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Central Lab for Agricultural Expert Systems

Design of Generic Tool For Building Fertilization Expert System

TR/CLAES/281/2004.4

By

Eng. Gamal Al-Shorbagi

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TABLE OF CONTENTS

I) Introduction 3

II) Modifiable Concepts 4

1. Crop Elements Ratio Settings 4
2. Variety Instances 5
3. Organic Manure (OM) Instances 6
4. Microelement fertilizers Instances 7
5. Macro Element fertilizers Instances 8
6. Macro Element Fertilizer Schedule Settings 10

III) Built in/Required Concepts 12

1. Concept plantation 12
2. Concept irrigation 12
3. Concept Farm 12
4. Concept fertilizer 12
5. Concept macro element 12
6. Concept micro element 13
7. Concept fertilizer_schedule 14
8. Concept environment 14
9. Concept soil 15
10. Concept water 16
11. Concept organic manure 17
12. Concept crop 18
13. Concept variety 20
14. Concept previous_crop 20
15. Concept task_parameters 20

IV) Modifiable Domain Knowledge 21

1. Determine default values for the soil elements (determine_default_soil) 21
2. Determine default values for the water elements (determine_default_water) 21
3. Determine microelements fertilizer quantities (determine_microelements) 21
4. Determine total fertilizer quantity (“<Fertilizer_name>_ total_quantity”) 21

5. Determine scheduled fertilizer quantity (<Fertilizer_name>_ scheduled_quantity) 22
V) Built in/Required Domain Knowledge 23
1. Determine the plantation–predicted yield factor (Deduce Cluster) 23
2. Determine the available elements quantity in the crop (plant_calculation). 24
3. Determine the available elements quantity in the environment (environment_calculation) 25
VI) Expected Fertilization Scheduling Schema 28
VII) Expected Schedule model 29
VIII) Task Knowledge 30
IX) Proposed Run Time User Interfaces 32
1. Input data Screen 32
2. Microelements schedule output screen 32
3. Macro elements schedules output screens 33
X) Database Associations 34
XI) Built-In/Required Dependency Graphs: 35
1. Predicted Yield Factor 35
2. Crop N_Contents Element 35
3. Crop Elements Contents 36
4. Crop Elements Contents 37

I. Introduction:

The aim of this document is to present a detailed design of generic fertilization expert system building tool. This tool could be used to help both the developers/designers of a fertilization expert system and the implementers of an expert system tool in developing rapid plant fertilization systems.

To do so, we have aimed to identify and capture all knowledge that is related to fertilization task for crops and vegetables regardless of the crop variety. A typical fertilization expert system is made out of concepts and relations, on top of which a task layer is built. The reusable concepts and relations are basically taken from two technical reports for fertilization **TR/CLAES/140/2000.3, AND TR/CLAES/232/2002.1.** Of course, important improvements are made to these basics to reach our goal.

In the design presented, a fertilization schedule could be obtained either on weekly, monthly or stages bases. The first two types, which called a normal schedule type, are depending on the irrigation method (dripping or flooding); while the stages bases fertilization schedule is generated when the specified schedule type is not normal. In this case, expert system developer must identify the schedule stages (slots) as explained later in section II. Also, it is important to note that the fertilization calculations cover the case of planting within an open field, a high tunnel, or a low tunnel.

II. Modifiable Concepts:

1. Crop Elements Ratio Settings:

Here, a default values for the crop macro elements and crop microelements ratios is determined. The following crop elements should assigned their default values:

- ratio_of_n
- ratio_of_p
- ratio_of_k
- ratio_of_ca
- ratio_of_mg
- ratio_of_fe
- ratio_of_zn
- ratio_of_cu
- ratio_of_mn

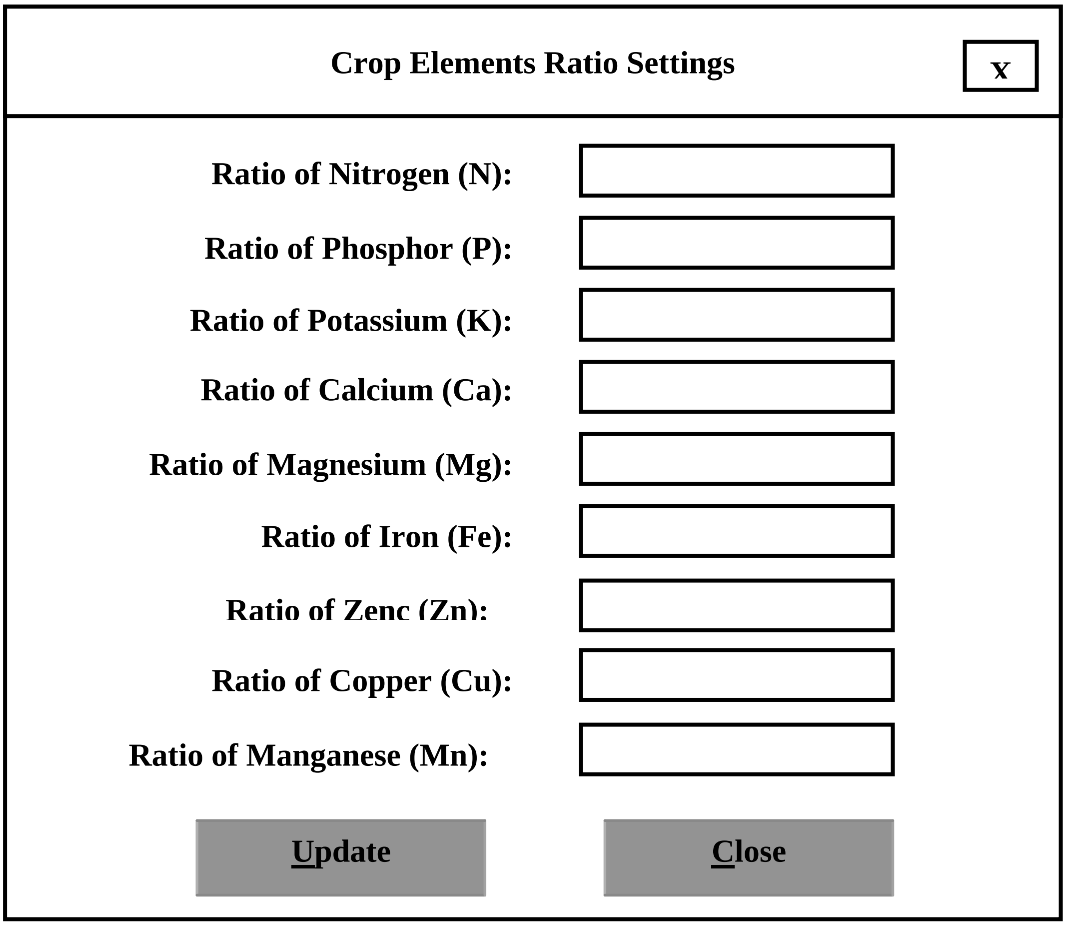

Figure 1: Crop Elements Ratio Settings

Figure 1 shows the proposed crop elements ratio editor that allows user to update the crop elements ratio default values.

2. Variety Instances:

These concepts represent all varieties that the developed expert system can be managed. There are three types of varieties according to their farm type, which are:

- Open Field Varieties
- High Tunnel Varieties
- Low Tunnel Varieties

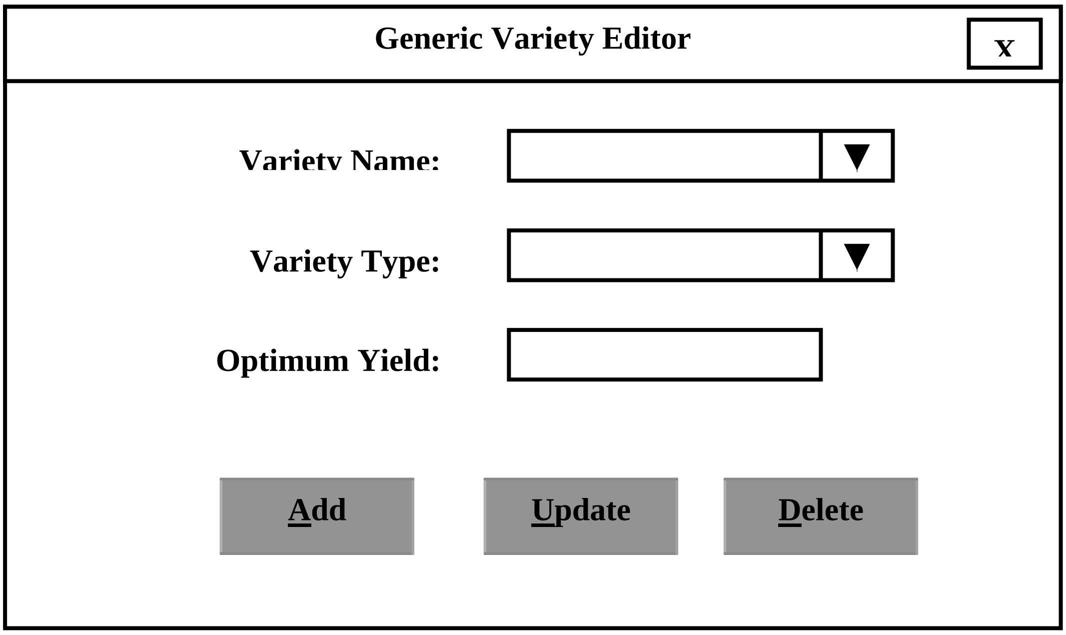

Figure 2: Generic variety editor

Figure 2 shows the proposed generic variety editor that allows user to add new and update or delete an existing variety.

3. Organic Manure (OM) Instances:

These are organic manures the expert system can be used. Each OM instance should assigned default value for each one of the following properties:

- ratio_of_n
- ratio_of_p
- ratio_of_k
- ratio_of_ca
- ratio_of_mg
- weight

Figure 3 shows the proposed generic organic manure editor that allows user to add new or update or delete an existing one.

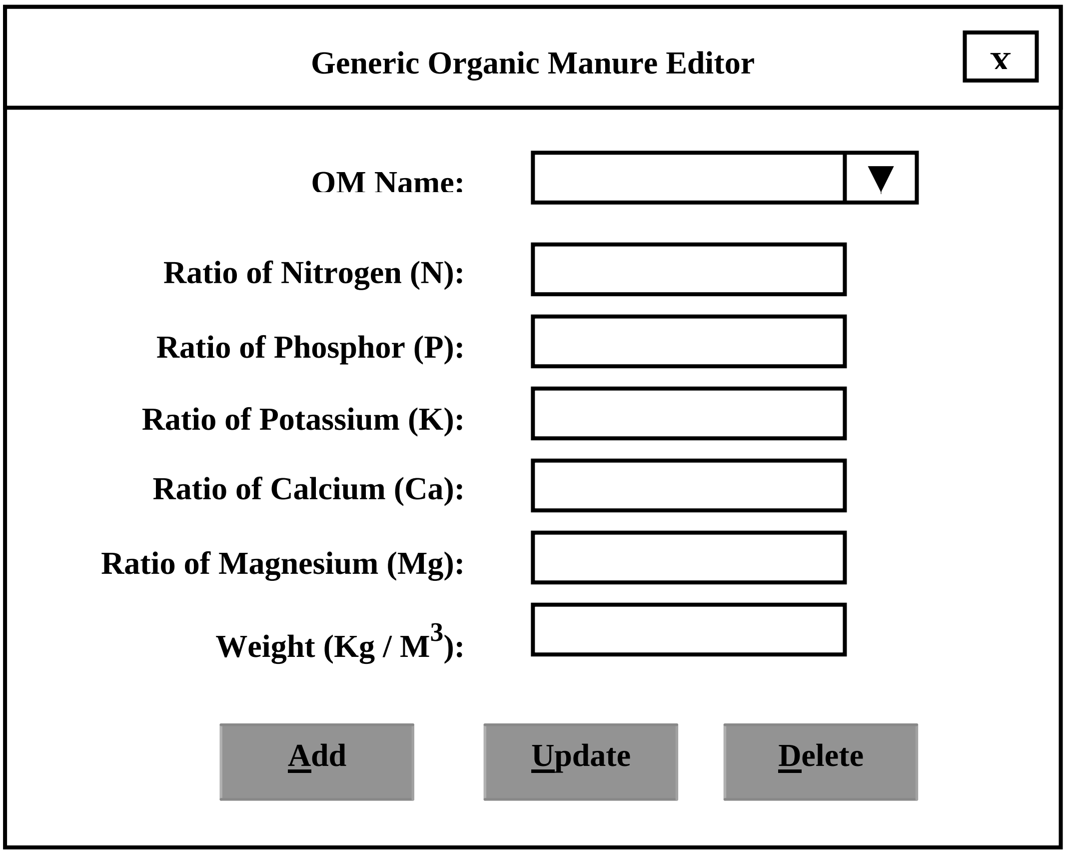

Figure 3: Generic Organic Manure Editor

4. Microelement fertilizer Instances:

These are microelements fertilizers, which can be used by the developed expert system in the fertilization process. The following list represents the available microelements:

- Iron (Fe)
- Zinc (Zn)
- Copper (Cu)
- Manganese (Mn)

In general, microelement fertilizer can contain one or more microelement, so that ratio for each microelement should be stated as a default value. Figure 4 shows the proposed generic microelement fertilizer editor that allows user to add new or update or delete an existing one. In addition to elements ratio, an important value of the property "usefulness_coefficient" must be stated.

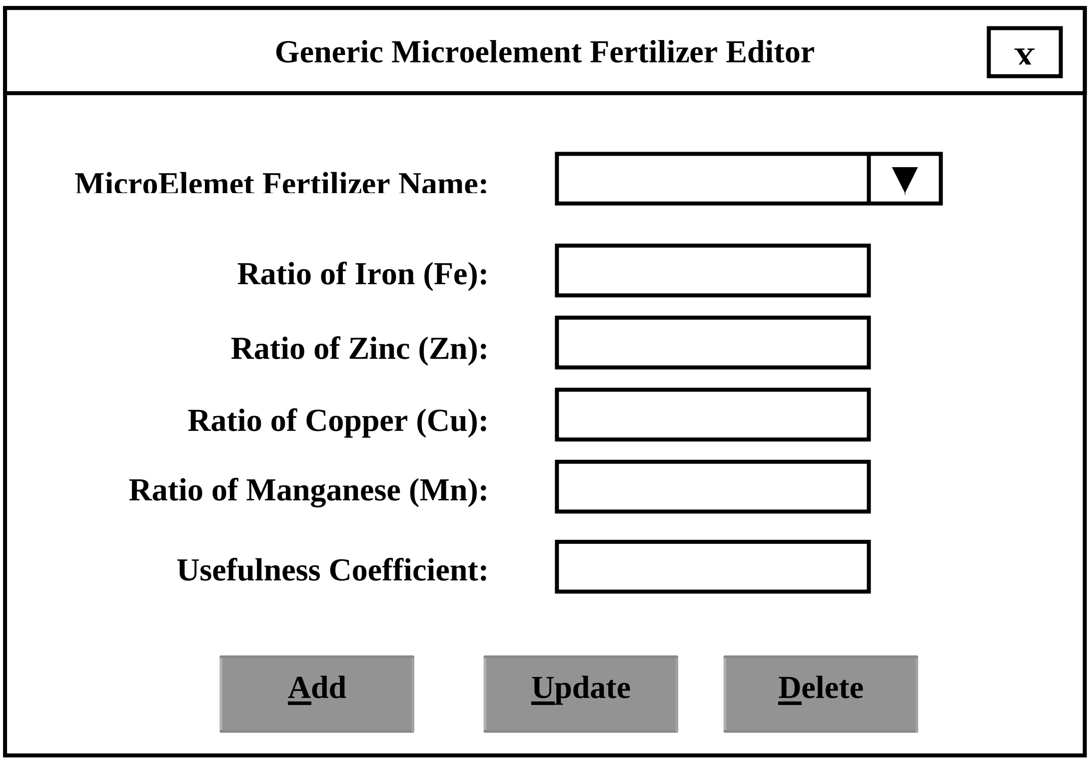

Figure 4: Generic Microelement Fertilizer Editor

Note:

- During the Add and Update process, it is preferable to add or remove the microelement fertilizer properties so that only properties with default value could be taken.

5. Macro Element fertilizer Instances:

These are macro elements fertilizers, which can be used by the developed expert system in the fertilization process. The following list represents the available macro elements:

- Nitrogen (N)
- Phosphor (P)
- Potassium (k)
- Calcium (Ca)
- Magnesium (Mg)

In general, macro element fertilizer can contain one or more macro elements, so that ratio for each macro element should be stated as a default value. Figure 5 shows the proposed generic macro element fertilizer editor that allows user to add new or update or delete an existing one. In addition to elements ratio, an important value of the property "usefulness_coefficient" must be stated.

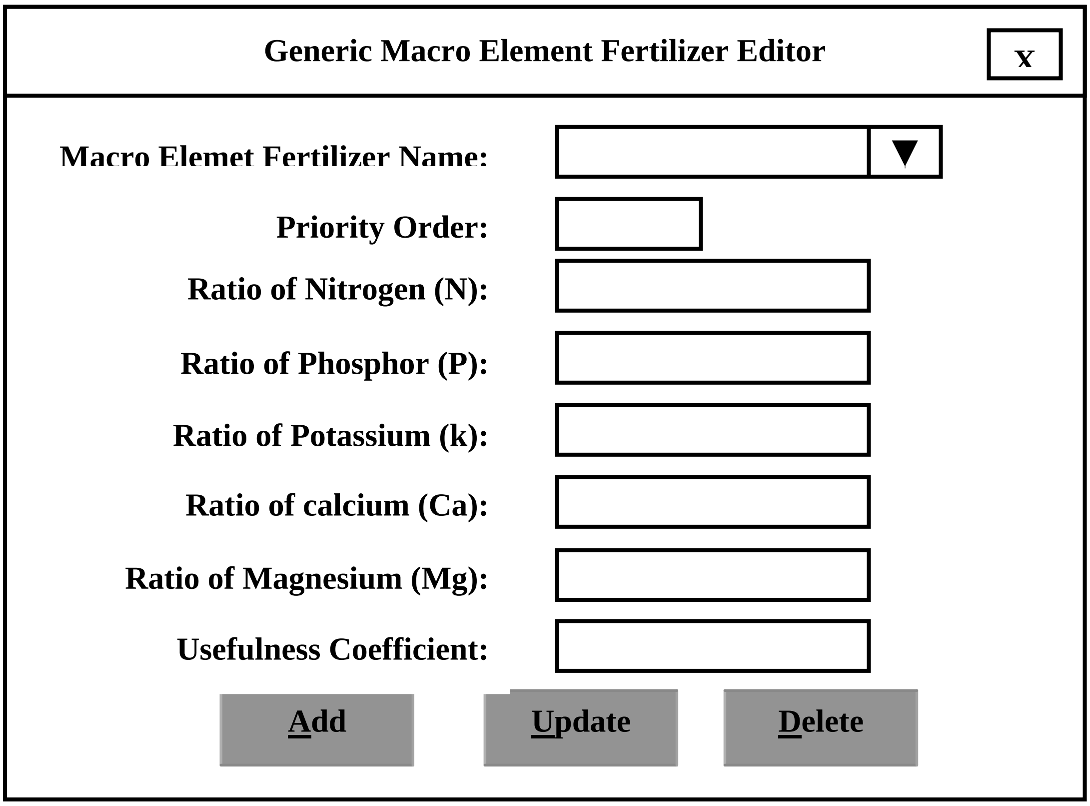

Figure 5: Generic Macro Element Fertilizer Editor

Notes:

- The value of "Priority Order" would be added as a default value to the property "periority_order" of the specified fertilizer. This value used by the task program to determine which fertilizer need to get value of its total_quantity property first.

- During the Add or Update processes, it is preferable to add or remove the macro element fertilizer properties so that only properties with default value could be taken.

- During the Add, Update or Delete processes, an automatic handling of a special two clusters of the defined fertilizer should be made. The name of this clusters are:

  - “<Fertilizer_name>_total_quantity”
  - “<Fertilizer_name>_ scheduled_quantity”

- During the Add, Update or Delete processes, an automatic handling of dependency graph for the property named “quantity” of the defined fertilizer should be made. The elements of this dependency graph are:

  - Concept name = “Fertilizer_name>”
  - Property name = “total_quantity”
  - Link name = “<Fertilizer_name>_total_quantity”
  - Source of value type = “Cluster”
  - Source of value = “<Fertilizer_name>_total_quantity”
  - Link Condition = “true”

- During the Add, Update or Delete processes, an automatic handling of dependency graph for the property named “quantity” of the defined fertilizer should be made. The elements of this dependency graph are:

  - Concept name = “<Fertilizer_name>”
  - Property name = “Scheduled_quantity”
  - Link name = “<Fertilizer_name>_ scheduled_quantity”
  - Source of value type = “Cluster”
  - Source of value = “<Fertilizer_name>_ scheduled_quantity”
  - Link Condition = “true”

6. Macro Element Fertilizer Schedule Settings:

These settings are crop dependents in the sense that each crop has its own growth period and also the developed expert system may be used to generate fertilization schedule to a crop in deferent farm types (e.g. open field or high or low tunnel) or in deferent irrigation systems.

In general, the developed expert system can be used to generate fertilization schedule to drip based irrigation farms or flooding based irrigation farms. Usually, weekly schedule would be generated for drip-irrigation based farms, while monthly schedule would be generated for flood-irrigation based farms. Expert system developers also can plan their fertilization schedule in distinct – developer defined – stages. Thus, we have two different classes of expert systems according to the generated schedule as follow:

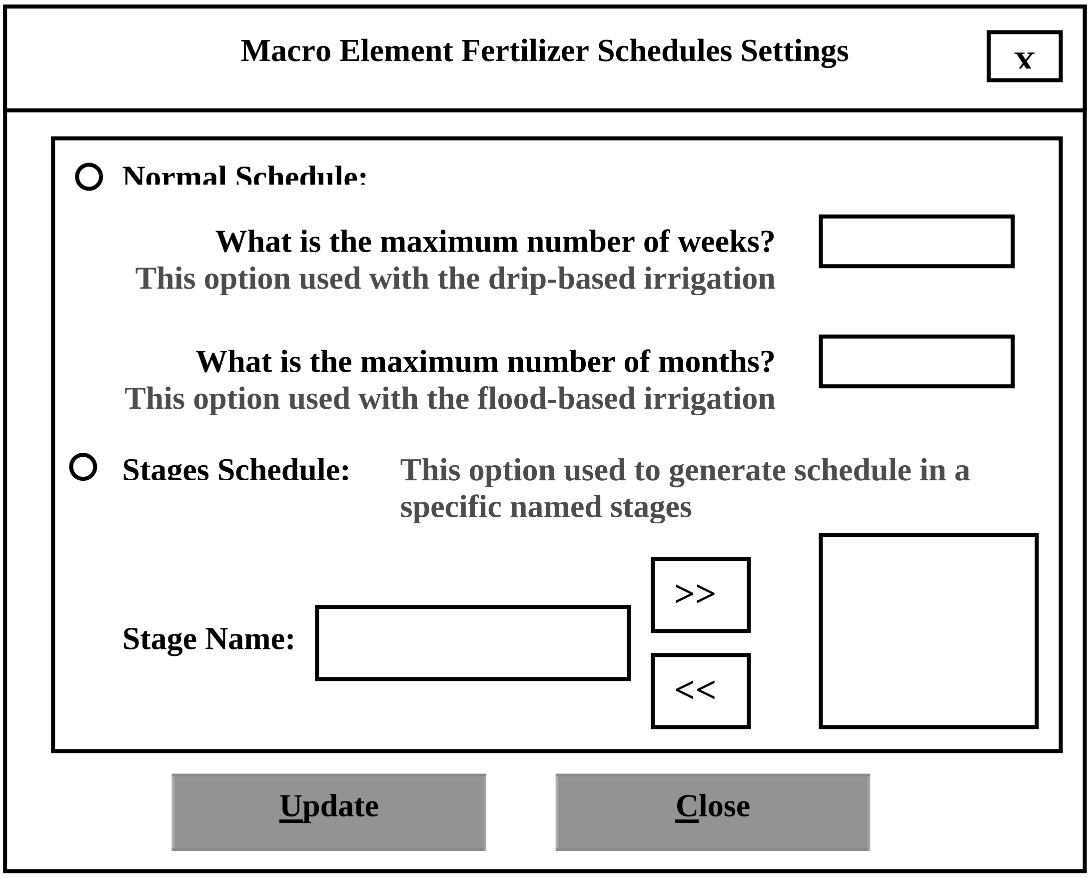

Figure 6: Macro Element Fertilizer Schedules Settings

- **Normal Schedules:**
  - Weekly schedule: In the normal schedule type, it will be used for drip-irrigation based farms
  - Monthly schedule: In the normal schedule type, it will be used for flood-irrigation based farms

- **Stages Schedules:**

  - Stages schedule: Used only when the schedule type is not normal. So, the expert system developers define the schedule elements.

Notes:

- The selected scheduled fertilization type is added as a default value to the property “type” of the concept “fertilization_schedule”.

- The defined stages schedule elements should be added as legal values to the property “stages_names” of the concept “fertilization_schedule”.

- The maximum number of weeks and months added as a default value of the properties “no_of_weeks” and “no_of_months” of the concept “fertilization_schedule”.

III. Built in/Required Concepts:

Concept **plantation;**

Properties:

date: date;

source of value: Database

cardinality: single;

predicted yield factor: numeric;/* a coefficient when multiply by the optimum yield gives the predicted yield */

source of value: derived;

cardinality: single;

Concept irrigation;

Properties:

method: {flooding, dripping, sprinkling, pivot};

source of value: Database;

cardinality: single;

Concept farm;

Properties:

type: {open field, tunnels, low tunnels};

source of value: Database;

cardinality: single;

area: numeric;

source of value: Database;

cardinality: single;

Concept fertilizer;

Properties:

usefulness coefficient: numeric;

source of value: system;

cardinality: single;

advice: string;

source of value: derived;

cardinality: single;

Concept macro element;

Sub-type-of: fertilizer;

Properties:

ratio_of_n: number;

source of value: system;

cardinality: single;

ratio_of_p: number;

source of value: system;
cardinality: single;

ratio_of_k: number;
source of value: system;
cardinality: single;

ratio_of_ca: number;
source of value: system;
cardinality: single;

ratio_of_mg: number;
source of value: system;
cardinality: single;

periority_order: number;
source of value: system;
cardinality: single;

scheduled quantity: number;
source of value: derived;
cardinality: single;

total quantity: number;
source of value: derived;
cardinality: single;

Concept micro element;

Sub-type-of: fertilizer;

Properties:

ratio_of_fe: number;
source of value: system;
cardinality: single;

ratio_of_cu: number;
source of value: system;
cardinality: single;

ratio_of_mn: number;
source of value: system;
cardinality: single;

ratio_of_zn: number;
source of value: system;
cardinality: single;

quantity: numeric;
source of value: derived;
cardinality: single;

Concept fertilizer_schedule;
Properties:

stages_names: {Modifiable List};
source of value: system;
cardinality: single;

no of weeks: numeric {Modifiable Default Value};
source of value: system;
cardinality: single;

no of months: numeric {Modifiable Default Value};
source of value: system;
cardinality: single;

type: {normal, stages}; {Modifiable Default Value}
source of value: system;
cardinality: single;

microelements_fertilizers_used: string (Multi value);
source of value: user;
cardinality: Multi value;

macroelements_fertilizers_used: string (Multi value);
source of value: user;
cardinality: Multi value;

Concept environment
Properties:

N quantity: numeric;
source of value: derived;
cardinality: single;

P quantity: numeric;
source of value: derived;
cardinality: single;

K quantity: numeric;
source of value: derived;
cardinality: single;

Ca quantity: numeric;
source of value: derived;
cardinality: single;

Mg quantity: numeric;
source of value: derived;
cardinality: single;

Fe quantity: numeric;
source of value: derived;

cardinality: single;

Zn quantity: numeric;
source of value: derived;
cardinality: single;

Mn quantity: numeric;
source of value: derived;
cardinality: single;

Cu quantity: numeric;
source of value: derived;
cardinality: single;

Concept soil;

Properties:

type: {clayey, loamy, sandy};
source of value: database;
cardinality: single;

salinity: numeric; % in m. mhos
source of value: database;
cardinality: single;

ec: numeric; % in m. mhos
source of value: database;
cardinality: single;

soil_analysis: {yes, no};
source of value: database;
cardinality: single;

calcium carbonate: numeric; % percentage
source of value: database;
cardinality: single;

Ca quantity: numeric; % in ppm
source of value: database or derived;
cardinality: single;

N quantity: numeric;
source of value: database or derived;
cardinality: single;

P quantity: numeric;
source of value: database or derived;
cardinality: single;

K quantity: numeric;
source of value: database or derived;

cardinality: single;

Mg quantity: numeric;
source of value: database or derived;
cardinality: single;

Fe quantity: numeric;
source of value: database or derived;
cardinality: single;

Zn quantity: numeric;
source of value: database or derived;
cardinality: single;

Mn quantity: numeric;
source of value: database or derived;
cardinality: single;

Cu quantity: numeric;
source of value: database or derived;
cardinality: single;

Concept **water;**

Properties:

salinity: numeric;
source of value: database;
cardinality: single;

eciw: numeric;
source of value: database;
cardinality: single;

quantity: numeric; % the irrigation volume in cubic meter/feddan
source of value: database;
cardinality: single;

water analysis: {yes, no};
source of value: database;
cardinality: single;

Ca quantity: numeric;
source of value: database or derived;
cardinality: single;

N quantity: numeric;
source of value: database or derived;
cardinality: single;

P quantity: numeric;
source of value: database or derived;

cardinality: single;

K quantity: numeric;
source of value: database or derived;
cardinality: single;

Mg quantity: numeric;
source of value: database or derived;
cardinality: single;

Fe quantity: numeric;
source of value: database or derived;
cardinality: single;

Zn quantity: numeric;
source of value: database or derived;
cardinality: single;

Mn quantity: numeric;
source of value: database or derived;
cardinality: single;

Cu quantity: numeric;
source of value: database or derived;
cardinality: single;

Concept organic manure;

Properties:

name: {chicken manure for meat product, chicken manure for egg product, cow manure, residual farm manure, horse manure, sewage sludge manure, town refuse manure, pigeon manure};
source of value: database;
cardinality: single;

weight: numeric; % weight of 1 cubic meter in Kg
source of value: system;
cardinality: single;

ratio of N: numeric;
source of value: system;
cardinality: single;

ratio of P: numeric;
source of value: system;
cardinality: single;

ratio of K: numeric;
source of value: system;
cardinality: single;

ratio of Ca: numeric;
source of value: system;
cardinality: single;

ratio of Mg: numeric;
source of value: system;
cardinality: single;

volume: numeric;
source of value: database;
cardinality: single;

Concept crop;

Properties:

name: {tomato, cucumber, melon, rice, bean, fababean, …};
source of value: system;
cardinality: single;

elements: nominal;
source of value: system;
cardinality: multiple;

variety: nominal;
source of value: database;
cardinality: single;

optimum yield: numeric;
source of value: system;
cardinality: single;

N ratio: real number;
source of value: system;
cardinality: single;

P ratio: real number;
source of value: system;
cardinality: single;

K ratio: real number;
source of value: system;
cardinality: single;

Ca ratio: real number;
source of value: system;
cardinality: single;

Mg ratio: real number;
source of value: system;
cardinality: single;

Fe ratio: real number;
source of value: system;
cardinality: single;

Mn ratio: real number;
source of value: system;
cardinality: single;

Cu ratio: real number;
source of value: system;
cardinality: single;

Zn ratio: real number;
source of value: system;
cardinality: single;

N content: real number;
source of value: derived;
cardinality: single;

P content: real number;
source of value: derived;
cardinality: single;

K content: real number;
source of value: derived;
cardinality: single;

Ca content: real number;
source of value: derived;
cardinality: single;

Mg content: real number;
source of value: derived;
cardinality: single;

Fe content: real number;
source of value: derived;
cardinality: single;

Mn content: real number;
source of value: derived;
cardinality: single;

Cu content: real number;
source of value: derived;
cardinality: single;

Zn content: real number;
source of value: derived;

cardinality: single;

Concept variety;
Sub-type-of: crop;

Concept previous_crop;
Properties:
type: {vegetable, grouses, others};
source of value: database;
cardinality: single;

Concept task_parameters;
Properties:
week_no: number;
source of value: system;
cardinality: single;

month_no: number;
source of value: system;
cardinality: single;

stage_name: string;
source of value: system;
cardinality: single;

IV. Modifiable Domain Knowledge:

1. Determine default values for the soil elements (determine_default_soil)

This cluster would be used only if there is no soil analysis data in the database.

- **Input Rolls:**
  - **soil-soil_analysis**
  - **soil-type**
- **Output Rolls:**
  - **soil-ca_quantity**
  - **soil-n_quantity**
  - **soil-p_quantity**
  - **soil-k_quantity**
  - **soil-mg_quantity**
  - **soil-mn_quantity**
  - **soil-cu_quantity**
  - **soil-calcium_carbonate**

2. Determine default values for the water elements (determine_default_water)

This cluster would be used only if there is no water analysis data in the database.

- **Input Rolls:**
  - **water-water_analysis**
- **Output Rolls:**
  - **water-ca_quantity**
  - **water-n_quantity**
  - **water-p_quantity**
  - **water-k_quantity**
  - **water-mg_quantity**
  - **water-mn_quantity**
  - **water-cu_quantity**

3. Determine microelements fertilizer quantities (determine_microelements)

This cluster would be used to determine every thing about the microelements needs.

- **Input Rolls:**
  - **Farm-type**
- **Output Rolls:**
  - **"<Micro_element_fertilizer_name>-quantity"**
  - **micro_element-advice**
  - **micro_element-application_method**
  - **micro_element-application_date**

4. Determine total fertilizer quantity ("<Fertilizer_name>_ total_quantity")

These clusters are generated automatically during the handling of the fertilizers used by the developed ES. All these clusters can be modified so that ES developers can define the proposed equation used to determine the total quantity needed for each fertilizer. The cluster name is: ***"<Fertilizer_name>_ total_quantity",*** and the output of these clusters is the “<Fertilizer_name>- total_quantity” which represents the total amount required from the specified fertilizer.

- **Input Rolls:**
  - **Farm-type**
  - **Irrigation-method**
  - **Soil-calcium_carbonate**
  - **Fertilization_schedule-fertilizer_used**
- **Output Rolls:**
  - **“<Fertilizer_name>-total_quantity”**

5. Determine scheduled fertilizer quantity (<Fertilizer_name>_ scheduled_quantity)

These clusters are generated automatically during the handling of the fertilizers used by the developed ES. All these clusters can be modified so that ES developers can define the proposed schedule for each fertilizer. The cluster name is: ***“<Fertilizer_name>_ scheduled_quantity”,*** and the output of these clusters is the “<Fertilizer_name>-scheduled_quantity” which represents the quantity during the specified week_no, month_no, or stage_name.

- **Input Rolls:**
  - **Task_parameter-week_no**
  - **Task_prameter-month_no**
  - **Task_parameter-stage_name**
  - **Farm-type**
  - **Irrigation-method**
  - **Soil-calcium_carbonate**
- **Output Rolls:**
  - **“<Fertilizer_name>- *scheduled_quantity*”**

V. Built in/Required Domain Knowledge:

1. Determine the plantation–predicted yield factor (Deduce Cluster).

Rules	Description
R1	**IF** @soil.ec < 3 && @water.eciw < 2 **THEN** @plantation.predicted_yield_factor=1;
R2	**IF** @soil.ec < 3 && @water.eciw >= 2 **THEN** @plantation.predicted_yield_factor=0.9;
R3	**IF** @soil.ec < 4 && @soil.ec >= 3 && @water.eciw < 2.8 **THEN** @plantation.predicted_yield_factor=0.9;
R4	**IF** @soil.ec < 4 && @soil.ec >= 3 && @water.eciw >= 2.8 **THEN** @plantation.predicted_yield_factor=0.75;
R5	**IF** @soil.ec < 6 && @soil.ec >= 4 && @water.eciw < 4 **THEN** @plantation.predicted_yield_factor=0.75;
R6	**IF** @soil.ec >= 4 && @water.eciw >= 4 **THEN** @plantation.predicted_yield_factor=0.5;

Table 1: Deduce cluster contents

2. Determine the available elements quantity in the crop (plant_calculation).

Rules	Description
R1	**IF** @crop.elements == "p" **THEN** @crop.p_content=@crop.p_ratio*1000*@plantation.optimum_yield*@plantation.predicted_yield_facto r*0.6;
R2	**IF** @crop.elements == "k" **THEN** @crop.k_content=@crop.k_ratio*1000*@plantation.optimum_yield*@plantation.predicted_yield_facto r*0.4;
R3	**IF**

	@crop.elements == "ca" **THEN** @crop.ca_content=@crop.ca_ratio*1000*@plantation.optimum_yield*@plantation.predicted_yield_factor*0.2;
R4	**IF** @crop.elements == "mg" **THEN** @crop.mg_content=@crop.mg_ratio*1000*@plantation.optimum_yield*@plantation.predicted_yield_factor*0.03;
R5	**IF** @crop.elements == "fe" **THEN** @crop.fe_content=@crop.fe_ratio*1000*@plantation.optimum_yield*@plantation.predicted_yield_factor*200;
R6	**IF** @crop.elements == "zn" **THEN** @crop.zn_content=@crop.zn_ratio*1000*@plantation.optimum_yield*@plantation.predicted_yield_factor*200;
R7	**IF** @crop.elements == "mn" **THEN** @crop.mn_content=@crop.mn_ratio*1000*@plantation.optimum_yield*@plantation.predicted_yield_factor*200;
R8	**IF** @crop.elements == "cu" **THEN** @crop.cu_content=@crop.cu_ratio*1000*@plantation.optimum_yield*@plantation.predicted_yield_factor*200;
R9	**IF** @crop.elements == "n" && @previous_crop.value == "vegitable" **THEN** @crop.n_content=@crop.n_ratio*1000*@plantation.optimum_yield*@plantation.predicted_yield_factor*0.6*0.85;
R10	**IF** @crop.elements == "n" && @previous_crop.value == "grouses" **THEN** @crop.n_content=@crop.n_ratio*1000*@plantation.optimum_yield*@plantation.predicted_yield_factor*0.6*1.15;
R11	**IF** @crop.elements == "n" && @previous_crop.value == "others" **THEN** @crop.n_content=@crop.n_ratio*1000*@plantation.optimum_yield*@plantation.predicted_yield_factor*0.6;

Table 2: Plant_calculation cluster contents

3. Determine the available elements quantity in the environment (environment_calculation)

Rules	Description
R1	**IF** @crop.elements == "ca"&& @farm.type != "high_tunnel" **THEN** @environment.ca_quantity=@soil.ca_quantity+(@water.ca_quantity*@water.qty/1000.0)+(@organic_manure.ratio_of_ca*@organic_manure.quantity*@organic_manure.weight);
R2	**IF** @crop.elements == "n"&& @farm.type != "high_tunnel" **THEN** @environment.n_quantity=@soil.n_quantity+(@water.n_quantity*@water.qty/1000.0)+(@organic_manure.ratio_of_n*@organic_manure.quantity*@organic_manure.weight);
R3	**IF** @crop.elements == "p"&& @farm.type != "high_tunnel" **THEN** @environment.p_quantity=@soil.p_quantity+(@water.p_quantity*@water.qty/1000.0)+(@organic_manure.ratio_of_p*@organic_manure.quantity*@organic_manure.weight);
R4	**IF** @crop.elements == "k"&& @farm.type != "high_tunnel" **THEN** @environment.k_quantity=@soil.k_quantity+(@water.k_quantity*@water.qty/1000.0)+(@organic_manure.ratio_of_k*@organic_manure.quantity*@organic_manure.weight);
R5	**IF** @crop.elements == "mg"&& @farm.type != "high_tunnel" **THEN** @environment.mg_quantity=@soil.mg_quantity+(@water.mg_quantity*@water.qty/1000.0)+(@organic_manure.ratio_of_mg*@organic_manure.quantity*@organic_manure.weight);
R6	**IF** @crop.elements == "mg"&& @farm.type == "high_tunnel" **THEN** @environment.mg_quantity=@soil.mg_quantity+(@water.mg_quantity*@water.qty/1000.0)+(@organic_manure.ratio_of_mg*(@organic_manure.quantity*4200/@farm.area)*@organic_manure.weight);
R7	**IF** @crop.elements == "fe" **THEN** @environment.fe_quantity=@soil.fe_quantity+(@water.fe_quantity*@water.qty/1000.0);
R8	**IF** @crop.elements == "k"&& @farm.type == "high_tunnel" **THEN** @environment.k_quantity=@soil.k_quantity+(@water.k_quantity*@water.qty/1000.0)+(@organic_manure.ratio_of_k*(@organic_manure.quantity*4200/@farm.area)*@organic_manure.weight);
R9	**IF** @crop.elements == "zn" **THEN** @environment.zn_quantity=@soil.zn_quantity+(@water.zn_quantity*@water.qty/1000.0);
R10	**IF** @crop.elements == "p"&&

	@farm.type == "high_tunnel" **THEN** @environment.p_quantity=@soil.p_quantity+(@water.p_quantity*@water.qty/1000.0)+(@organic_manure.ratio_of_p*(@organic_manure.quantity*4200/@farm.area)*@organic_manure.weight);
R11	**IF** @crop.elements == "mn" **THEN** @environment.mn_quantity=@soil.mn_quantity+(@water.mn_quantity*@water.qty/1000.0);
R12	**IF** @crop.elements == "n"&& @farm.type == "high_tunnel" **THEN** @environment.n_quantity=@soil.n_quantity+(@water.n_quantity*@water.qty/1000.0)+(@organic_manure.ratio_of_n*(@organic_manure.quantity*4200/@farm.area)*@organic_manure.weight);
R13	**IF** @crop.elements == "cu" **THEN** @environment.cu_quantity=@soil.cu_quantity+(@water.cu_quantity*@water.qty/1000.0);
R14	**IF** @crop.elements == "ca"&& @farm.type == "high_tunnel" **THEN** @environment.ca_quantity=@soil.ca_quantity+(@water.ca_quantity*@water.qty/1000.0)+(@organic_manure.ratio_of_ca*(@organic_manure.quantity*4200/@farm.area)*@organic_manure.weight);

Table 3: Environment_calculation cluster contents

VI. Expected Fertilization Scheduling Schema

To obtain a specific fertilization scheduling we have to perform two generic steps: -

1. Calculation of each fertilizer quantity (Total Quantity)
2. Distribute the calculated fertilizers quantities over specific period of time

Because we have a dynamic list of fertilizers defined during run time and each of these fertilizers can be used to fertilize one or more elements. So, the following is an **expected equation** used to perform the first step indicated above. This equation is presented in figure 7.

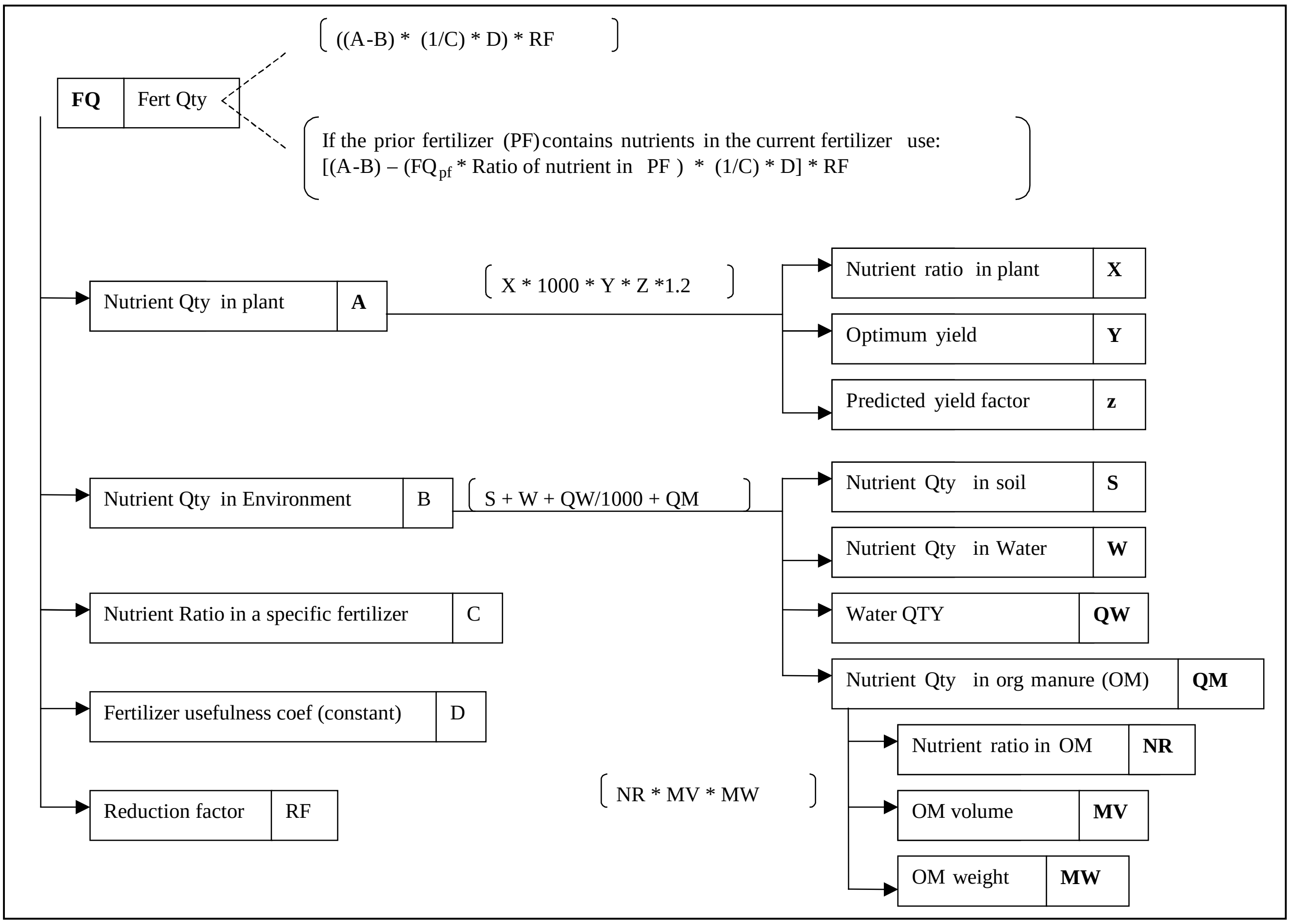

Figure 7: Expected Fertilizers Total Quantities Computations

Thus, we can use this equation as a guide to the expert system developers. On the other hand to perform the second step we distribute the calculated quantities of each fertilizers over a specified or required period of time (either on monthly, weekly or specific stages bases) using a specific **disputation factor** (parameter) that should be acquired from the expert.

The **expected relation** used for this purpose is called **expected scheduling model** shown in the following section.

VII. Expected Schedule model

The objective of scheduling model is to distribute the fertilization quantities calculated in the previous step based on the following schema. **Expected relation** instance for this relation schema can be found in TR/CLAES/140/2000.5 and TR/CLAES/232/2002.1.

- **Task_parameter-week_no**
- **Task_prameter-month_no**
- **Task_parameter-stage_name**
- **Farm-type**
- **Irrigation-method**
- **Soil-calcium_carbonate**

⇒

<Fertilizer_name>- ***scheduled_quantity*** **= FQ * disputation factor**

VIII. Task Knowledge

Task: fertilization scheduling;

Task-definition:

Goal: get the fertilization scheduling for macro and micro elements;
Input: organic manure, crop, plantation type, irrigation type, soil data, water data, fertilizer specification;
Output: result, schedule

Task-body:

Type: composite
Subtasks:

OBTAIN user data
OBTAIN data from database
DEPENDENCY GRAPH (concept (micro_element), property (quantity))
DEPENDENCY GRAPH (concept (<?macroelement_name>), property (total_quantity))
DEPENDENCY GRAPH (concept (<?macroelement_name>), property (scheduled_quantity))

Additional-roles: element quantity in plant, element quantity in environment, soil parameters, fertilizer

Control-Structure:

OBTAIN User data (Fig. 8); <The Used Microelements and Macro elements Fertilizers >
OBTAIN data from database <All Associated properties with the database fields, as shown in Table 4>
GENERALIZE Organic_Manure_data <This is by setting the elements ratio from the specified organic manure into the parent concept (named: organic_manure) >
Begin Microelements:

DEPENDENCY GRAPH (concept (micro_element), property (quantity))

DETERMINE Microelements_List <Values to “microelements_fertilizers_used” property of the concept “fertilization_schedule” >

PRESENT (As shown in figure 9, Microelements_List elements with their WM values of the property “quantity” and also the values of the properties “application_method”, “application_date”, “advice” respectively could be presented).

End Microelements

Begin Macroelements:

GENERALIZE Organic_Manure_data (This is by
DETERMINE Macro_elements_List <Values to “macroelements_fertilizers_used” property of the concept “fertilization_schedule” >

```
SORT Macro_elements_List <Sort according to the value of the property
                          "periority_order" >

For each Element in Macro_elements_List
        DEPENDENCY GRAPH  (concept (Element), property (total_quantity))
End For

DETERMINE  ScheduleSlots_List  (According to the schedule type and irrigation
                                  type)
PRESENT (The elements of ScheduleSlots_List )

DO:
ON_ELEMENTCHOICE ( ScheduledSlot_List )
Begin
  If fertilization_schedule:type = normal
    If irrigation:type = drip
        Set_to_WM (concept (task_parameter), property (week_no),
                        value (Element))
    Else
        Set_to_WM (concept (task_parameter), property (month_no),
                        value (Element))
    End If
  Else
    Set_to_WM (concept (task_parameter), property (stage_name),
                value (Element))
  End If
  For each Element in Macro_elements_List
        DEPENDENCY GRAPH  (concept (Element),
                                 property (scheduled_quantity))
  End For
  PRESENT (As shown in figure 10, the selected ScheduledSlot_List element and
        Macroelements_List elements with their WM values of the property
        "quantity". Also the values of the properties "application_method" and
        "advice" could be presented)
REPEAT:
```

IX. Proposed Run Time User Interfaces

1. Input data Screen

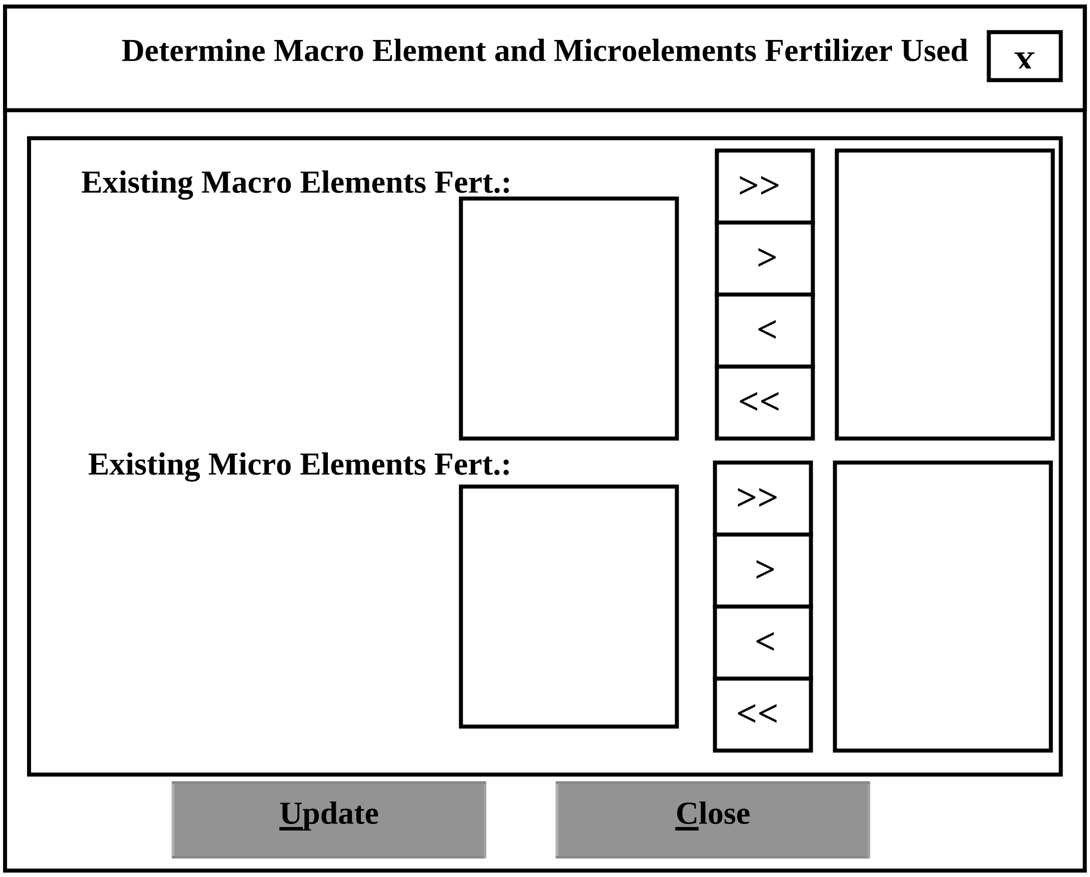

Figure 8: Determine Used Macro Element and Microelements Fertilizers

2. Microelements schedule output screen

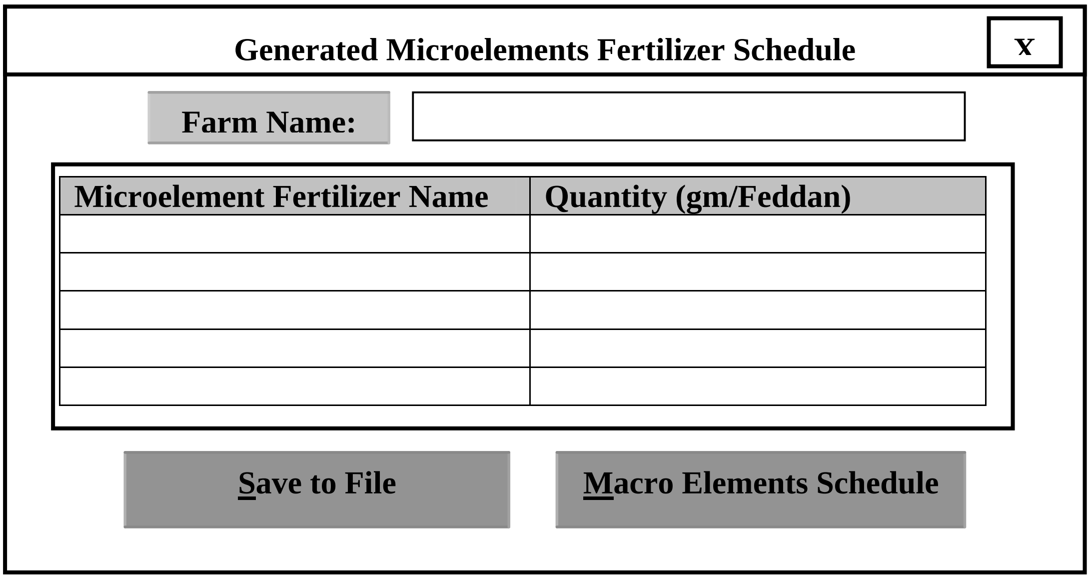

Figure 9: Generated Microelement Schedule

3. **Macro elements schedules output screens**
    a. **Weekly bases schedule screen**
    b. **Monthly bases schedule screen**
    c. **Stages schedule screen**

Figure 10: Generated Macro element Schedule

X. Database Associations:

The following table indicates knowledge base properties, which has database as source of value, and its associated database fields.

Concept	Property	Table	Field
previous_crop	value	farm_table	previous_crop
water	water_analysis	water_analysis_table	water_analysis
Soil	mg_quantity	soil_analysis_table	magnesium_quantity
Soil	mn_quantity	soil_analysis_table	manganese_quantity
water	mg_quantity	water_analysis_table	magnesium_quantity
Soil	n_quantity	soil_analysis_table	nitrogen_quantity
water	mn_quantity	water_analysis_table	manganese_quantity
water	p_quantity	water_analysis_table	phosphorus_quantity
Soil	soil_analysis	soil_analysis_table	soil_analysis
organic_manure	quantity	farm_table	organic_manure_qty
water	qty	water_table	quantity
organic_manure	name	farm_table	organic_manure_name
Soil	k_quantity	soil_analysis_table	potassium_quantity
Soil	cu_quantity	soil_analysis_table	copper_quantity
water	eciw	water_table	eciw
Farm	type	farm_table	type
water	cu_quanity	water_analysis_table	copper_quantity
Soil	ca_quantity	soil_analysis_table	calcium_quantity
Soil	type	soil_table	soil_type
Soil	ec	soil_table	ec
Farm	area	farm_table	area
water	n_quantity	water_analysis_table	nitrogen_quantity
water	ca_quantity	water_analysis_table	calcium_quantity
irrigation	method	farm_table	irrigation_method
Soil	fe_quantity	soil_analysis_table	iron_quantity
water	k_quantity	water_analysis_table	potassium_quanity
Crop	variety	farm_table	variety_name
Soil	p_quantity	soil_analysis_table	phosphorus_quantity
Soil	calcium_carbonate	soil_analysis_table	percentage_calcium_carbonate
water	fe_quantity	water_analysis_table	iron_quantity
Soil	zn_quantity	soil_analysis_table	zinc_quantity
plantation	date	farm_table	plantation_date
water	zn_quantity	water_analysis_table	zinc_quantity

Table 4: Knowledge base and Database Association properties

XI. Built-In/Required Dependency Graphs:

1. Predicted Yield Factor

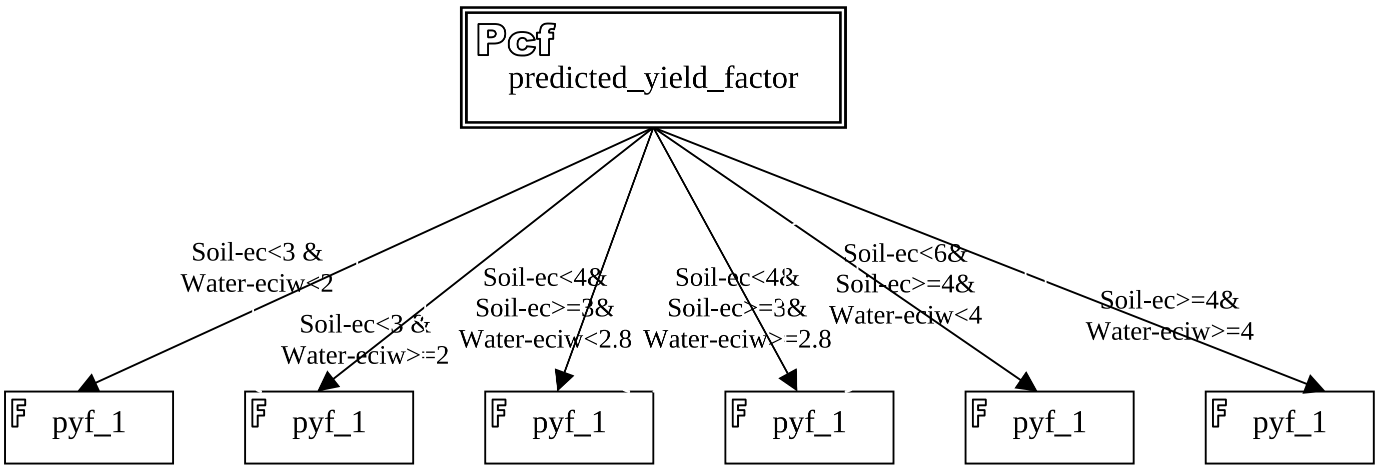

Figure 11: A Conceptual Overview of Predicted Yield Factor

2. Crop N_Contents Element

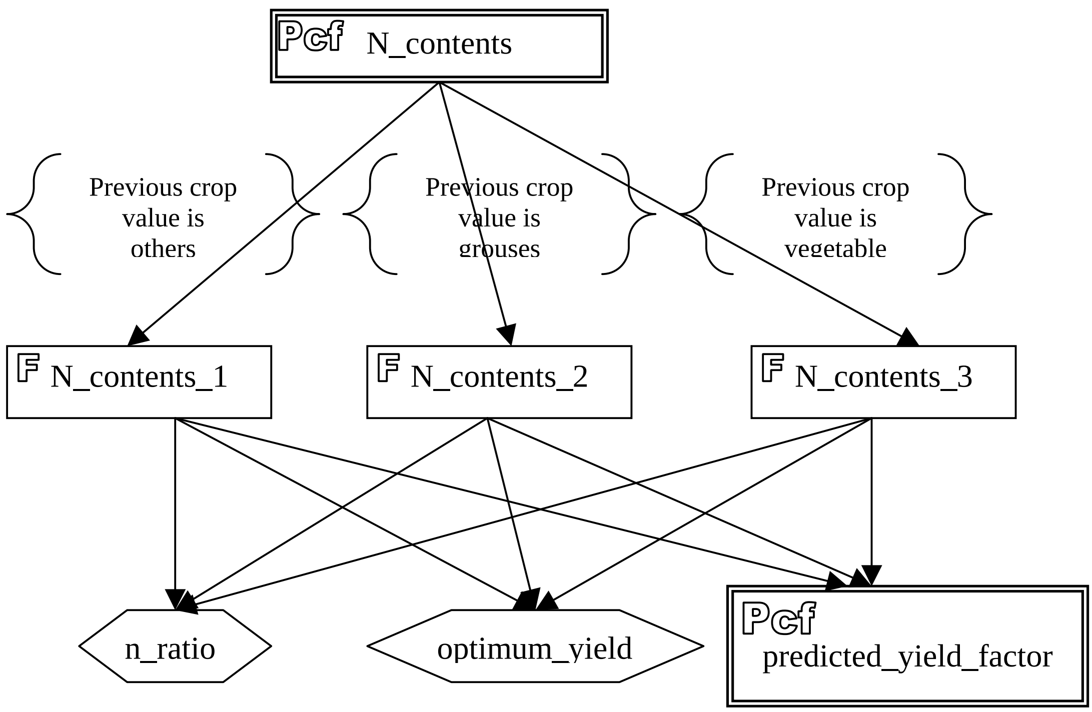

Figure 12: A Conceptual Overview of Crop N_Content Element

3. Crop Elements Contents

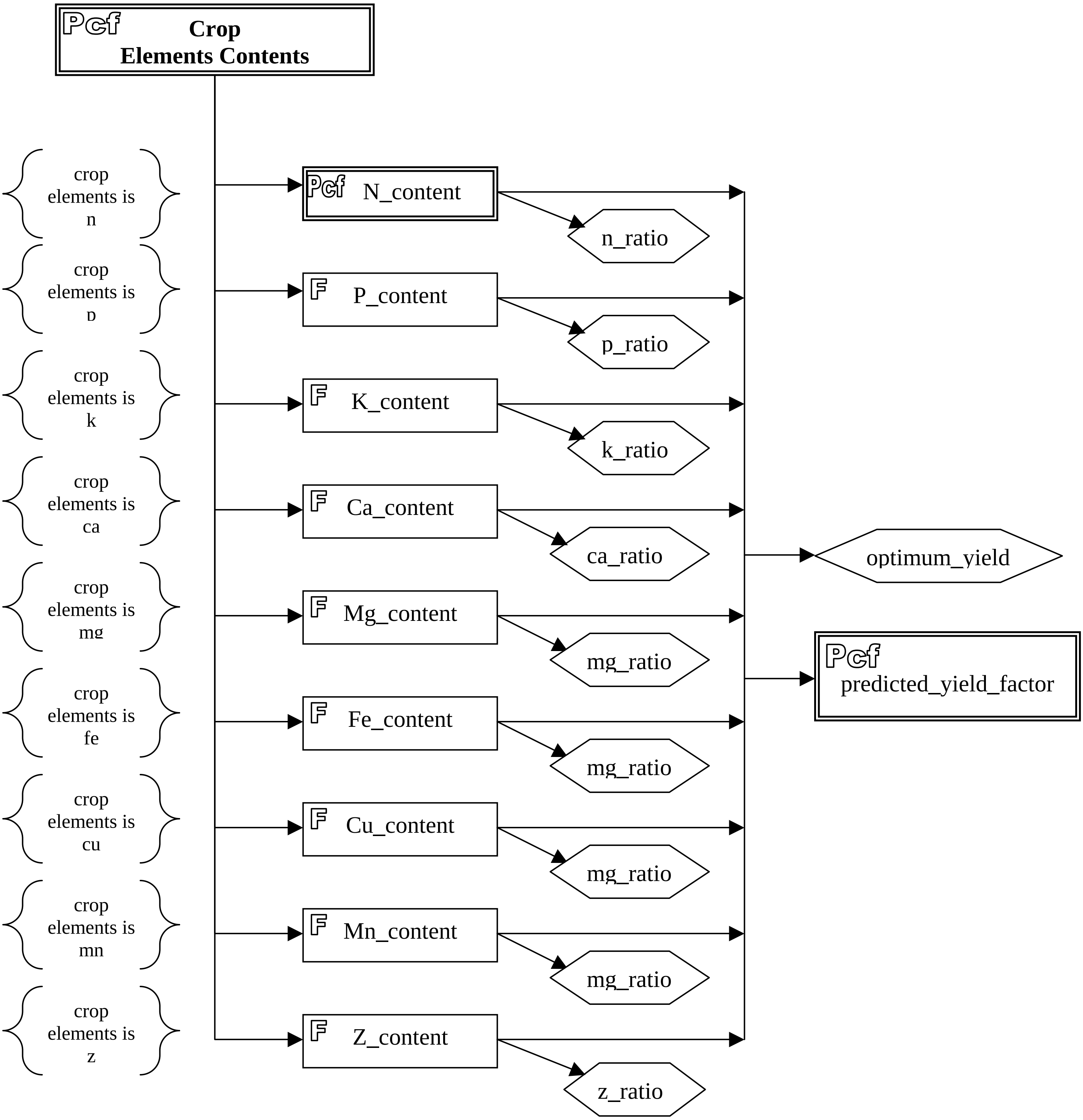

Figure 13: A Conceptual Overview of Crop Elements Contents

4. Environment Elements Contents

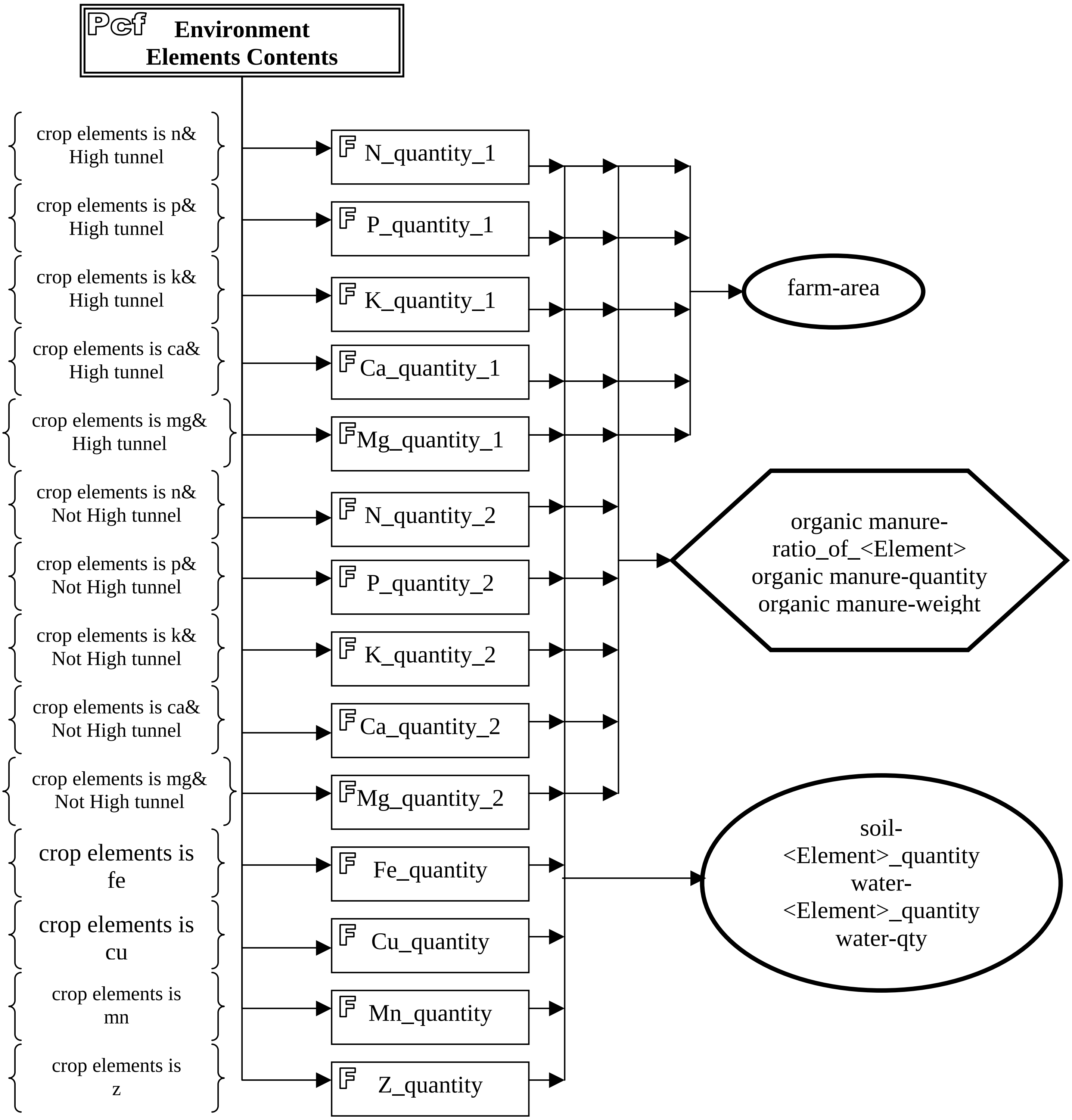

Figure 14: A Conceptual Overview of Environment Elements Quantity