow: Expected yield/price

Entity type: Product

Attributes:

status (planned,harvested,store)

expected price

Yield capacity

- Data Flow: identified parasite/weed
  Entity type: Weed * Symptoms
  Attributes:
  Status (expect,estimat.,count.)
  Entity type: Parasite * symptoms
  Attributes:
  Status (expect.,detect.,count.)
  Entity type: Weed
  Attributes:
  Name
  Development stage
  Entity type: Parasite
  Attributes:
  Name
  Development stage
  Relations: Weed is compared to Weed * Symptoms
  Parasite is compared to Parasite * symptoms
- Data Flow: infestation prognosis
- Data Flow: estimated damage parasite/weed
  Entity type: Product
  Attributes:
  description of product
  status (planned,harvested,store)
  Yield capacity
  Expected yield loss
- Data Flow: soil & field restrictments
  Entity type: Field
  Attributes:
  Field code
  Description
  Water catchment area (Y/N)
  Entity type: Soil type
  Attributes:
  organic matter content
  classific.size of soil particles
  Relations: Field is described by Soil type
- Data Flow: stock
  Entity type: Stock
  Attributes:
  time of inspection of stock
  quantity in stock
  Entity type: Crop protection agent
  Attributes:
  Name of crop protection agent
  Content of chemical act. agent
  Relations: Crop protection agent is available Stock
  Crop protection agent contains Content of chemical act. agent
- Data Flow: Crop conditions

Entity type: Actual Crop status

Attributes:

development stage

Entity type: Crop

Attributes:

Crop code

Name

Relations: Actual Crop status describes the status of a Crop

- Data Flow: equipment

Entity type: Set of equipment

Entity type: Tangible fixed asset

Attributes:

code

type code

width of tyres

width of spraying arm

Relations: Tangible fixed asset is put on Set of equipment

- Data Flow: environmental effects op.

Entity type: Environmental effects assessment

Attributes:

Risk for persistence

Risk for eluviation

Toxicity to warm-blooded org.

Toxicity to non-target org.

Entity type: Operation

Attributes:

name

type of operation

Relations: Environmental effects assessment is caused by Operation

- Data Flow: Actual weather conditions

Entity type: Actual weather conditions

Attributes:

date of measurement

time of measurement

temperature

vaporization

relative humidity

global radiation

dew point

figure for rainfall

Period of registration

- Data Flow: actual soil conditions

Entity type: Soil type

Entity type: Field

Attributes:

Field code

	location
Entity type:	Crop rotation plan
Attributes:	
	Status (planned, implemented)
Entity type:	Actual soil condition
Attributes:	
	Stock of freely avail. nitrogen
Relations:	Field is destined to Crop rotation plan
	Field is described by Soil type
	Actual soil condition is known by Field

Process: **Describe the symptoms**

Definition: Describe the characteristics of the host plant, weed or insect detected in the cultivated crop.

Is source of:

- Data Flow: symptoms

Entity type:	Actual description weed symptoms
Attributes:	
	Name
	Description of symptom
Entity type:	Actual descript. parasite symp.
Attributes:	
	Name
	Description of symptom

Is Destination of:

- Data Flow: planned observation

Entity type:	Observation
Attributes:	
	Status (plan., impl., carr.out)
	planned date

- Data Flow: crop destination

Entity type:	Crop rotation plan
Entity type:	Crop
Entity type:	Field
Relations:	Field is destined to Crop rotation plan
	Crop belongs to Crop rotation plan

Process: **Det. allowed prot. agents**

Definition: Determine which crop protection agents are allowed and can be applied under the given circumstances.

Process: **Determine the normative data**

Definition Determine all feasible (normative) conditions (e.g. development stage crop, development stage disease/pest, diseases which are able to attack the crop) which can appear on the farm.

Process: **Determine operation crit.**

Definition: Determine all criteria which are relevant for the implementation of an operation. The criteria are also based on historical data.

Process: **Determine probability of infest.**

Definition: Determine the probability of infestation for a certain parasite or weed. Based on the outcome of this process the farmer will plan actual observations of specific parasites or weeds.

Is source of:

- Data Flow: Actual weather conditions
  - *Entity type:* Actual weather conditions
    - *Attributes:*
      - date of measurement
      - time of measurement
      - temperature
      - vaporization
      - relative humidity
      - global radiation
      - dew point
      - figure for rainfall
      - Period of registration
- Data Flow: Crop conditions
  - *Entity type:* Actual Crop status
    - *Attributes:*
      - development stage
  - *Entity type:* Crop
    - *Attributes:*
      - Crop code
      - Name
  - *Relations:* Actual Crop status describes the status of a Crop
- Data Flow: planned observation
  - *Entity type:* Observation
    - *Attributes:*
      - Status (plan., impl., carr.out)
      - planned date

Is Destination of:

- Data Flow: Normative crop status
  - *Entity type:* Normative crop status
    - *Attributes:*
      - Expected field emergence
      - Expected field damage
      - Development stage

Process: **Determine the crop conditions**

Definition: Determine the crop conditions (e.g. development stage) at a given moment.

Is source of:
- Data Flow: Crop conditions
  Entity type: Actual Crop status
  Attributes:
  development stage
  Entity type: Crop
  Attributes:
  Crop code
  Name
  Relations: Actual Crop status describes the status of a Crop

Is Destination of:
- Data Flow: Normative crop status
  Entity type: Normative crop status
  Attributes:
  Expected field emergence
  Expected field damage
  Development stage

Process: **Determine the crop rotation plan**

Definition: Determine the crop rotation plan for several cropping cycles.

Is source of:
- Data Flow: crop destination
  Entity type: Crop rotation plan
  Entity type: Crop
  Entity type: Field
  Relations: Field is destined to Crop rotation plan
  Crop belongs to Crop rotation plan

Is Destination of:
- Data Flow: farming system
  Entity type: Farming system
  Attributes:
  Description
  type of production system
- Data Flow: subdivision of cult. area

Process: **Determine the observation crit.**

Definition: Determine which criteria are relevant for an observation procedure. The criteria are based on:

- normative data;
- crop protection plan.

Process: **Determine the production poss.**

Definition: Determine the technical and (socio-) economic possibilities or conditions for production.

Process: **Determine the suitable prot. op.**

Definition: Determine a suitable protection operation taking into account the crop, available equipment, and restrictions for a specific tank mix.

Is source of:

- Data Flow: suitable operations
  - *Entity type:* Operation
    - *Attributes:*
      - name
      - type of operation

Is Destination of:

- Data Flow: alternatives for a tank mix
  - *Entity type:* Tank mix
    - *Attributes:*
      - Name of tank mix
      - Status (prop., prep., sprayed)
- Data Flow: equipment
  - *Entity type:* Set of equipment
  - *Entity type:* Tangible fixed asset
    - *Attributes:*
      - code
      - type code
      - width of tyres
      - width of spraying arm
  - *Relations:* Tangible fixed asset is put on Set of equipment

Process: **Divide cultivation area**

Definition: Divide the farm into one or more plots and the plot into one or more fields.

Is source of:

- Data Flow: subdivision of cult. area

Is Destination of:

- Data Flow: soil & field restrictments
  - *Entity type:* Field
    - *Attributes:*
      - Field code
      - Description
      - Water catchment area (Y/N)
  - *Entity type:* Soil type
    - *Attributes:*
      - organic matter content
      - classific.size of soil particles
  - *Relations:* Field is described by Soil type
- Data Flow: geographic data

Process: **Estimate dam. parasite/weed**

Definition: Estimate the damage caused by the detected parasite using the figure for infestation pressure.

Is source of:

- Data Flow: estimated damage parasite/weed
  Entity type: Product
  Attributes:
  description of product
  status (planned,harvested,store)
  Yield capacity
  Expected yield loss

Is Destination of:

- Data Flow: growth rate
  Entity type: Par ° Pop. dyn. parameter
  Attributes:
  event specific growth parameters

infestation pressure

Process: **Estimate damage prot. operation**

Definition: Carrying out a crop protection operation can cause damage to the crop. Using a spraying machine in cereals will cause for example loss of grain yield by wheelings. Damage can also be caused by toxix effects of the chemical agents.

Is source of:

- Data Flow: estimated damage operation

Is Destination of:

- Data Flow: Actual weather conditions
  Entity type: Actual weather conditions
  Attributes:
  date of measurement
  time of measurement
  temperature
  vaporization
  relative humidity
  global radiation
  dew point
  figure for rainfall
  Period of registration
- Data Flow: Crop conditions
  Entity type: Actual Crop status
  Attributes:
  development stage
  Entity type: Crop
  Attributes:
  Crop code
  Name
  Relations: Actual Crop status describes the status of a Crop
- Data Flow: actual soil condition
  Entity type: Actual soil condition

- Data Flow: suitable operations
  Entity type: Operation
  Attributes:
  name
  type of operation

Process: Estimate the epid. growth

Definition: Estimate or calculate the epidemic growth using parasite or weed specific growth parameters.

Is source of:

- Data Flow: growth rate
  Entity type: Par * Pop. dyn. parameter
  Attributes:
  event specific growth parameters

Is Destination of:

- Data Flow: weed/par. specific growth pa
  Entity type: Population dynamic parameter
  Attributes:
  Relative growth rate
  Leaf area index
  Par * Pop. dyn. parameter
  Entity type: Parasite
  Attributes:
  Name
  Development stage
  Weed
  Relations: Parasite is described by Par * Pop. dyn. parameter
  Par * Pop. dyn. parameter is described by Population dynamic parameter
  Par * Pop. dyn. parameter describes Weed
- Data Flow: norm. weather data
  Entity type: Normative weather conditions
  Attributes:
  average temperature
  average figure for rainfall
  average vaporization
  average global radiation
  average relative humidity
- Data Flow: normative crop data
  Entity type: Crop
  Attributes:
  Crop code
  Name
  Scientific name
- Data Flow: actual soil conditions
  Entity type: Soil type
  Entity type: Field

Attributes:

Field code

location

Entity type: Crop rotation plan

Attributes:

Status (planned, implemented)

Entity type: Actual soil condition

Attributes:

Stock of freely avail. nitrogen

Relations: Field is destined to Crop rotation plan

Field is described by Soil type

Actual soil condition is known by Field

Process: **Estimate the preventable loss**

Definition: The degree of potential loss caused by parasites and/or weeds which could be prevented is calculated for each suitable crop protection operation.

Is source of:

- Data Flow: total benefits of an operation

Entity type: Product

Attributes:

description of product

status (planned,harvested,store)

expected price

preventable yield loss

Is Destination of:

- Data Flow: efficacy of an operation

- Data Flow: estimated damage operation

- Data Flow: estimated damage parasite/weed

Entity type: Product

Attributes:

description of product

status (planned,harvested,store)

Yield capacity

Expected yield loss

Process: **Estimate the total costs**

Definition: Estimate the total costs for each suitable operation.

Is source of:

- Data Flow: figure for total costs

Entity type: Operation

Attributes:

name

expected total costs

Is Destination of:

- Data Flow: total costs equipment

Entity type: Operation

Entity type: Set of equipment

Entity type: Tangible fixed asset

Relations: Set of equipment is used by Operation

Tangible fixed asset is put on Sel of equipment

-Data Flow: total costs tank mix

Process: **Evaluate crop protection activ.**

Definition: The evaluation of all crop protection activities at operational level

Process: **Examine the availability**

Definition: Examine whether the recommended crop protection agent can be supplied from stock. Otherwise the farmer has to decide to buy the crop protection agent and he should know if the protection agent can be supplied in time for the operation.

Is source of:

- Data Flow: selected operation

- Data Flow: plan next observation

Entity type: Tank mix

Attributes:

Name of tank mix

efficacy

Status (prop., prep., sprayed)

residual activity period of mix

Agent * mixture

Entity type: Crop protection agent

Attributes:

residual activity period agent

Entity type: Operation

Attributes:

name

status (planned,prep, carr. out)

date of ending

Relations: Agent * mixture defines Tank mix

Crop protection agent is part of Agent * mixture

Tank mix is used by Operation

Is Destination of:

- Data Flow: stock

Entity type: Stock

Attributes:

time of inspection of stock

quantity in stock

Entity type: Crop protection agent

Attributes:

Name of crop protection agent

Content of chemical act. agent

Relations: Crop protection agent is available Stock

Crop protection agent contains Content of chemical act. agent

- Data Flow: selected operation

Process: **Form. a paras./weed contr. pl.**

Definition: A plan focused on the control of parasites and weeds taking into account several cultivation years.

Is source of:

- Data Flow: parasite control plan
  - *Entity type:* Parasite control plan
    - *Attributes:*
      - date
      - type of operation recomended
  - *Entity type:* Plot
    - *Attributes:*
      - Plot code
      - Cadastral numbers
      - Description
      - location
  - *Relations:* Plot knows Parasite control plan
- Data Flow: weed control plan
  - *Entity type:* weed control plan
    - *Attributes:*
      - type of recommended operation
      - date

Is Destination of:

- Data Flow: crop * weed/parasite relation
  - *Entity type:* Crop * weed
  - *Entity type:* Crop * parasite
  - *Entity type:* Crop
    - *Attributes:*
      - Crop code
      - Name
  - *Entity type:* Weed
    - *Attributes:*
      - Name
      - Development stage
  - *Entity type:* Parasite
    - *Attributes:*
      - Name
      - Development stage
  - *Relations:*
    - Crop knows Crop * parasite
    - Crop knows Crop * weed
    - Crop * weed belongs to Weed
    - Crop * parasite belongs to Parasite
- Data Flow: norm. occurence par./weed
  - *Entity type:* Norm.occurrence of a parasite/we
    - *Attributes:*
      - expected occurrence

Process: **Form. a soil desinf. pl.**

Definition: Formulate a soil desinfection plan taking into account several cultivation years.

Is source of:

- Data Flow: weed control plan
  - *Entity type:* weed control plan
    - *Attributes:*
      - type of recommended operation
      - date
  - *Entity type:* Plot
    - *Attributes:*
      - Cadastral numbers
      - Description
      - location

Is Destination of:

- Data Flow: crop * weed/parasite relation
  - *Entity type:* Crop * weed
  - *Entity type:* Crop * parasite
  - *Entity type:* Crop
    - *Attributes:*
      - Crop code
      - Name
  - *Entity type:* Weed
    - *Attributes:*
      - Name

	area		Development stage
Relations:	weed control plan is defined for Plot	*Entity type:*	Parasite
		Attributes:	
			Name
			Development stage
		Relations:	Crop knows Crop * parasite
			Crop knows Crop * weed
			Crop * weed belongs to Weed
			Crop * parasite belongs to Parasite
		- Data Flow: norm. occurence par./weed	
		Entity type:	Norm.occurrence of a parasite/we
		Attributes:	
			expected occurrence

Process: **Form. labour plan**

Definition: Formulate a labour plan, taking into account all the operations which should be carried out taking into account several cultivation years.

Process: **Form. manag. plan for cult.**

Definition: Formulate a management plan which can be subdivided into plans for crop protection, fertilisation, harvest, sale and marketing, acquisition and treatment of parental material and auxiliary materials.

Process: **Form. the objectives of the farm**

Definition: Formulate the objectives of the farmer and the farm as a whole and per section.

Process: **Harvest product**

Definition: The harvest and store management of the product (potatoes, sugarbeet, grain etc.).

Process: **Identify parasite or weed**

Definition: Compare the observed characteristics with normative characteristics of parasites or weeds which can cause damage to the cultivated crop. The result of this process is a number of detected parasites and weeds.

Is source of:

- Data Flow: make an observation

- Data Flow: evaluate an operation

Entity type: Operation

Attributes:

name
type of operation
date of starting
date of ending
time of beginning
time of ending
main task period
speed of working
price or required labour
total price of required equipm.
usage of tank mix

Entity type: Tank mix

Attributes:

active ingredient
Name of tank mix
Status (prop., prep., sprayed)

Entity type: Crop protection agent

Attributes:

Name of crop protection agent
average price (guild./kg)
Agent * mixture
Content of chemical act. agent

Relations:

Tank mix is used by Operation
Agent * mixture defines Tank mix
Crop protection agent is part of Agent * mixture
Crop protection agent contains Content of chemical act. agent

Is Destination of:

- Data Flow: estimated damage parasite/weed

Entity type: Product

Attributes:

description of product
status (planned,harvested,store)
Yield capacity
Expected yield loss

- Data Flow: equipment

Entity type: Set of equipment

Entity type: Tangible fixed asset

Attributes:

code
type code
width of tyres
width of spraying arm

Relations: Tangible fixed asset is put on Set of equipment

- Data Flow: soil & field restrictments

Entity type: Field

Attributes:

Field code
Description
Water catchment area (Y/N)

Entity type: Soil type

Attributes:

organic matter content
classific.size of soil particles

Relations: Field is described by Soil type

- Data Flow: Actual weather conditions

Entity type: Actual weather conditions

Attributes:

date of measurement
time of measurement
temperature
vaporization
relative humidity
global radiation
dew point
figure for rainfall
Period of registration

- Data Flow: Crop conditions

Entity type: Actual Crop status

Attributes:

development stage

Entity type: Crop

Attributes:

Crop code

Name

Relations: Actual Crop status describes the status of a Crop

- Data Flow: infestation prognosis

- Data Flow: environmental effects op.

Entity type: Environmental effects assessment

Attributes:

Risk for persistence

Risk for eluviation

Toxicity to warm-blooded org.

Toxicity to non-target org.

Entity type: Operation

Attributes:

name

type of operation

Relations: Environmental effects assessment is caused by Operation

- Data Flow: stock

Entity type: Stock

Attributes:

time of inspection of stock

quantity in stock

Entity type: Crop protection agent

Attributes:

Name of crop protection agent

Content of chemical act. agent

Relations: Crop protection agent is available Stock

Crop protection agent contains Content of chemical act. agent

- Data Flow: Expected yield/price

Entity type: Product

Attributes:

status (planned,harvested,store)

expected price

Yield capacity

- Data Flow: protection threshold

Entity type: Protection threshold

Attributes:

limit weed density

unit

- Data Flow: identified parasite/weed

Entity type: Weed * Symptoms

Attributes:

Status (expect,estimat.,count.)

Entity type: Parasite * symptoms

Attributes:

Status (expect.,detect.,count.)

Entity type: Weed

Attributes:

Name

Development stage

Entity type: Parasite

Attributes:

Name

Development stage

Relations: Weed is compared to Weed * Symptoms

Parasite is compared to Parasite * symptoms

Process: Infestation prognosis

Definition: The prediction of the outbreak of an infestation for a specific point in time in a cultivation area or a crop.

Is source of:

- Data Flow: infestation pressure

Entity type: Weed * Symptoms

Attributes:

Figure for infestation pressure

Status (expect,estimat.,count.)

Entity type: Parasite * symptoms

Attributes:

Figure for infestation pressure

Status (expect.,detect.,count.)

- Data Flow: infestation prognosis

Is Destination of:

- Data Flow: identified parasite/weed

Entity type: Weed * Symptoms

Attributes:

Status (expect,estimat.,count.)

Entity type: Parasite * symptoms

Attributes:

Status (expect.,detect.,count.)

Entity type: Weed

Attributes:

Name

Development stage

Entity type: Parasite

Attributes:

Name

Development stage

Relations: Weed is compared to Weed * Symptoms

Parasite is compared to Parasite * symptoms

Process: Implement crop protection meas.

Definition: Select, prepare and carry out a crop protection measure.

Process: **Match the description**

Definition: Match the descriptions of a parasite or weed with the normative descriptions of weeds and parasites in the crop. The result is a identified parasite or crop.

Process: **Make an observation**

Definition: Carry out an observation.

Is source of:

- Data Flow: identified parasite/weed
  - *Entity type:* Weed * Symptoms
    - *Attributes:*
      - Status (expect,estimat.,count.)
  - *Entity type:* Parasite * symptoms
    - *Attributes:*
      - Status (expect.,detect.,count.)
  - *Entity type:* Weed
    - *Attributes:*
      - Name
      - Development stage
  - *Entity type:* Parasite
    - *Attributes:*
      - Name
      - Development stage
  - *Relations:*
    - Weed is compared to Weed * Symptoms
    - Parasite is compared to Parasite * symptoms

Is Destination of:

- Data Flow: symptoms
  - *Entity type:* Actual description weed symptoms
    - *Attributes:*
      - Name
      - Description of symptom
  - *Entity type:* Actual descript. parasite symp.
    - *Attributes:*
      - Name
      - Description of symptom
- Data Flow: crop * weed/parasite relation
  - *Entity type:* Crop * weed
  - *Entity type:* Crop * parasite
  - *Entity type:* Crop
    - *Attributes:*
      - Crop code
      - Name
  - *Entity type:* Weed
    - *Attributes:*
      - Name
      - Development stage
  - *Entity type:* Parasite
    - *Attributes:*
      - Name
      - Development stage
  - *Relations:*
    - Crop knows Crop * parasite
    - Crop knows Crop * weed
    - Crop * weed belongs to Weed
    - Crop * parasite belongs to Parasite

Process: **Observe circumst. around farm**

Definition: Observe conditions in the neighbourhood of the farm which can influence

the conditions for the crop protection on the farm.

Process: **Plan an observation on weeds/par**

Definition: Plan an observation aimed at determining the parasite or weed status in the crop.

Is source of:
- Data Flow: planned observation
  Entity type: Observation
  Attributes:
  Status (plan., impl., carr.out)
  planned date

Is Destination of:
- Data Flow: necessity of an observation

Process: **Plan an prot. operation**

Definition: Decide on the timing and reserve the necessary equipment for treatment.

Is source of:
- Data Flow: make an observation

Is Destination of:
- Data Flow: selected operation

Process: **Plan crop protection measures**

Definition: Plan how and when protection activities should be implemented, based on the normative and actual conditions.

Is source of:
- Data Flow: estimated damage parasite/weed
  Entity type: Product
  Attributes:
  description of product
  status (planned,harvested,store)
  Yield capacity
  Expected yield loss
- Data Flow: Actual weather conditions
  Entity type: Actual weather conditions
  Attributes:
  date of measurement
  time of measurement
  temperature

Is Destination of:
- Data Flow: norm. weather data
  Entity type: Normative weather conditions
  Attributes:
  average temperature
  average figure for rainfall
  average vaporization
  average global radiation
  average relative humidity
- Data Flow: make an obeservation
- Data Flow: Normative crop status
  Entity type: Normative crop status
  Attributes:

vaporization
relative humidity
global radiation
dew point
figure for rainfall
Period of registration

Expected field emergence
Expected field damage
Development stage

- Data Flow: Crop conditions
  Entity type: Actual Crop status
  Attributes:
  development stage
  Entity type: Crop
  Attributes:
  Crop code
  Name
  Relations: Actual Crop status describes the status of a Crop
- Data Flow: infestation prognosis

- Data Flow: identified parasite/weed
  Entity type: Weed * Symptoms
  Attributes:
  Status (expect,estimat.,count.)
  Entity type: Parasite * symptoms
  Attributes:
  Status (expect.,detect.,count.)
  Entity type: Weed
  Attributes:
  Name
  Development stage
  Entity type: Parasite
  Attributes:
  Name
  Development stage
  Relations: Weed is compared to Weed * Symptoms
  Parasite is compared to Parasite * symptoms

Process: **Plan the crop prot. progr.**

Definition: Formulate a management plan for plant protection taking into account the widest range of circumstances which the crop may encounter, so that remedies to the problems which may arise have at least been considered.

Is source of:
- Data Flow: crop protection plan
  Entity type: Actual soil condition

Is Destination of:
crop destination

Entity type: weed control plan
Entity type: Parasite control plan

Process: **Prepare the land**

Definition: Prepare the structure of the top soil and soil profile as required.

Process: **Prepare the protection measure**

Definition: Determine the suitable conditions and equipment for the implementation of protection measures (e.g. time, place, dosage, and equipment).

Is source of:
- Data Flow: prepared operation
Entity type: Operation
Attributes:
name
status (planned,prep, carr. out)

Is Destination of:
- Data Flow: selected operation

Process: **Prognosis potential damage**

Definition: Loss prognosis seeks to assess the extent of expected economic loss in relation to the intensity of diseases or the weed densities or the population densities of a pest organism and the environmental and regulatory factors of significance to their development (Heitefuss, 1989).

Comments: Taking all circumstances into consideration, its aim is to decide in advance whether there is a risk of damage and whether control measures should be taken.

Is source of:
- Data Flow: estimated damage parasite/weed
Entity type: Product
Attributes:
description of product
status (planned,harvested,store)
Yield capacity

Is Destination of:
- Data Flow: infestation pressure
Entity type: Weed * Symptoms
Attributes:
Figure for infestation pressure
Status (expect,estimat.,count.)
Entity type: Parasite * symptoms

Expected yield loss

Attributes:

Figure for infestation pressure

Status (expect.,detect.,count.)

- Data Flow: norm. weather data

Entity type: Normative weather conditions

Attributes:

average temperature

average figure for rainfall

average vaporization

average global radiation

average relative humidity

- Data Flow: actual soil conditions

Entity type: Soil type

Entity type: Field

Attributes:

Field code

location

Entity type: Crop rotation plan

Attributes:

Status (planned, implemented)

Entity type: Actual soil condition

Attributes:

Stock of freely avail. nitrogen

Relations: Field is destined to Crop rotation plan

Field is described by Soil type

Actual soil condition is known by Field

Process: **Propose a tank mix**

Definition: Compose an alternative tank mixture taking into account its efficacy for the identified parasites or weeds.

Is source of:

- Data Flow: alternatives for a tank mix

Entity type: Tank mix

Attributes:

Name of tank mix

Status (prop., prep., sprayed)

Is Destination of:

- Data Flow: allowed prot. agents

Entity type: Crop protection agent

Attributes:

Name of crop protection agent

Entity type: Content of chemical act. agent

Attributes:

content

dimension

Relations: Crop protection agent contains Content of chemical act. agent

- Data Flow: Actual weather conditions

Entity type: Actual weather conditions

Attributes:

date of measurement
time of measurement
temperature
vaporization
relative humidity
global radiation
dew point
figure for rainfall
Period of registration

- Data Flow: crop protection agents

Entity type: Crop protection agent

Attributes:

Name of crop protection agent
lower limit for organic content
upper limit for silt content
upper limit for organic content
lower limit for silt content

Entity type: Content of chemical act. agent

Attributes:

content
dimension
Agent * mixture
Weed * agent
Parasite * agent

Relations: Crop protection agent contains Content of chemical act. agent

Process: **Protect crops**

Definition: All operational activities with the aim of protecting the crop against diseases, pests and weeds.

Process: **Purchase of crop protection ag.**

Definition: The purchase of crop protection agents needed for the control of pests, diseases and weeds.

Is Destination of

- Data Flow: stock

Entity type: Stock

Attributes:

time of inspection of stock
quantity in stock

Entity type: Crop protection agent

Attributes:

Name of crop protection agent

Content of chemical act. agent

Relations: Crop protection agent is available Stock

Crop protection agent contains Content of chemical act. agent

- Data Flow: supply

Process: Restrict number of prot. agents

Definition: If the tank mix is used in the early stage of the crop for the protection against weeds (called a soil herbicide), restrictions for soil type and water catchment area have to be taken into account.

Is source of:

- Data Flow: allowed prot. agents

Entity type: Crop protection agent

Attributes:

Name of crop protection agent

Entity type: Content of chemical act. agent

Attributes:

content

dimension

Relations: Crop protection agent contains Content of chemical act. agent

Is Destination of:

- Data Flow: Crop conditions

Entity type: Actual Crop status

Attributes:

development stage

Entity type: Crop

Attributes:

Crop code

Name

Relations: Actual Crop status describes the status of a Crop

- Data Flow: soil & field restrictments

Entity type: Field

Attributes:

Field code

Description

Water catchment area (Y/N)

Entity type: Soil type

Attributes:

organic matter content

classific.size of soil particles

Relations: Field is described by Soil type

- Data Flow: crop protection agents

Entity type: Crop protection agent

Attributes:

Name of crop protection agent

lower limit for organic content

upper limit for silt content

upper limit for organic content

lower limit for silt content

Entity type: Content of chemical act. agent

Attributes:

content
dimension
Agent * mixture
Weed * agent
Parasite * agent

Relations: Crop protection agent contains Content of chemical act. agent

- Data Flow: identified parasite/weed

Entity type: Weed * Symptoms

Attributes:

Status (expect,estimat.,count.)

Entity type: Parasite * symptoms

Attributes:

Status (expect.,detect.,count.)

Entity type: Weed

Attributes:

Name
Development stage

Entity type: Parasite

Attributes:

Name
Development stage

Relations: Weed is compared to Weed * Symptoms
Parasite is compared to Parasite * symptoms

Process: **Sow or plant**

Definition: Sow or plant a variety in a designated field.

Process: **Stock control for auxiliary mat.**

Definition: Stock control of auxiliary materials

Is source of:

- Data Flow: stock

Entity type: Stock

Attributes:

time of inspection of stock
quantity in stock

Entity type: Crop protection agent

Attributes:

Name of crop protection agent
Content of chemical act. agent

Relations: Crop protection agent is available Stock
Crop protection agent contains Content of

Is Destination of:

- Data Flow: evaluate an operation

Entity type: Operation

Attributes:

name
type of operation
date of starting
date of ending
time of beginning
time of ending
main task period
speed of working

chemical act. agent

price or required labour
total price of required equipm.
usage of tank mix

Entity type: Tank mix

Attributes:

active ingredient
Name of tank mix
Status (prop., prep., sprayed)

Entity type: Crop protection agent

Attributes:

Name of crop protection agent
average price (guild./kg)
Agent * mixture
Content of chemical act. agent

Relations: Tank mix is used by Operation
Agent * mixture defines Tank mix
Crop protection agent is part of Agent * mixture
Crop protection agent contains Content of chemical act. agent

Process: **Use the protection threshold**

Definition: Determine which protection measures are economically beneficial

Is source of:

- Data Flow: most efficient operation

Entity type: Operation

Attributes:

name
status (planned,prep, carr. out)
expected total costs
expected total benefits

Is Destination of:

- Data Flow: infestation pressure

Entity type: Weed * Symptoms

Attributes:

Figure for infestation pressure
Status (expect,estimat.,count.)

Entity type: Parasite * symptoms

Attributes:

Figure for infestation pressure
Status (expect.,detect.,count.)

- Data Flow: protection threshold

Entity type: Protection threshold

Attributes:

limit weed density
unit

Appendix E Description of the data model

Entity type: **Actual Crop status**

Definition: Description of the crop status observed at a given moment according to specific characteristics. These include the morphological status (incl. stadium), physiological status (incl. growth stage, maturity), prevention of parasites and weeds.

Relationship:

describes the status of a	Crop
does influence	Probability of parasite/weed
selects	Crop protection agent
is described by	Normative crop status
determines	Operation
is delivered by	Observation

Attributes:

development stage
initial number of plants
leaf area index
plant density
root zone
field emergence
frost damage

Entity type: **Actual descript. parasite symp.**

Definition: Gives an actual description of observed parasites. The description is used for the identification of a parasite.

Relationship:

compares	Parasite * symptoms
is delivered by	Observation

Attributes:

name

description of symptom

Entity type: **Actual description weed symptoms**

Definition: Gives an actual description of the symptoms of a crop. The description is used for the identification of the parasite.

Relationship:

compares	Weed * Symptoms
is delivered by	Observation

Attributes:

name

description of symptom

Entity type: **Actual soil condition**

Definition: The soil condition at the time of observation.

Relationship:

is known by	Field
is delivered by	Observation
depends on	Par * Pop. dyn. parameter
effects	Probability of parasite/weed
determines	Operation

Attributes:

soil moisture
rainfall
rainfall distribution
fraction of soil part. <2um
lime unit
organic content
fraction of stones
workability
soil temperature
occurrence of clods
incidence of mechanical damage
Stock of freely avail. nitrogen

Entity type: **Actual weather conditions**

Definition: The weather conditions at the time of observation.

Relationship:

effects	Probability of parasite/weed
are classified	Normative weather conditions
determines	Parasite * agent
determines	Weed * agent
determines	Operation
is delivered by	Observation

Attributes:

date of measurement
time of measurement
temperature
vaporization
wind speed

wind direction
relative humidity
global radiation
dew point
rainfall
period of registration

Entity type: **Agent * mixture**

Definition: Indication that a number of protection agents are compatible and can be mixed by the farmer himself without giving undesirable reactions. Undesirable reactions are for example:

- a reduction in efficacy on parasites or weeds to be controlled;
- certain mixtures cause damage to the crop;
- certain mixtures clog nozzles;
- certain mixtures can give unexpected chemical reactions.

Relationship:

defines	Tank mix
consists of	Crop protection agent

Attributes:

dose of agent

Entity type: **Chemical active ingredient**

Definition: The chemical ingredient of a crop protection agent which determines the efficacy of an agent on a parasite or weed.

Relationship:

is part of	Content of chemical act. agent

Attributes:

name of active ingredient
chemical formula
solubility in water
chemical category
mode of action
toxicity
minimum organic content
maximum organic content
minimum silt content
maximum silt content

Entity type: **Content of chemical act. agent**

Definition: Content of a specific chemical active agent as part of a crop protection agent.

Relationship:

is specified by	Crop protection agent
specifies	Chemical active ingredient
causes	Environmental effects

Attributes:

content
dimension

Entity type: **Crop**

Definition: A collection of cultivated plants which are grown as an entity in one field or several adjacent fields.

Relationship:

known as a "host" of	Weed
knows	Crop * weed
knows	Crop * parasite
belongs to	Crop rotation plan
effects	Par * Pop. dyn. parameter
is necessary for	Operation
is described by	Normative crop status
contains	Variety
known as a host of	Parasite
is described by	Actual Crop status
has	Observation

Attributes:

crop code
name
scientific name

Entity type: **Crop * parasite**

Definition: Determines the specific relationship between a parasite and host (the cultivated crop).

Relationship:

belongs to	Parasite
restricts	Parasite control plan
belongs to	Crop

Entity type: **Crop * weed**

Definition: Determines the relationship between weed and host (the cultivated crop). If these relation exists it means that a weed can cause damage to a crop.

Relationship:

belongs to	Weed
restricts	weed control plan
belongs to	Crop

Entity type: **Crop protection agent**

Definition: Chemicals applied for the control of pests, diseases or pests.

Relationship:

is part of	Agent * mixture
can be sold as	Trademark
contains	Content of chemical act. agent
is restricted by	Field
is available	Stock
is described by	Actual Crop status
controls	Parasite * agent
controls	Weed * agent

Attributes:

name of crop protection agent
efficacy
lower limit for organic content
upper limit for silt content
upper limit for organic content
lower limit for silt content
average price (guild./kg)
residual activity period agent

Entity type: **Crop rotation plan**

Comments: Previous rotational history or planned rotation of different crops on

different fields. Concerning crop protection it gives an indication of possible sources of infection or infestation. The choice of crop protection may also be restricted because of residues which do effect the next crop.

Relationship:

situates	Observation
belongs to	Field
is destined to	Crop

Attributes:

sowing date
year of implementation
planned year
status (planned, implemented)

Entity type: **Environmental effects**

Definition: Effect (negative) of an operation (e.g. crop protection) on the environment.

Relationship:

is caused by	Operation
is caused by	Content of chemical act. agent

Attributes:

risk for persistence
risk for eluviation
toxicity to warm-blooded org.
Toxicity to non-target org.

Entity type: **Farm**

Definition: An independent production organization which endeavours through the

sale of products to earn an income which is such that in the longer term the income will exceed the costs and thereby guarantee continuity.

Relationship:

consists of Plot

Attributes:

- name
- place of business
- postal address street
- postal address house number
- postal address post box
- postal address municipality
- telephone number
- type of farm

Entity type: **Farming system**

Definition: Defines the cultivation purpose (e.g. for animal feed, seed propagation) and objects of the farming (e.g. non use of chemical agents).

Relationship:

describes variety * farming system

Attributes:

- description
- type of production system

Entity type: **Field**

Definition: A continuous piece of land, considered to be homogeneous by the farmer with regard to soil type, production capacity, crop rotation plan, history and other

requirements of the farmer. Different crops are usually grown consecutively in a field.

Relationship:

is part of	Plot
is destined to	Crop rotation plan
is described by	Soil type
knows	Actual soil condition
knows	Planned soil condition
restricts	Crop protection agent

Attributes:

- field code
- description
- location of field
- shape of field
- length
- width
- water catchment area (y/n)
- location
- area

Entity type: **host * parasite**

Definition: Defines the relation between a host and parasite

Relationship:

describes	Parasite
describes	Variety

Entity type: **Norm.occurrence of a parasite/we**

Definition: Normative occurrence of a parasite or weed as relation of crop and weather data.

Relationship:

is influenced by	Normative crop status
is effected by	Normative weather conditions
predicts	Probability of parasite/weed

Attributes:

expected occurrence

Entity type: **Normative crop status**

Definition: Description of the status expected at a given moment according to specific characteristics. These include the morphological status (incl. growth stage), and maturity.

Relationship:

describes	Actual Crop status
influences	Norm.occurrence of a parasite/we
describes	Crop

Attributes:

expected field emergence
expected field damage
development stage

Entity type: **Normative weather conditions**

Definition: Description of the state of environment which can be expected at a given

moment at a certain location according to specific characteristics.

Relationship:

effects	Norm.occurrence of a parasite/we
effects	Par * Pop. dyn. parameter
classifies	Actual weather conditions
determines	Operation

Attributes:

average temperature
period of measurement
average figure for rainfall
average vaporization
average global radiation
average relative humidity

Entity type: **Observation**

Definition: Assess the actual conditions which have an important bearing on decisions regarding crop protection operations.

Relationship:

on	Crop
delivers	Actual descript. parasite symp.
delivers	Actual description weed symptoms
delivers	Parasite * symptoms
delivers	Actual Crop status
delivers	Actual weather conditions
delivers	Weed * Symptoms
is type of	Operation
is determined by	Operation
delivers	Actual soil condition

is situated at	Crop rotation plan

Attributes:

date of observation
status (plan., impl., carr.out)
planned date
Implemented date
date carried out
limiting weather specifications
description of procedure

Entity type: **Operation**

Definition: A technically cohesive aggregate of activities whereby at a given moment a characteristic status of a specific object (e.g. field, crop, building, machine) is observed, carried out, or prevented.

Comments: Possible values in context of crop protection are:

- spraying all over the field;
- spraying the rows;
- spraying by plane.

Relationship:

is type van	Observation
is determined by	Actual soil condition
is determined by	Actual Crop status
is determined by	Normative weather conditions
determines	Observation
is carried out for	Crop
estimates	Yield loss
causes	Environmental effects
is determined by	Actual weather conditions

is determined by	Protection threshold
estimates	Product

Attributes:

- name
- type of operation
- efficacy
- status (planned,prep, carr. out)
- date of starting
- date of ending
- time of beginning
- time of ending
- work method instruction
- net area of cultivation
- task period
- main task period
- speed of working
- desired experience of applier
- repetition
- price or required labour
- total price of required equipm.
- efficacy for type of operation
- expected total costs
- expected total benefits
- usage of tank mix

Entity type: **Par * Pop. dyn. parameter**

Definition: Defines the set of population dynamic parameters for the estimation of damage caused by a specific parasite or weed.

Relationship:

is described by	Population dynamic parameter
describes	Weed
describes	Parasite
is influenced by	Crop
is influenced by	Soil type
is influenced by	Normative weather conditions
is influenced by	Actual soil condition

Attributes:

event specific growth parameters

Entity type: **Parasite**

Definition: An organism that obtains its nutrients wholly or partly from another living organism and may cause damage to the crop.

Relationship:

known as a parasite of	Crop
ex1 causes	Yield loss
is compared to	Parasite * symptoms
is described by	Par * Pop. dyn. parameter
is controlled by	Parasite * agent
knows	Crop * parasite
has a	Protection threshold
has	host * parasite

Attributes:

name
scientific name
protection threshold
development stage

Entity type: **Parasite * agent**

Definition: Defines the permission of using a certain crop protection agent in a specific crop.

Relationship:

is controlled by	Crop protection agent
is controlled by	Parasite
is determined by	Actual weather conditions

Entity type: **Parasite * symptoms**

Definition: Matches all the normative symptoms to the described symptoms as result of an observation. The result is an identified parasite.

Relationship:

can cause	Product
can cause	Yield loss
compares	Parasite
is compared to	Actual descript. parasite symp.
is delivered by	Observation

Attributes:

initial population
figure for infestation pressure
status (expect.,detect.,count.)

Entity type: **Parasite control plan**

Definition: A strategy for the control of parasites taking into consideration several cultivation years.

Relationship:

is defined for	Plot
is restricted by	Crop * parasite

Attributes:

date

type of operation recommended

Entity type: **Planned soil condition**

Definition: Planned soil necessary for the implementation of specific operation.

Relationship:

is known by	Field

Entity type: **Plot**

Definition: A continuous piece of land consisting of one or more fields belonging to the arable farm.

Relationship:

knows	Parasite control plan
consists of	Field
belongs to	Farm
has a	weed control plan

Attributes:

plot code

cadastral numbers

description

location

area

length
width

Entity type: **Population dynamic parameter**

Definition: A specific parameter used for describing the growth of crops, parasites and weeds.

Relationship:

Estimation damage	parasite/weed
is used for	Par * Pop. dyn. parameter

Attributes:

relative growth rate
leaf area index

Entity type: **Probability of parasite/weed**

Definition: The probability that a certain parasite or weed is present in the crop.

Relationship:

is predicted by	Norm.occurrence of a parasite/we
determines the need of	Observation
is influenced by	Actual Crop status
is effected by	Actual weather conditions
is effected by	Actual soil condition

Entity type: **Product**

Definition: A consignment of plants or parts of plants which are the result of harvesting or processing.

Relationship:

has an	Yield loss
is estimated by	Operation
is influenced by	Yield loss
is caused by	Weed * Symptoms
is caused by	Parasite * symptoms

Attributes:

product consignment code
product type
description of product
date of delivery
description of quality
status (planned,harvested,store)
expected price
realized price
realized yield
yield capacity
expected total yield loss
preventable total yield loss
name/description
determine the actual environm.

Entity type: **Protection threshold**

Definition: Economic threshold based on the prognosis of yield reduction caused by a specific density of weeds or parasites. A prerequisite is experimental research into the relationship between weed density and yield.

Relationship:

is determined by	Yield loss
is defined for	Weed

determines	Operation
is defined for	Parasite

Attributes:

limit weed density

unit

Entity type: **Set of equipment**

Definition: All the equipment needed for an operation.

Relationship:

is used by	Operation
uses	Tangible fixed asset

Entity type: **Soil type**

Definition: The classification of soil types using physical parameters.

Relationship:

effects	Par * Pop. dyn. parameter
describes	Field

Attributes:

available water capacity

pH

occurrence of clods

organic matter content

incidence of mechanical damage

classification of soil texture

classific.size of soil particles

Entity type: **Stock**

Definition: The quantity of parental material, auxiliary material or product at a specific date.

Relationship:

consists of	Trademark
contains	Crop protection agent

Attributes:

time of inspection of stock
quantity in stock
dimension

Entity type: **Tangible fixed asset**

Definition: Production resource which is administered by the farm or hired, and can be used for production over a period of several years.

Comments: In the field of crop protection the following entities are relevant:

- spraying machine;
- dutch hoe etc.;

Relationship:

is put on	Set of equipment

Attributes:

code
type code
width of tyres
width of spraying arm

Entity type: **Tank mix**

Definition: The use of one protection agent in combination with other agents. The tank mix is made by the farmer himself.

Comments: Motives for preparing tank mixes:

- giving efficacy against a bigger range of parasites or weeds;
- less sprayings resulting in the decreasing need of labour and lower costs

Relationship:

is used by	Operation
is determined by	Agent * mixture

Attributes:

active ingredient
compound waiting period
name of tank mix
efficacy
status (proposed, prepared, sprayed)
residual activity period of mix

Entity type: **Trademark**

Definition: The trade name of a chemical protection agent given by the supplier.

Relationship:

is part of	Stock
belongs to	Crop protection agent

Attributes:

name
permission (yes/no)

permission number
name of company
name of supplier
indication of specific risks
starting date of permission
ending date of permission
mutation date of permission
only on prescription (Y/N)

Entity type: **Variety**

Definition: A group of plants belonging to a crop which can be considered as independent unit.

Relationship:

belongs to	variety * farming system
has a	host * parasite
is part of	Crop

Entity type: **variety * farming system**

Definition: The relationship which defines if a variety is can be applied for a specific farming system.

Relationship:

is part of	Farming system
describes	Variety

Entity type: **Weed**

Definition: A type of plant which can cause yield reduction to the cultivated crop.

Relationship:

ex1 causes an	Yield loss
is compared to	Weed * Symptoms
is controlled by	Weed * agent
known as a weed of	Crop
has	Crop * weed
has a	Protection threshold
is influenced by	Par * Pop. dyn. parameter

Attributes:

name
scientific name
protection threshold
development stage

Entity type: **Weed * agent**

Definition: Defines the permission of using a specific crop protection agent in a specific crop.

Relationship:

is controlled by	Crop protection agent
is controlled by	Weed
is determined by	Actual weather conditions

Entity type: **Weed * Symptoms**

Definition: Matches all the normative symptoms with described symptoms. The result is an detected weed.

Relationship:

are delivered by	Observation

can cause	Product
can cause	Yield loss
compares	Weed
is compared to	Actual description weed symptoms

Attributes:

number of detected weeds
figure for infestation pressure
status (expect,estimat.,count.)

Entity type: **weed control plan**

Definition: Strategy for the control of weeds taking into consideration several cultivation years.

Relationship:

is defined for	Plot
is restricted by	Crop * weed

Attributes:

type of recommended operation
date

Entity type: **Yield loss**

Definition: Yield loss caused by one detected weed, parasites or operation.

Relationship:

is caused by	Parasite * symptoms
is caused by	Weed * Symptoms
is estimated by	Operation
influences	Product

is caused by	Weed
is caused by	Parasite
defines	Protection threshold
is calculated with	Product

Attributes:

infestation figure
morphological status
physiological status
figure for expected yield loss
figure for observed yield loss
prevented yield loss

is caused by	Weed
is caused by	Parasite
defines	Protection threshold
is calculated with	Product

Attributes:

infestation figure

morphological status

physiological status

figure for expected yield loss

figure for observed yield loss

prevented yield loss

Nog verkrijgbare PAGV-uitgaven [1)]

Verslagen

6.	De betekenis van vrijlevende wortelaaltjes bij maïs. Ir. C.A.A.A. Maenhout et al,januari 1983	*f*	10,-
8.	Onderzoek naar verschillen in opbrengst en kwaliteit van consumptie-aardappelen in het zuidwesten van Nederland. Ir. C.B. Bus, ing. K.W. Bosma (CA-Barendrecht) en ir. D.W. de Hoop (LEI), februari 1983	*f*	10,-
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PAGV-uitgaven	akkerbouw-praktijk	akkerbouw-totaal	vollegrondgr.-praktijk	vollegrondsgr.-totaal	totaal-praktijk	totaal-verslagen	totaal-PAGV
Werkplan	x	x	x	x	x	x	x
Jaarverslag	x	x	x	x	x	x	x
Jaarboek	x	x	x	x	x		x
Kwantitatieve Informatie	x	x	x	x	x		x
publikaties akkerbouw	x	x			x		x
publikaties vollegrondsgroenteteelt			x	x	x		x
publikaties algemeen	x	x	x	x	x		x
teelthandleidingen akkerbouw	x	x			x		x
teelthandl. vollegrondsgroenteteelt			x	x	x		x
verslagen akkerbouw		x				x	x
verslagen vollegrondsgroenteteelt				x		x	x
verslagen algemeen		x		x		x	x
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