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SUMMARY

Many farmers claim that their main purpose is to make money, but that is too simplistic. Nowadays sustainability and environmental issues are becoming more important. Practices are the management options that apply to a particular sector. Operational elements describe the particular field operations. To be able to manage these forms of complex variability, a co-ordinated approach is required, integrating personal strategies, farm management goals and field operations. The strategies should reflect the values and preferences of the manager in the form of farm management goals. The field operations then implement what is required to meet the management goals.

This report presents a holistic farm management system combining formal management strategies, personal management goals and the technology used. The personal management goals have been identified and analysed. A case study to combine the organic farming standard and the personal management goals for the major field operations is also presented.

The report first categorises and defines the management strategies and practices into three main categories. The first category includes the formal management strategies, which have been analysed on Deliverable 2.1.1.and are the following:

- Cross Compliance
- Integrated Crop Management
- Organic Farming
- Water Policy
- Market-based Farming
- Field subsistence

The second category is the farm management goals, which are:

- Maximised Yield
- Maximised Return
- Minimised Environmental Impact
- Input Replenishment
- Minimised Financial Risk
- Minimised Cost of Production

The third category covers technologies and methods that can be applied to all or sub-operations, which are:

- Conventional Practices
- Intercropping
- Variable Rate Technologies
- Controlled Traffic
- Contour Cultivation
- Conservation Tillage
- Robots

- Autoguidance
- Tracking – Tracing
- Selective Harvesting.

Finally, six field operations have been chosen in consultation with Dr. Edward Nash, leader of WP4 that will be used on the development of the FMIS, which are:

(1) Tillage
(2) Seeding
(3) Fertilising
(4) Irrigation
(5) Spraying
(6) Harvesting

For each of these field operations the farm management goals that apply to them have been identified and analysed. The analysis structure for each goal on each field operation includes the following stages: description of the management goal; principal information needed; decision objective and decision outcome.

CONTENTS

INTRODUCTION

This report on the 'Analysis of Management Strategies and Practices' aims to identify the personal management strategies and practices that a farmer may follow, when (s)he makes decisions throughout the growing season.
This section presents the general framework of the management strategies listing the decision levels, the personal management goals and the technologies that match the listed field operations.

Decision Levels

There are three levels of decisions that a farm manager makes during the growing season; strategic, tactical and operational. Figure 1 shows the three levels of decisions in the shape of triangle on a top down approach[1] (Figure 1). Strategic decisions are in the top of this triangle, because are the major decisions of the farm occur occasionally from year to year. The second level is the tactical or practical decisions. Here the farmer, depending on data and information that can be collected, chooses the best tactical decisions for her/his farm. During the crop season, the farmer can change her/his previous decisions depending on additional information that may have been collected. The last level is the operational decisions. There are in the bottom of the triangle, because of the necessity of taking decisions during everyday work.

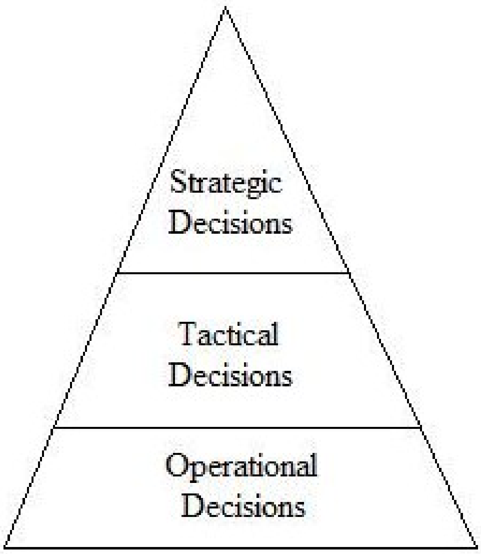

Figure 1. Levels of decisions

Table 1 presents the farm management system. The first column includes the "formal strategies", which the farm manager has to follow, which are management strategies such as Cross Compliance, Organic Farming or Integrated Crop Management or they may choose traditional strategies (conventional farming). The vast majority of the farmers follow at least one of the recognised or formal strategies because their income depends on EU subsidies or their products should follow some regulations or requirements for quality assurance and be competitive in the international market. Secondly, farm managers put their personal values on managing the farms to achieve the best outcome on each field operation. They have to follow one or a combination of "personal goals" (e.g. maximising return and minimising environmental risk).

For carrying out these management strategies and goals farmers should have the appropriate equipment and technologies. To follow a particular management goal specific equipment or technology is necessary and therefore technology is becoming an integral part of the farm management system. Six field operations (fourth column) have been analysed the management goals that are associated with each have been identified. The structure for the analysis of the management goals on each operation includes a description of the goal, the principal information needed, in terms of data and knowledge needed to follow this goal, the decision objective and the decision outcome.

Table 1. Farm management system

Formal Management Strategies	Farm Management Goals	Methods - Tools	Field Operations
Cross Compliance Organic Farming Integrated Crop Management Water Policy Market-based Farming Field Subsistence	Maximised yield Maximised Return Minimised Environmental Impact Input Replenishment Minimised Financial Risk Minimised Cost of Production	Conventional Practices Variable Rate Technology (VRT) Controlled Traffic Contour cultivation Intercropping Conservation tillage Robots Autoguidance Tracking – Tracing Selective Harvesting	Tillage Seeding Fertilising Irrigation Spraying Harvesting

Personal farm management goals

Definitions of personal management goals

The definitions of the personal management goals that have been identified are given below:

Maximum yield is a target of the farmer to increase the crop yield. The main concept is to achieve the highest yield by optimising field conditions (tillage, weather, irrigation, nutrients).

Maximised return has as target to keep the balance between production cost and farm income. Production cost includes all kinds of operations which are related to each crop, energy cost and human labour, while the farm income is related to the product price and external subsidies.

Minimised environmental impact is a basic issue for most of the EU agricultural legislation based on protection of the environmental protection. This management goal tries to reduce the adverse effects that are caused by a development, industrial, or infrastructural project or by the release of a substance in the environment.[3]

Input replenishment is the goal to restore the previous condition of the field as far as fertility and natural resources are concerned. This is an issue of sustainable farming. Sustainable farming is a modern way of land cultivation, which restricts the use of natural resources and implies that the production is economic viable.[4, 12]

Minimised cost of production includes anything that is necessary for plant growth. The major part of the cost of production is labour and energy. This means that the farmer can reduce the production costs in a level which is affordable.

Minimised Financial Risk focuses on avoiding operations which increase cost, but their outcome is doubtful. This means that the farmer must decide when a new technology or method is capable of increasing the income.

Methods - Tools

The commonly used methods and tools that the farmers incorporate in their management goals are listed below and their definitions are given.

Conventional Practices are all kind of operations which are commonly used. They include techniques for achieving the best outcome for a crop, such as managing pests or adapting the crop to relative climatic conditions.

Variable Rate Technology (VRT) is technology which based on information and data that has been collected from the field, in order to manage parts of field with different rates of each application (fertiliser, water).[4]

Intercropping is the management practice of cultivating two or more crops in proximity to promote interaction between them. Plant distance between two crops must be adequate for each crop in order to maximise cooperation and minimise competition. For this issue, the following points must be taken into account: 1) spatial arrangement, 2) plant density, 3) maturity dates of the crops being grown, and 4) plant architecture.[2]

Controlled traffic farming (CTF) is all about managing soil compaction – confining it to narrow strips across the land and maximising the remaining undamaged soil area for cropping. In practice it means matching machinery tracks so they take up the least possible area. Although this is made simpler by satellite guidance, it can be achieved with conventional marking systems. Farm conversion to CTF initially means adopting a CTF "mindset" – the belief that separating wheels and crops is a key method of reducing costs and increasing returns. From here on it is simply a matter of good planning and timely investment that ensures a minimum 15% return on capital, an increase in crop returns and a substantial reduction in costs.[5]

Contour Cultivation performs all tillage and planting of crops on or near the same elevation or "contour." It is applicable on relatively short slopes up to about 8 percent steepness with fairly stable soils. With this system the farmer is avoiding erosion because the contours ridges slow or stop the water flow.[6]

In *conservation tillage*, crops are grown with minimal cultivation of the soil. Conservation Tillage is a method for maintaining more than 30% of previous crop in field, aiming to improve the soil structure with increasing soil organic matter and reducing the cost for tillage. Conservation tillage is part of sustainable farming.[6,7]

Robotics is a new technology approach for improving efficiency. Robots are intelligent machines, which can recognise, depending on collected information, where different management is required. With this technology valuable natural resources and money may be saved.[8]

Operator assist (Auto-steering guidance) is a system which helps the farmer to guide the tractor inside the field. This system consists of a GPS navigation device, in order to locate the tractor, and from one program which have saved all paths within field. Thus, the farmer can save valuable time and increases productivity of operations.[4, 5]

In farming, *tracking* and *tracing*, concerns a process starting with determining the beginning and the end of a product. With this methodology, each consumer is able to know from where this product comes from (place, farm, field), in order to choose the right product for their interests.[6]

Selective Harvesting involves the concept of harvesting only those parts of field which determine the harvesting criteria. There are two different approaches of selective harvesting. The first one depends on quality thresholds and the second one on the ripening stage of crop.[8]

ANALYSIS OF MANAGEMENT GOALS

Management goals for tillage

Tillage is the mechanical manipulation of soil for any desired purpose, but in agriculture the term is usually restricted to the changing of soil conditions for the enhancement of crop production. There are different types of tillage according to the tillage depth, tillage tools and tillage system.[11]

For this field operation, the *management goals* identified and analysed are:

1. Maximising yields

2. Maximising returns
3. Minimising adverse effects to the environment

Additionally, for this field operation a number of <u>*tillage systems*</u> were identified and analysed, which are:

1. Conventional Tillage
2. Minimum Tillage
3. Reduced Tillage
4. No tillage
5. Conservation Tillage

Maximising yield

Description
The farmer is interested to maximise the yield. The highest yields are achieved with conventional tillage. Soil inversion and deep loosening lead to better control of residues of the previous year crops, reduce weeds and other pest infestations and enhance crop growth and yield. At the same time the farmer has to spend more energy and more labour is required. In the long term this goal can cause a decrease of soil fertility but in the short term gives the best yields. Especially when used in sloppy fields it increases soil erosion leading to skeletal soils with low fertility, a condition that can be only reversed with high fertiliser inputs and high costs. This is a goal usually applied when product prices are high and the additional costs to that end are justified.

Data Required
- Crop
- Variety
- Soil type and conditions

Knowledge Required
- Machinery available

Decision Objective
The management goal is to achieve high crop yield by using conventional tillage which gives the best yields.

Decision Outcomes
High yields by using tillage system that requires more energy and labour but achieving better pest control, better seedbed preparation and soil conditions for better crop growth.

Maximising returns

Description
The target is the reduction of the production costs even with small decreases of yield giving finally higher returns. This management goal uses some type of reduced or minimum tillage to reduce the costs, energy and labour requirements. Usually

maintains a deep soil loosening (up to 20 cm) without soil inversion leaving the crop residues on the soil.

Data Required

- Crop
- Tillage system (reduced / minimum tillage)

Knowledge Required

- Machinery available

Decision Objective

The management goal is to achieve the highest possible net income.

Decision Outcomes

Applying this management goal, farmer benefits from maximised return, which is the most important. Furthermore (s)he will maintain soil fertility in field. The main problem from this management goal is the comprehension from farmer, which machine is suggested for these systems of tillage (reduced/minimum).

Minimising adverse effects to the environment

Description

Tillage can affect the soil resource from many points of view. The minimal soil disturbance and the coverage of the soil by crop residues can have a lot of beneficial effects to the soil and the environment. No tillage or strip tillage can increase soil organic matter, the animal and the micro-organisms of the soil (biodiversity) and reduce soil loss due to erosion. All these are very important for the long term soil productivity. This management goal is mostly important in sloppy fields where soil erosion can cause soil deterioration.

Data Required

- Previous Crop
- Tillage system (no-tillage, strip tillage)

Knowledge Required

- Machinery available

Decision Objective

The management goal is to minimise the impact to the soil environment.

Decision Outcomes

From this management goal, Soil environment does not affect from tillage. This means that soil is improving because of minimised tillage. But farmer must apply particular tillage systems (i.e. no-tillage) which require special knowledge and machinery.

Tillage systems

Conventional tillage

Description
One of the most important operations of a crop is tillage. Soil tillage aims at preparing a soil which will enhance crop growth during the growing season and the final yield, preparing a seedbed for crop establishment, controlling weeds and pests, controlling the previous year crop residues, and facilitating mechanical harvesting. Seedbed for crop establishment is achieved through soil disturbance at different depths, soil inversion and soil pulverisation. In this goal, the farmer passes through the field many times, in order to achieve the required result. Tillage as seen by many agronomists aims at preserving soil fertility (maintenance of soil organic matter and structure), increase water infiltration and soil animals, increase stability of clods and reduce erosion risk. Although conventional tillage is defined by ASABE standards as the tillage system prevailing in an area and for European conditions is connected with soil inversion by ploughing.

Data Required
- Crop
- Variety
- Conditions of seeding (soil, climate)
- Machinery

Knowledge Required
- Root development conditions
- Soil mechanics and physics
- Soil chemistry and microbiology

Decision Objective
This management goal is achieved by the best preparation for seedbed, and minimise pests in the field.

Decision Outcomes
With this management goal, the farmer can achieve the best outcome for the preparation of the seedbed and usually the best yields. But there are many objections because the uncovered soil increases water runoff and soil erosion and the deep soil disturbance increases organic matter decay and ultimately this goal requires high energy and labour inputs for all the passes. This goal also increases water evaporation causing soil drying, which affects crop growth.

Minimum tillage

Description
Minimum tillage is the tillage system when the farmer does least soil disturbance to achieve crop establishment and growth. This means that (s)he tries to meet the minimum tillage requirements under existing soil conditions.

Data Required

- Soil structure
- Soil type
- Crop residues

Knowledge Required

- Minimum tillage requirements

Decision objective

Management goal is the best conditions for seeding with minimum soil disturbance and passes in the field.

Decision outcomes

From this goal, farmer is reducing the passes through the field, which means less soil compaction, less energy and labour requirements. The main problem for the farmer is to find the minimum tillage requirements for the specific soil conditions (type and structure) of the farm.

Reduced tillage

Description

In Reduced tillage, the farmer try to maintain a 15-30% of the crop residues cover over the soil with fewer and less intensive operations. In this goal, the farmer's target is to improve the soil properties (nutrients, humidity, and structure) without reducing the population of pests. Additionally the farmer with this management goal reduces the energy and labour inputs.

Data Required

- Energy costs
- Tillage conditions
- Pests
- Crop residues
- Soil types

Knowledge Required

- Machinery
- Avoid needless operations

Decision objective

Sustainability of the soil conditions is the management goal (fertility, structure).

Decision outcomes

The farmer tries to avoid a number of passes during tillage to reduce the energy and labour costs. Besides that, the farmer benefits from this goal, as soil properties are improved, due to less compaction and the increasing soil humidity. But this goal is not possible for all soil types. Furthermore, crop residues are places where the pests can hibernate and probably will cause damage in the next crop. The machinery that the farmer will use for this management goal and the subsequent sowing is specific and they need careful operation and settings.

No-Tillage

Description
The problems that are caused by continuous tillage may be managed with the no-tillage system. In this system, the farmer does not disturb the soil for the new crop except for the formation of a furrow to place the seed in; the farmer is seeding with crop residues on the soil surface. This is very difficult because it is depends on the amount and type (length, strength, water content) of crop residues and requires special equipment. No-tillage cannot be used in badly drained soils as well as in soils that are compacted easily (silty soils).

Data Required

- Crop residues (previous crop)
- Tillage conditions (climatic, soil)
- Pests (weeds, insects)

Knowledge Required

- Conditions for growth.
- Use of the machines

Decision objective
The goal is to sow the field without any tillage.

Decision outcomes
The benefits from this management goal are to conserve soil humidity. Soil organic matter is increased at least in the upper soil layers. Water infiltration and soil structure are also improved. Soil erosion is restricted, because crop residues restrict rain drop impact to the soil reducing the soil particles detachment from the soil clods. The major problem for this management goal is that the use of special and expensive machinery is needed. Furthermore, the weed and pest management is more difficult, because they remain on the soil surface and they continue the cycle. Problems are also attributed to the compaction of the soil which is not alleviated by tillage.

Conservation Tillage

Description
In this management goal, the farmer tries to avoid the problems which can be caused by using no-tillage system or conventional tillage. Conservation tillage describes systems that keep at least 30% of the soil surface covered by crop residues. This means that ploughing and deep burial of the residues is not applied. The system has all the advantages of minimum soil disturbance systems of increased soil organic matter, improved structure, reduced runoff and soil erosion but also some of the disadvantages of reduced residues management causing problems to the work of sowing machinery, increased weed and pest infestations. There are several systems that can be listed under this name such as the reduced tillage strip tillage, contour tillage and other no soil inversion systems. In strip tillage the farmer tills only a narrow strip of the field while leaving the rest undisturbed. The seed is place in a well prepared seedbed without weed completion. It can develop the root without encountering compacted soil which could prevent or delay the root development. At

the same time there are the advantages of not disturbed soil. Contour tillage can reduce water runoff and soil erosion loss.

Data Required

- Crop residues (previous crop)
- Tillage conditions (climatic, soil)
- Pests (weeds, insects)

Knowledge Required

- Conditions for growth.
- Use of the machines

Decision objective

The aim of this management goal is to place the seed in a well tilled strip while maintaining the benefits of conservation tillage.

Decision outcomes

With this management goal, the farmer can better manage the pests and mainly the weeds, than with no-tillage system, and (s)he restricts soil erosion. The major problem from this management goal is the specialised machines that are used. These machines are expensive and they require special knowledge in order to achieve the best performance.

Management goals for seeding

Seeding is the operation by which farmer places seeds on or in the soil for the creation of a crop or a pasture. Seed can be placed n the soil (usually by drilling) or scattered on top of the soil (broadcasting).[10]

For this field operation, the *management goals* identified and analysed were:

1. Maximised yield
2. Maximised return
3. Minimised Environmental Impact (soil cover)
4. Intercropping (method-practice)

Maximised yield

Description

One of the main factors affecting yields is crop establishment. Achieving the target plant density at the best establishment time is the basis of a successful crop. The farmer should choose the right crop and the variety which has the highest adaptability in the region. When the weather is optimal with sufficient soil humidity and the seed is placed at the required depth and sufficiently covered, the output is usually good. The seed rate is a crucial factor, as an increased seeding density may cause competition between the plants causing increased vegetation development and reduced yields. Most crops have an optimum plant density for each region and soil conditions. Usually a higher number of seeds are placed in the soil accounting for seed losses due to low emergence rate. Seed quality, seedbed quality and weather conditions following sowing as well as pest activity define the final population.

Optimum population is the basis for maximum yield. However many factors during the growing period contribute to the final yield.

Data Required

- Crop
- Variety
- Seeding season
- Soil texture and structure
- EC maps
- Elevation maps
- Sowing machine quality and settings

Knowledge Required

- Competitions between previous year crop residues
- Seeding application method (including VRA)
- History of seeding

Decision Objective

The aim of the farmer is to achieve the optimal plant population where the competition does not affect the yield (reduction of yield) and thereby maximise yields.

Decision Outcomes

The target from this management goal is to achieve high yield. In most crops (cotton, sugar beet, maze, corn) there is an optimum plant population that gives the highest yields. The plants have to be evenly distributed in the field in order to compete for sun light and nutrients. Plant population is different for different varieties and soil fertility. Many crops are not sown during the best weather conditions (e.g. cotton, maize), because the farmer wants to be able to schedule the period of harvesting. This is one of the main shortcomings in order to achieve the best seeding conditions. In terms of minimised labour requirements, the optimum plant density/population establishment requires all the skills of the farmer to define seed rate, and depth of seed placement for the prevailing conditions of weather and seedbed.

Maximised Return

Description

The farmer when cultivating the land is thinking how (s)he will maximise the return from the crop. So, (s)he must consider the prices of seeds and machinery input as part of the seeding operation. When the distance between plants is reduced, then the competition is increased and the yield is reduced. The aim is to find the optimum plant density so the crop yield is not affected from the inter-competition. Direct energy consumption such as fuel is important because it is needed as the energy source for the machinery. The competition is also increased when the field is invaded by pests such as insects or weeds. It is important for the farmer to check the population of the pest which affects the competition (mostly weeds).

Data Required

- Price of seeding (seeding, oil)
- Growing conditions (climatic, soil, topography)

- Local history
- Pests (weeds, insects)

Knowledge Required

- Competition between stalks
- Season and timing of seeding

Decision objective

Achieve the maximised economic return.

Decision outcomes

By employing this management goal, the farmer will achieve a high net economic return, and possibly will increase the return by maximising the crop yield. However, this depends on a high germination rate of the seeds and the prevailing growing conditions. When (s)he will try to sow under difficult conditions, it will be possible to sow for a second time because of low germination. Besides that, it is difficult to find the optimal rate when the rate of stalks does not affect significantly the crop yield. In order to achieve high germination, the farmer must take into account the cultivation conditions (seedbed). This means that only with the appropriate seedbed, (s)he will achieve high output.

Minimised Environmental Impact (Soil cover)

Description

A major concern nowadays is the erosion of soil. One of the reasons for soil erosion is the sodification of soil. Sodification occurs when the soil concentration of sodium is high and will leads to poor soil structure. Small particles of the soil are removed and the large particles remaining do not have the capability to hold nutrients. During the rainy season, it is also important to cover the soil with a crop in order to avoid soil erosion. The most important steps in order to sustain soil fertility is to use a crop which is tolerant to bad weather, such as wheat or oilseed rape and to take actions to prevent soil erosion according to soil type and climate.

Data Required

- Soil structure and conditions/Soil thematic maps
- Climate/ weather

Knowledge Required

- erosion potential (salination, sodification)
- Crop coverage

Decision objective

The management goal is to improve the soil fertility.

Decision outcomes

By using this management goal, the farmer will sustain the fertility of the soil for a long period. It is however difficult to manage the problem of soil fertility, because it cannot restore the previous conditions. Taking soil samples every year is very expensive for the farmer. Moreover, the farmer must have special knowledge in order to understand where the field is susceptible to this problem

Intercropping

Description
The practice of intercropping is very important because the mutual growth of two different crops is achieved. The basic impact is the cooperation between the two crops which is one of the most important principles in nature. The biggest problem of this practice is to understand when the competition between the two crops affects the yields of them. It is also very important to gain knowledge on the best period for sowing each crop, in order reduce yield effect on any of them.

Data Required
- Row distances
- Portion of each crop

Knowledge Required
- Intercrop competition - cooperation
- Season of seeding (different or same timing)

Decision objective
Target of this practice is to gain mutual beneficial relationship between the crops.

Decision outcomes
The benefits from this practice are the co-operation between each crop: applied properly; this will lead to higher yield and improved protection against pests. But the problem of applying this practice is that it requires expensive and specialised machinery, which may require enhanced knowledge for operation. It is also very complex to understand which combination and ratio (portion) of crops that will give the best result.

Management goals for fertilising

Fertilising is the operation by which the farmer is adding chemical or organic substance to the soil, in order to supply those elements required in the nutrition of plants.[12]

For this field operation, the *management goals* identified and analysed were:
1. Maximised yield
2. Maximised return
3. Replenishment
4. Nutrient Balance
5. Minimised Environmental Impact
6. Intercropping
7. Acidification management

Maximised yield

Description

To achieve maximised yield, we must fertilise with the demand related rate. Necessary information for this goal is to know the response of the crop as a function of the fertilisation rate and the process of the fertiliser transition in the soil. The optimal rate for this goal is when in the dose – response curve tend to be asymptotic. It is very important to know when and how each crop can absorb the most of the quantity of the fertiliser applied. Fertilisation time can affect the leaching and generally the movement of the nutrient in the soil. The movement of the nutrient in the soil also depends on the fertiliser form. The machinery which is used for fertilisation is also very important for achieving uniformity or variable-rate application.

Data Required

- Crop
- Variety
- Fertilisation timing
- Fertiliser composition (Nutrients)
- Fertiliser type (dry, liquid)

Knowledge Required

- Growth stage
- LAI, chlorophyll indexes
- Method of estimation
- Real time canopy management
- Fertilisation timing
- Fertilisation application method (including VRA)
- History of fertilisation

Decision Objective

Increase crop yield as a result of optimised to fertilisation rate and application method

Decision Outcomes

The result of this management goal is to have the highest achievable yield in each field. However, in some parts of the field there may be problems of leaching or runoff of fertilisers which are at higher rates than expected. This is the most important reason for the eutrophication and contamination of the sea and fresh water. The farmer will possibly realise that this goal is expensive because of the increasing prices of fertilisers.

Maximised Return

Description

Most farmers want to maximise their income in order to continue to cultivate their land and stay in business. It is therefore important to know the prices of the final product (e.g. wheat, cotton) and of the inputs (fertilisers). Besides that, it is very important to know the costs and the benefits of the crop production. This means that he must know two variables, the price of final product and the price of fertilisers. This analysis contains two parts. The first one is the relationship between the fertiliser factor (price of fertiliser) which is the independent factor and the yield as dependent factor. This means that the response of each crop to the fertiliser depends on the biological circle of the plant and in the local environment. The second part of this model is the relation between the prices of product according to the yield. When the deviation between the two curves (price of fertiliser-yield and price of product-yield) is the maximum, then this is the optimal rate of yield with the maximised return.

Data Required

- Price of final product (crop)
- Price of fertiliser
- Previous year's yield
- Growing conditions (climatic, soil)
- Season and timing of seeding

Knowledge Required

- Response of yield to fertiliser rate
- Partial economic analysis, specifically cost benefits
- Yield Potential

Decision objective

Achieve the maximised economic return.

Decision outcomes

Taking this goal, the farmer will have a high net economic return. That means that they will earn more money than from maximising the crop yield. But very often this is not possible because the prices through the year are not constant and so the optimal fertiliser rate is changing through the season. It is also difficult for the farmer to understand the response of the plant on the fertilisation in order to understand which rate is the optimal at a given time. Besides that, this management goal needs a huge quantity of data, which is very difficult for the farmer to collect and analyse.

Replenishment

Description

In this practice, the farmer must know what the crop removes from the soil every year and try to apply equivalent quantities to make up for the removal of nutrients. For this practice, it is necessary to know which nutrients the crop extracts from the soil and also in which concentration. It is therefore important to know which system of crop-rotation the farmer should use.

Data Required

- Yield mapping
- Previous crop (tissue analysis)
- Crop-rotation

Knowledge Required

- Yield trend maps

Decision objective

Replace the quantity of the nutrients consumed by the previous crop

Decision outcomes

In this practice, the soil fertility remains constant. The problem for applying this practice is to have knowledge about the requirements for each crop. The farmer should also take soil samples each year because it is necessary to dynamically estimate the best rate of fertiliser every year in order to restore the previous fertility condition of the soil. This problem can be avoided if the farmer takes samples from various tissues of the plant like leaves, in order to fertilise depending on the nutrients uptakes from the crop. However, this method is very expensive and maybe needs special knowledge in order to be in performed a comprehensive way.

Nutrient Balance

Description
The objective and target of this management goal is to reduce the limiting factors which affect the crop growth. Generally in this goal, the farmers try to eliminate deficiencies of nutrients by using particular fertilisers. For example, for deficiency of boron it is possible to use boric acid in a particular rate and concentration. It is therefore important to have information about the nutrients which affect the growth of the crop and in which concentration they are needed. For this management goal it is necessary to map the most important nutrients for the crop. For fertiliser application it is necessary to know the nutrients loss, which is mostly from previous crop biomass and leaching/runoff.

Data Required
- Soil sampling - mapping (macronutrients – micronutrients)
- Tissue analysis
- Nutrients loss
    - Previous Crop (species and age)
    - Leaching/Runoff

Knowledge Required
- Nutrients type and quantity which affect the crop growth. (limiting factors)
- Timing of needs

Decision objective
Maintain the crop yield and soil fertility in a sustainable way.

Decision outcomes
The result of this management goal is to produce a balanced crop without problems of growth. The biggest impact is on the income because sometimes it will need to use specialised fertiliser in order to face this problem, like some micronutrients, which means high cost for this application. Besides that, the cost of soil or tissue sampling may prevent the farmer from using this goal, because they are expensive methods.

Minimised Environmental Impact

Description
Nowadays, the protection the environment attracts a lot of attention. The micronutrients in the soil move directly to the roots or combine into colloids of the soil or are leaching. It is important to know the possible movements of nutrients in the soil, in order to fertilise the crop with the optimum rate for avoiding leaching. For avoiding run off, the farmer should cultivate the field in the contour line. For the best application, it is important to know how it is better to incorporate the fertiliser in the soil, because most of the ingredients in the fertiliser are volatile, and this will create

emission problems. The rate of the fertiliser is calculated by the current crop needs and the previous crop.

Data Required

- Soil sampling/ Soil thematic maps
- Previous crop

Knowledge Required

- Model of the nutrients' movement in the soil (mostly macronutrients)

Decision objective

Reduce the fertiliser to an amount that has low impact on the environment and provides a yield that does not affect the farmer's income.

Decision outcomes

This is a management goal that reduces significantly the impact of leaching and runoff to the sub-surface water and lakes. The cost of soil sampling is a limiting factor for following this goal. This cost is reduced if the previous crop is a legume or a crop with low requirements for inputs. However, the predominant difficulty to apply this goal is the required knowledge of the movement of nutrients in the soil. The cultivation in the contour-line is also difficult because of the difficult driving conditions.

Intercropping

Description

In order to reduce the nitrogen application in the farm, farmers try to cultivate two crops simultaneously; one is legumes (vetch, beans) and the other is a common crop such as wheat or oil-seed rape. The aim is to reduce the rate of nitrogenous fertilisers, using a second crop which has the ability for nitrogen-fixation. It is important to know which crop will be used, because the competition between the crops affects the main crop. Apart from the competition, the farmer must know which the best row distance between the two crops is. The seeding season it is up to the season's conditions and timing of seeding of each crop is depending on the growth rate.

Data Required

- Row distances
- Season of seeding
- Different or same timing of seeding

Knowledge Required

- Intercrop competition

Decision objective

To reduce the rate of nitrogenous fertilisers using a second crop which has the ability to fix nitrogen.

Decision outcomes

From this practice the advantage is the reduction of nitrogenous fertilisers which is the biggest problem in the contamination of the fresh water. The biggest problem for this practice is that it is obligatory to use special equipment with high investment costs. It is also important to know which of the two crops is more competitive in order to use the best fit to the practice.

Acidification management

Description
The biggest problem of the soils in regions with high rate of rainfalls is acidification. The problem is aggravated when using mainly nitrogenous fertilisers. The farmers should reduce the use of fertilisers which will eventually reduce the pH in the soil. The acidification causes deficiencies in most micronutrients such as iron, because they are combined with the soil colloids.

Data Required
- Soil sampling
- pH map

Knowledge Required
- Identifying possible reasons for acidification (rainfall, mother stone, fertilisers)

Decision objective
Increase the soil pH using various fertilisers (mainly calcic and ferrous).

Decision outcomes
The problem of acidification is minimised by using this management goal. The deficiencies of micronutrients will reduce, because the soil pH will increase and the nutrients will be available for the plant. But the problem for this goal is to find and use the right fertiliser in order to force it. The quantity of the fertiliser depends on the gravity of the problem. The cost of soil sampling is usually high, so it makes it difficult to follow this goal to a large extent.

Management goals for irrigation

Application of water by artificial means is Irrigation. Purposes for irrigating may include, but are not limited to, supplying evapotranspiration needs, leaching of salts, and environment control.[13]

For this field operation, the *management goals* identified and analysed were:
1. Maximised yield
2. Maximised return
3. Minimised Environmental Impact
4. Replenishment

Maximised yield

Description
The most important factor for crop growth is water. It is generally acceptable that crop yield and the amount of water are highly correlated. This means that the crop yield is increasing when there is adequate water. Water application level is connected to yield with a sigmoid curve. At very low water applications there is no yield reaction. At higher levels yield is increasing at high rates till a level when yield is stabilised. Higher water applications cause water logging and the destruction of plants.

The farmer therefore needs to know the real needs of the crop to apply the proper water levels. Additionally, crops such cotton require at some periods of the growth cycle to be under water deficiency stress to enter the productive stage. Full water applications could lead the plant to remain in a vegetative stage and reduce yield. The farmer, in order to achieve maximum yield, should know how much and when the water should be applied in the field to avoid causing any yield limitations and at the same time does not cause any other problems, such as fungus growth. The amount of water also depends on other field operations, such as tillage and fertilisation, the growing stage of the crop and the weather conditions expected in the next time period. Different crops or varieties also have different interaction with irrigation. That means that different varieties could achieve maximum yield with different irrigation scheduling and amount of water.

Data Required

- Crop
- Variety
- Climate
- Soil type and conditions
- Method of irrigation

Knowledge Required

- Relation between water and yield
- Specific crop requirements

Decision Objective

The management goal is to reach the maximum achievable yield.

Decision Outcomes

From this management goal the farmer will achieve maximum yield. Nowadays, however, in order to irrigate the fields, there is the necessity to sustain the natural resources and not to over-irrigate in regions where water resources are limited. Additionally, the cost of irrigation is getting higher. Farmers will often have to build water reservoirs in the farm to irrigate during the growing season.

Maximised Return

Description

In many cases irrigation stress is required to achieve the productive stage of the crop (cotton) but also to achieve the best quality and obtain premium price for the product (grapes for wine production are paid based on the sugar content which is affected by irrigation water availability during the season). In this goal, the farmer must consider all costs for the cost of pumping plant installation and its efficiency affecting the farmer’s net income. The cost of irrigation energy is one of most important factors of production costs. The cost of energy depends on kind of energy (electricity, oil), the pricing policy in each country and the depth of pumping water from the ground aquifers. The needs of a crop are higher when the season is dry, as in summer; because rainfalls are not enough for cover. Yield and the price of the end-product is the factor which affects the final amount of the applied water.

Data Required

- Crop
- Irrigation system
- Growth Season
- Cost (water, electricity, oil)
- Yield and Product price

Knowledge Required

- Crop water requirements
- Specific crop requirements

Decision objective

The management goal is to achieve maximised economic return.

Decision outcomes

Following this goal, the farmer will have considered the factors for a high net economic return. That means that (s)he will earn more money than from maximising the crop yield. The major problem for the farmer is to find the amount and the timing of water application that can achieve maximum net income. This is very difficult because the price of product and the energy cost are changing and this makes difficult the calculation of the final return. The amount of rainfall from year to year is changing. This means that every year has different requirements for irrigation. In cases where water supply is in shortage the selection of a proper crop rotation can offer final return benefits.

Minimised Environmental Impact

Description

In this management goal, the farmer tries to achieve the minimum cost to the biosphere. This means that (s)he should protect the surface and underground water. In order to apply this management goal, (s)he should cultivate crops and varieties which are tolerant to drought or irrigate with the minimum water for crop growth. Most crops of the rotation for this management goal must be rainfed. There are two aspects the farmer should observe. To pump every year the amount of water that can be replaced in the aquifer and use application methods that increase water use efficiency (water used by plants over the applied water). Drip irrigation is the most efficient water application method.

Data Required

- Tolerant crops/cultivars to drought
- Growth season
- Soil type
- Irrigation system efficiency
- Water losses
- Water replacement rates of the aquifer

Knowledge Required

- Minimum water requirements

Decision objective

The management goal is to increase the water deposits in biosphere.

Decision outcomes
The basic impact from this management goal is the sustainability of water resources. This means that farmer manages his/her crop a sustainable way. The major problem from this management goal is the reduced yields or the low income crops in the rotation which means for the farmer low income. Besides that, it is very difficult for the farmer to calculate the minimum for the growth water demands, because it depends on factors which are very complex, such as soil.

Replenishment

Description
The basic issue in irrigation in places with water shortages is to replenish the water losses. There are available algorithms which could calculate these demands. The basic parameters of this calculation are the climatic data of region (temperature, wind gust, rainfall etc), the soil type, as well as the growth stage of crop. This means that the crop has higher demands when it is flowering or the fruit is “growing”.

Data Required
- Climatic conditions (data)
- Growth stage
- Crop
- Soil type
- Season Growth

Knowledge Required
- Calculation of evapotranspiration (ET)

Decision objective
Management goal is to gain mutual beneficial relationship between the crops.

Decision outcomes
With this management goal, the proper water amounts are secured. The crop is not adversely affected by irrigation. This means that the demands of crop are covered by supplying the proper amount of water. The main problem in this management goal is the calculation of ET. It is very difficult to calculate ET for every day, because it requires special knowledge about the algorithm. Besides that, ET measurement is based on previous years’ data, which differ from year to year.

Management goals for Spraying

Water or other liquid moving in a mass of dispersed droplets, in a form of a wave, is spraying application. There are different types of spraying depending on the way of application (broadcasting, strips, site-specific) and the size of droplets.[6,11]

For this field operation, the ***management goals*** identified and analysed were:
1. Maximised yield
2. Maximised return
3. Minimised Environmental Impact

Maximised yield

Description
The most difficult part of cultivation is plant protection. The farmer should use agrochemicals in order to maintain the crop in a high yielding level. In order to maximise yield, the farmer should spray the crop following either a fixed annual spraying programme every year or spray based on field scouting and using the economic damage threshold. This programme depends on the potential and actual threats (weeds, insects, animals, viruses), the growth stage and the weather conditions.. Moreover, it is important for the spraying program to achieve the highest plant protection per pesticide input. The most important factor which affects the spraying efficiency is the weather conditions. For example, when the weather is wet diseases are developed and more applications are required to protect the production. On the other hand rainy and windy conditions reduce spraying efficiency and in many cases make the application impossible. Additional necessary information for this management goal is to know the composition (active ingredients and form type) of agrochemicals, in order to spray with the appropriate pesticide. The machinery used for spraying is also very important for achieving uniformity (even distribution) of pesticide application. Variable-rate spraying could increase efficiency when properly applied. Integrated pest control is a new idea to reduce pesticides use. Spraying is based on the definition of a threshold of damage that is required before a spraying is applied. It gave good results of plant protection at a low pesticide use and minimal environmental problems.

Data Required
- Crop
- Variety
- Pests cycle (Weather conditions-adversities, enemies)
- Spraying timing
- Agrochemicals composition (effective substance)
- Pesticide type (liquid, powder)
- Growth stage

Knowledge Required
- Pesticide cycles
- Damage to the crop
- LAI, chlorophyll indexes
- Real-time canopy management
- Spraying application method (including VRA)
- History of spraying

Decision Objective
The management goal is to achieve high crop yield with chemical pest control.

Decision Outcomes
The output of this management goal is to achieve the highest possible yield. The major problem when applying this management goal is the potential danger to wildlife and the natural enemies of the pests. The frequent use of pesticides could cause

problems in the biosphere (air, fresh waters, seas, subsurface water). In 1960s a new term was added in our life, the bioaccumulation, as some pesticides (like DDT) are accumulation in the food chain due to slow or lack of degradation, leading to contamination of higher animals, including humans. The cost of eliminating any pest is very high and is increasing as the agrochemicals prices increased, mainly due to the raise of the oil price. As a result, it may be very difficult to completely protect the crops from any possible pests, weeds and diseases.

Maximised Return

Description
The main driver for the majority of farmers is to achieve the largest profit, in order to remain in the farming business. The most critical factor for the farmer to know is the cost of the damage. Only when this cost is higher than the economic threshold the farmer should spray. Economic threshold is the pest density at which management intervention must be taken to prevent the pest from reaching the economic injury level[10]. The cost of spraying has to include at least the machinery depreciation and use, labour cost and pesticides' cost. Additionally, the farmer may have to adopt new farming management goals, such as changing season or timing of seeding or crop rotation, in order to reduce the risk of threats. This depends on the growing condition (mostly climatic but also soil, rotation etc) and the period when the pest causes bigger damages.

Data Required
- Cost of spraying (agrochemicals, diesel oil)
- Growing conditions (climatic, soil)
- Season and timing of seeding
- Local history
- Growth stage

Knowledge Required
- Growth stages of the plants prone to pests damages
- Method for define economic threshold
- Modelling of damage
- Deep knowledge of pests biology

Decision objective
Achieve the maximum economic return.

Decision outcomes
If the farmer follows this management goal, (s)he will have a high net economic return. That means that (s)he will earn more money than from maximising the crop yield. The main problems to follow this management goal are the difficulty of finding the economic thresholds and define the appropriate times for pesticide applications. This is very difficult, because for each pest, the farmer must find the respective economic threshold. Even when this is defined it is difficult to make the application in time to avoid any further damage. Size of the farm, weather conditions could stop spraying operations and delay the application. Besides that the prices change through the season, which complicates the problem.

Minimised Environmental Impact

Description
Nowadays, the basic issue is the protection of the environment. The farmer should be very careful. The biocides in the agro eco system follow two pathways. The first one is the absorption of the active ingredient from the plants through the leaves and roots and control the pest. The second is through evaporation to the air or through run off (leach) to underground waters. In this case it pollutes the environment. To avoid pollution and environmental damage it is very important to know the possible movements of the biocides in the agro system and their fate in the time. When a farmer is spraying, (s)he must check if (s)he will affect the ecological balance of the agro system, because it is possible to increase the population of other pests, which can cause damage to the crop. One of the systems is organic farming that eliminates almost entirely the use of pesticides.

Data Required
- Soil structure and conditions and hence leaching potential (through sampling)

Knowledge Required
- Pest biology
- Pest, weather, crop interactions
- Movement of the biocides in the environment of field (plant uptake, absorption of soil particles, runoff or leaching, volatilisation).

Decision objective
Reduce the environmental impact of spraying while maintaining a large profit for the farmer.

Decision outcomes
The farmer will have two significant outputs from following this management goal. First, (s)he will reduce the concentration of dangerous chemicals like most pesticides and produce more healthy products. Second, the farmer's health will not be in danger due to handling of harmful substances. The major problem for this management goal is the reduction of yield, due to the acceptance of damage before the application. Furthermore, most of the times, the quality of the product is deteriorating, because it may contains marks caused by pests that were not treated.

Management goals for harvesting

Harvest is the process of gathering the crop or product at the end of the growing season for use, consumption or processing.[10]

For this field operation, the ***management goals*** identified and analysed were:
1. Maximised yield
2. Maximised return
3. Minimised Financial Risk
4. Selective harvesting (sub-served practice)

Maximised yield

Description
In the goal of maximising the yield as related harvesting, the influencing factors are considered and managed by the farmers. First of all, the crop under consideration must be optimised in terms of variety adapted to the local microclimate. Next, it is very important to know when the right time for harvesting is. The scheduling of harvest depends on the performance of the harvesting machinery and the current state of the crop in terms of ripeness, moisture content, etc. and the weather forecast at any given time. When the crop is fully ripe for harvesting, then the crop losses are reduced. But the farmer should also consider mechanical harvesting losses, which are affected by machine speed, weather conditions during harvesting and harvest adjustments.

Data Required
- Crop / Variety
- Weather conditions/weather forecast
- Stage of harvest ripeness
- Machinery performance

Knowledge Required
- Relation between stage of ripeness, weather conditions and maximised yield

Decision Objective
The management goal is to reach the maximum achievable yield.

Decision Outcomes
Applying this management goal, the farmer achieves the highest potential yield in each field. The main problem of this management goal is the difficulty in determining when the crop is ripe for harvesting. This means that the period when the losses from harvesting are low is very short. Also, the quality of the final product may be compromised because the harvesting process will in many cases mix high and low quality.

Maximised Return

Description
By applying this management goal, the farmer will acquire a higher net income. For harvesting, farmers must use special machinery, such as a cotton picker. In order to reduce the cost of this operation, (s)he must restrict the cost of energy (usually fuel). Besides the cost of energy, (s)he must consider the cost of labour, which is one of the most important costs in agriculture. Also, if the driver has low productivity, this increases the cost. The overall costs of specialised machinery such as harvesters are high and can only be reduced by increasing its utilisation, i.e. increasing the yearly harvested area.

Data Required
- Crop
- Irrigation system
- Growth Season
- Cost (water, electricity, fuel)

- Yield and Product price

Knowledge Required
- Crop's water needs

Decision objective
The target of this management goal is to achieve the maximised economic return.

Decision outcomes
By applying this management goal, the farmer will acquire a high net economic return. Besides that (s)he will reduce the operational (energy, labour, etc.) cost which is very important not only for his/her income, but also in terms of minimising the environmental impact. The biggest problem from this management goal is to identify the proper period for harvesting, which is very difficult without any help from special analyses of laboratories. It is also difficult, depending on weather data, to reduce irrigation in order to harvest the product in the right conditions.

Note:
A high return for is achieved by balancing the costs of harvesting with the value of the harvested product. That might imply that the farmer accepts a lower yield (e.g. increased losses) in return for reduced harvesting costs.

Minimised Financial Risk

Description
The basic issue nowadays is the need of new technology in agriculture. This means that a farmer must consider the cost of introducing new technologies in his/her farm. Besides that (s)he does not want to risk his/her overall investment in agriculture .

Data Required
- Machinery Cost (Acquisition and operational)
- Yield and product price

Knowledge Required
- Calculation of difference between increasing income and cost of new technology

Decision objective
The management goal is to minimise financial risk (investment).

Decision outcomes
By minimising the financial risk, the farmer tries to avoid risk to his/her investment in agriculture. Most of the technologies that are used require high investment costs and are associated with high risks. The basic problem of this management goal is that the farmer will have problems with applying new technologies when they are necessary and (s)he will not have the ability to deal with new technologies.

Technology subserved practice - Selective Harvest

Description

Crops grow unevenly and with different rates across the field. This means that parts of the field will achieve the ripeness stage quicker than others. In order to achieve the highest possible quality for the crop, the farmer must harvest different parts of the field at different dates or harvest in different bins. In the first case, special machinery for this management goal is not needed, except for a GPS-receiver. In the last case, there is also a need for special equipment which can separate the harvested material in two or more different bins.

Data Required

- Thematic/Soil/Vegetation Indexes Maps
- Satellite/Airborne Images
- Weather conditions
- Quality parameters measurements

Knowledge Required

- Relation between harvest and ripeness stages

Decision objective

The aim of this management goal is to achieve the highest possible quality for the final product.

Decision outcomes

The basic benefit from this management goal is the improvement of product quality. The farmer can increase the income because of selling a higher quality product. The main problem associated with this management goal is the cost of buying special equipment which can distinguish the different areas within the field. Besides that, the farmer must have special operational knowledge in order to determine the best ripeness stage for harvesting.

Case study

A case study was developed to combine formal management strategies and personal management goals. For this case study “Organic farming” was chosen as formal management strategy (column 1 in Table 1) and the management goals that a farmer may choose during the growing season. This example is based on the EU standard for organic farming (Council Regulation (EC) No 834/2007) and based on Greek farming conditions.

The first step for applying organic farming is to choose the right crop and farming system with access to the needed nutrients. The crop is depended on adaptability on local conditions (climate, soil conditions). If the crop is not adapted to local conditions, then the farmer could not possibly comply with the organic standards.

Secondly, to achieve the best crop establishment soil cultivation should be taken into account. For soil cultivation, the farmer can use any tillage system that maintains or improves soil fertility such as no-tillage or strip tillage. The management goal that he is suggested to achieve is the adverse effects to the environment or a combination with maximising return.

Organic farming application demands farmers to use only seeds produced from organic fields. Otherwise, the use of conventional seeds should be followed by confirmation of non availability of organic ones as well as not being treated with a prohibited substance. The best goals for seeding in an organic field are soil protection (from erosion), intercropping and maximised return or a combination of them. Management goals which help to avoid soil erosion in any way are included in the organic farming standard. Intercropping is a practice that has very good outcomes for avoiding many problems, such as using inorganic nitrogen fertilisers and spraying for pests.

In organic farming, fertilisation is very restricted and is based mainly on organic material that is produced at the same farm or obtained from other organic farms. There is not any goal that satisfies the standard. Management goals that cover part of organic farming standard are intercropping, acidification management and replenishment and minimised environmental impact. Most of them are compliant with the basic issue of organic farming which is minimising the nitrogenous fertilisers by not using chemically synthesised inputs which are difficult to break down.

In order to use of irrigation water effectively, farmers should use an irrigation system with high efficiency such as drip irrigation. Therefore, the farmer has to decide mainly between two management strategies; replenishment and minimised environmental impact. The goal of Maximising returns needs to apply large volumes of water, which means that is not the best goal for an organic farm.

Crop protection from pests generally in organic farming is implemented by using natural enemies of pests or varieties of plants tolerant to them. Additionally, farmers can use products without negative impacts to environment, such as pesticides based on *B. Thurigiensis*.

Regarding the management goals for harvesting there are not any restrictions and that are possible to follow. The only issue is to have cleaning all the equipment from substances that are prohibited for organic farming, before using it in an organic farm.

CONCLUSIONS

It is important for farmers to see farm management as a holistic approach. Formal management strategies can be combined with personal management goals to improve the outcome for different field operations. Six personal management goals have been identified, described and analysed for six major field operations. These management goals are: maximised yield; maximised return; minimised environmental impact; input replenishment; minimised financial risk and minimised cost of production.

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