Project no.	**212117**
Project acronym:	**FUTUREFARM**
Project title:	**Integration of Farm Management Information Systems to support real-time management decisions and compliance of management standards**
Instrument:	**Collaborative project**
Start date of project:	**1st January 2008**
Duration:	**36 months**
Thematic Priority:	**THEME 2 FOOD, AGRICULTURE AND FISHERIES, AND BIOTECHNOLOGY**

Deliverable 5.1
System description of proposed Farm Management Information System (FMIS)

Due date of deliverable: **30/06/2008**
Actual submission date: **31/08/2008**
Accepted by Claus Aage Grøn Sørensen (AU) on 09/09/2008.

Work package 5: **Socio economic, technology assessment – economic and environmental impact**

Organisation name of lead beneficiary for this deliverable:
University of Copenhagen (UCPH) Revision**: Final**

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Project co-funded by the European Commission within the Seven Framework Programme (2007-2013)

Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Abstract

The outcome of this work package includes a description of a farm management information system which allows more intelligent decisions about the use of different input sources, treatments and information management systems (incl. precision farming systems) for a number of crop rotation systems. To achieve this, it was decided to assess the cost structure and potential benefit for these crop rotation systems for different technologies. Focus is on commonly produced crops in different European regions including wheat, rape seed, sugar beets, maize and other cereals, cotton or other crops.

For selected systems (in order to support WP 4), the model description makes a distinction between management at the strategic level (investment in new technology), the tactical level (farmers seed and crop choice etc.) and the operational level (decisions about nitrogen applications and pesticides at a particular time). However most of the focus in this model description is on the operational level.

With this approach we will estimate the cost of different information-intensive and safety systems for different scale capacities and compare it to conventional systems. Potential benefits related to these systems such as: labour and fuel savings or higher work quality will be estimated and used to quantify the new factor productivities. The model will be based on risk-averse behaviour and economic optimisation for different management scenarios in different rotations with different technology and technical safety levels.

For the model the following techniques will be investigated further at an operational level, taking into account (1) Variable rate application technology and (2) Information management for improved logistics:

- Automated steering and optimized route planning
- Planning of fertilizer application and variable rate application.
- Variable herbicide spraying based on weed maps and weather forecast
- Variable rate cultivation of soils based on soil maps
- Harvest logistics harvest timing with fleet management
- Variable rate seeding
- Chlorophyll content measuring before harvesting to optimize harvest procedures
- Management of areal subsidies

In the analysis of different systems we may also have to include the following:

For Precision farming: 1. Variable Rate Pesticides (insects and fungi) and 2. Variable Rate irrigation (especially in Southern Europe)

For Information Management we may have to include: (1) Automated farm record keeping, (2) Ad-hoc guidance and advice for carrying out organic farming and (3) Route-planning for autonomous vehicles in agriculture

The above systems will be aggregated in terms of their broader socioeconomic impact.

A system to optimise production

For the majority of farmers a key objective with arable farming is to improve the economic viability. However, in what sense is the farmer capable of improving the economic benefit from precision farming measures like variable lime, nitrogen and pesticide application? And if so, how can he measure any potential yield improvement or saving and what should be his reference to compare his management strategy with?

Even though the objective of "improving the economic benefit" is fairly clear and intuitive, it is very difficult for the farmer to measure and compare this improvement with any alternative situation like uniform application or more intelligent management of information - simply because there is no reference to compare with in this particular year. In this matter there are three vital issues to address:

1. Can we **expect** any difference in yield and input savings between site-specific and uniform application and more intelligent use of information?
2. Can we in practice **measure** changes in yields, quality and input reductions with these applications?
3. Is it possible to show any economic potential with Farm Management Information System (FMIS) compared with conventional application?

The first and second issue is in principle a matter of biological and agronomic concern and may be answered from practical tests and trials with GPS-related equipment. Finally, the third issue involves economic considerations such as cost structure, scale advantages, market prices and yield potentials.

The concept of FMIS causes the same difficulties as with other changes and innovations in arable farming practises. On a research farm it will be possible to measure the yield improvements in terms of such as uniform application versus site-specific farming practices, while for the individual farmer it seems difficult to measure the difference from year to year. The farm manager may have an idea about some improvements, for instance about the savings of pesticides and lime because he is able to visualise the areas that do not require treatment. Site-specific nitrogen application seems for instance more complicated to judge as it may involve both yields and protein contents.

The economic revenue of input applications thereby depends on the site-specific agronomic and biological differences in the field, different weather conditions, technical capabilities and yields. However, precision farming may also involve economic benefits that are not directly related to the spatial variation on the field or more intelligent use of information.

Improved logistics and fuel-savings

A thorough application of the GPS-system and intelligent automation gives the farmer a remedy to save fuels during, for example, harvest and bale handling. If for instance the tractor driver has on-line access to the position of other farm-vehicles. GPS and GIS-maps provide an opportunity for the tractor pilot to optimise and improve the co-ordination with the other tractor pilots and the combine harvester in the case of unloading filling grain from the combine to a tractor wagon. Automation optimises fuel consumption and keeps driver aware of situation of the system. Information about site-specific location of drainage areas (drain pipes), large stones and wells may be difficult to validate in economic terms but could be as valuable information as for instance spatial management of nutrients and chemicals.

Fleet management solutions for agriculture comprise a combination of tracking and route. By using fleet management it is possible to track the mobile units in the field in order to dynamically allocate the right unit to the right task in the right way. It will be possible to monitor and display the current position and other status information (time, current or expected capacity, working velocity, etc.) – see Sørensen & Thomsen (2006) for a comprehensive study on the potential of on-line machinery management.

A more advanced GPS system with high accuracy may also enable the farmer to save fuel on the field because of fever overlaps during harrowing, ploughing, harvest and field cultivation in general. The tractor pilot sometimes overlaps previously treated areas with up to 50-100 cm during ploughing and harrowing. With advanced GPS systems the driver just has to follow a light bar on the display in the tractor cabin.

All nutrients and parameters mentioned above could in principle and given the right hardware, software and org-ware be applied in variable amounts on the field to save inputs or improve yields.

Farm Management Model

The main task of this work package will include a model for the farmers more intelligent management of different input sources, treatment and information management systems (incl. precision farming systems) for a number of crop rotation systems.

For these crop rotations we will asses the cost structure and potential benefit for various systems. This part of the analysis is in general based on **strategic decisions** implying that we will provide an analysis to assess if a farmer should choose for instance variable rate fertiliser technology instead of conventional fertilising technology.

In this part focus will be placed on selected and commonly produced crops in different European regions including:

- Wheat
- Rape seed
- Sugar beets
- maize, and other cereals, cotton or other crops (dependent upon partner farms)

Based on the demonstration farms in different European regions, we intend to integrate current advanced information, precision farming and robotic/intelligent systems.

The economic assessment will include economic modelling of the use of factor inputs (like fertiliser, pesticides and lime) to the farmers' different crops based on actual/expected prices of factor inputs, (water, pesticides, seeds, fertilisers and other costs), product prices and yield response.

Moreover farmer savings of labour time will be included in the management model.

Differences in product quality are expressed in terms of price premiums and yields and nitrogen surplus and pesticide will for certain scenarios be based on climatic conditions and yield response functions.

Quality parameters
Quality parameters may include better protein content – easier certification with electronic traceability of crop origin, cultivation practices and use of fertiliser.

Decision support – and economic parameters

For a few **selected systems** we will extent the analysis and support Work Package 4 in designing a decision support system for selected crop rotations.

In this model a distinction will be made between management at the strategic level (investment in new technology), the tactical level (farmers seed and crop choice etc.) and the operational level (decisions about nitrogen applications and pesticides at a particular time) depending on the timeframe for choosing technology and operations.

The model will focus on the **operational level.** This implies that we have already taken the decision to apply for instance variable rate fertiliser techniques – and with this decision we have to decide if it is possible to optimise the use of fertiliser given better decision making.

The analysis will rely on a rational behaviour among farmers and assume that farmers are risk averse.

We will identify, how often the technology will induce the farmer to make a new decision and what consequences will that decision have for other future decisions. What are the consequences of that decision – in terms of physical yields and economic feasibility at that particular time? This task will be conducted in line with the management strategies in WP2.

Decision analysis
The decision support will be based on decision analysis and information modelling as outlined in WP3. This part describes a methodology for decision analysis on information management and precision farming to assist the farmer structuring his or her decisions on each farming operation in open-fields.

The methodology enables a detailed description of the decisions a farmer takes in a chronological order. Each decision can be analysed, addressing how often a decision is taken, what information is needed to support it, how the information is processed and which tools and resources are required.

This methodology may simplify the complexity of precision farming. It may enable us to get a better knowledge about farm management decisions - and it can end up with better management for the farmers due to more efficient farm operations on the field.

Cost structure and potential benefits

The cost of different information-intensive and safety systems (incl. sensors, safety controllers, navigation controllers, software modules etc.) will be estimated for different scale capacities and compared to conventional systems.

Potential benefits related to these systems such as: labour savings, fuel savings and higher work quality (accuracies) will be estimated and used to quantify the new cost structures and factor productivities that will be applied in task 4 (impact on socio-economics).

Moreover, data in relation to farmers' decision making including product prices (seasonality) will be collected during the project and incorporated in the overall information management model.

The economic management system/model will rely on risk-averse behaviour and economic optimisation for different management scenarios in different rotations with different technology and technical safety levels varying from low level control to high level control.

For this model we will use the 4 case-farmers in the FUTURE FARM project as reference farms. We will attempt to identify the cost structure and potential benefit for different management procedures with or without intelligent information systems.

The principle in this model is similar to a partial budget, which only focuses on those costs and benefits (revenues) that changes when using a specific practice. In this case, uniform treatment is indirectly the reference application in the overall analysis compared with different site-specific management systems.

Surplus change = Revenue change – Cost change

Causes and impact

The economic consequences of implementing new Farm Management Information procedures and operations implies a comparison between the present situation and a new situation.

What causes the economic benefit may depend on many parameters that can be difficult to distinguish from each other. A farm management system software and decision support system may not "in itself" provide better quality, improved yields or reduced factor costs - but it may enable other technologies to be implemented and used in an intelligent way.

To give an example, today it is possible to design weed maps manually and conduct variable rate weeding – but it will hardly be relevant for the farmer because it is too time consuming to collect the data manually.

By implementing intelligent software and sensing automation system that can register data about weed patches on GIS-maps on the run and thereby provide weed maps for patch spraying it may be possible to save herbicides, costs and maybe even labor time.

This cost saving and environmental benefit may not be caused by the FMIS system in itself but the system provide the possibility for doing so.

In this matter it is necessary to make clear and precise descriptions of the assumptions for these systems. What causes the change and what is needed to make the changes.

In the following is presented a number of farm operation systems that we intend to study at an operational level.

To assess the impact of new technologies it may be relevant to distinguish between three issues: Hardware, software and org-ware.

Hardware: A description of hardware technologies and technical devices, including function, performance and functionality.
Software: A description of the knowledge based technologies such as agronomic and biological decision support programs and other knowledge based information systems and sources.
Org-ware: A description of the organisation behind the technical systems. Org-ware involves the guidelines and advisory services about using the technology and its implications for the users. What are the barriers beyond technical functionality, for adopting technologies and what sociological implications affect the farmer when making decisions about implementation and use of new technologies?

The following chapters provide a presentation of numerous commercial precision farming practices:

We will focus on two key areas:

1. Variable rate application technology and

2. Information management for improved logistics

Variable rate application technologies

Crop inputs and nutrients
The various practices for gathering site-specific information on the field are presented in the following.

Site-specific information is of very little use unless a successful decision support and reliable technical equipment is available. In the following we will attempt to examine the various technologies for variable rate application and distribution of crop inputs and nutrients. Attention will focus on the distribution techniques and the interaction between the agronomic uncertainties and technology.

Nitrogen
Nitrogen is for many crops the most important nutrient. An adequate amount of nitrogen and a right timing of nitrogen could easily double the yield in many crops. Nitrogen should be applied in the right amounts and at the right time and it should coincide with the N needs of the crop.

The risks of nitrogen loss imply that the timing and amount of nitrogen application should be optimal during the growing season. In this respect, site-specific application may be able to optimise the application in order to minimise the risk of nitrogen loss.

Phosphorus
Phosphorus (P) is regarded as a more stable nutrient compared with nitrogen. Phosphorus is removed with the crop during the growing season and the nutrient is not as easily lost as nitrogen since it is held by soil particles. In this matter, the timing of phosphorus application is not as critical as it is for nitrogen. The phosphorus content could, however, vary according to the soil tillage methods. Phosphorus is important in the development of plant reproductive parts. Usually large amounts are found in seeds and fruits. Phosphorus is also essential for seed formation.

Potassium
Of the total amount of potassium (K) in the soil less than 10 percent is available to the plant. K has an impact on the plant enzymes and it can prevent the plant from water stress. The enzymes stimulate the growth process and potassium has an impact on these activities.

Secondary nutrients
Next to these three primary nutrients (NPK) the plant needs a number of secondary nutrients like: Calcium (Ca) magnesium (Mg) and sulphur (S). Magnesium is important for the production of chlorophyll, sugar starches and fats. Calcium has an impact on the root, stem and leaves growth and improves the decease resistance. Sulphur has an impact on the protein production and on resistance of, for instance, cold temperatures.

Micronutrients
The last group of nutrients are the micronutrients, which are required by the plant in small amounts and rarely deficient on the field. Some regions might however, have a deficit of some specific nutrients. Micronutrients that are considered essential for plant growth include: Boron (B), Chloride (Cl), copper (cu), iron (Fe) manganese (Mn), molybdenum (Mo) and Zinc (Zn). Soil testing for micronutrients and variable rate application might be relevant in certain areas and they could have an impact on the crop quality. Because of modest applications there have so far only been made little research into variable application of secondary nutrients and micronutrients.

Lime and soil pH.
The soil pH value is an indication of the soil acidity with high values indicating a low acidity and low values indicating high acidity. High acidity also implies that the soil has many free hydrogen ions floating around in the soil water, which reacts with the nutrients and make them less available to the plant. To compensate for high acidity *lime* is added to the soil.

Variable rate nitrogen application
Variable rate application has as indicated above the potential to either reduce nitrogen application or improve yields and crop quality. Several crop experts have attempted to estimate the appropriate dose of nitrogen site-specifically. Some studies have focused on soil data and others have based their approach on the application on yield data. Even though there are obvious considerations and difficulties about choosing the best application strategy there are also other concerns like the technical functionality of different technical systems.

Mineral fertilisers
The two most common systems for distributing fertilisers on the field are the centrifugal spreader and the phneumatic boom spreader. The centrifugal spreader is currently the most widely used of the two practices. To vary fertilisers site-specific, it is necessary to mount an electronic device on the spreader. This device is connected to the CANBUS system[1] and a task controlling computer (Task Controller, TC) in the tractor cabin. The regulation of fertilisers can either be carried out automatically or manually. With a GPS-receiver, a data-card and a GIS-application program it is possible to vary nitrogen on the run.

Variable application of fertilisers implies a chain of technical solutions in which each technical element must work properly including the positioning system, the on-board computer and the fertiliser distributor. The necessary electronic devices are mounted on the fertiliser distributor for variable adjustments during field work. There are in principle

[1] Tractors are at the moment not always equipped with canbus (older models). but are likely to be in the future. If tractor does not have canbus, external sensors for example speed detection are needed to add to the systems. If canbus exists the PA system can get the speed value from tractors internal system via canbus.

four potential sources of inaccuracy: Positioning, dosage, delay in reaction and inaccuracy of distribution.

Fertilisers from slurry and manure
Many farmers can see a benefit from variable application of slurry in combination with variable application of commercial fertilisers. In many crop-rotations, the application strategy should allow for commercial fertilisers as well as animal manure and slurry. With a combined application of nitrogen from slurry and commercial (mineral) fertilisers it is literally impossible to gain any yield improvement from varying the last dose of commercial nitrogen, simply because the residual N-quota after using the nitrogen in the slurry, is relatively low. Another problem is the *"second year effect"* of nitrogen from application of slurry in the previous year.

Variable rate application of phosphorus (P) and potassium (K)
Phosphorus and potassium are fertilisers that are "easy to handle" compared with nitrogen in the sense that these nutrients are fairly stable in the soil. Usually the farmer can regulate the amount of P and K by adding an amount similar to the amount removed by harvesting the crop.

In recent years, there has been concern about the environmental impact from intensive pig production and excessive surplus of phosphorus (P) from animal slurry in certain vulnerable areas. Most fertilisers are delivered as mixed NPK nutrient and in certain cases added with other micro-nutrients as well. This approach with mixed fertilisers has been applied for several years. Pre-mixed commercial/mineral fertilisers are easier to handle and distribute than separate fertilisers. The time and costs spend on distributing fertilisers is relatively high compared with the potential yield improvements from spatial yield improvements. In this respect, farmers tend to minimise the number of "runs" on the field. Site-specific application of P and K is carried out at the same time and with the same fertiliser distributors/spreaders as used for variable rate nitrogen application. However, for agronomic and environmental reasons, the ideal solution might be to apply all fertiliser separately.

The potential private economic benefit from appropriate applications of P and K appears to be relatively modest and the time for levelling out the soil content of nutrients within the field might take several years. In this respect we intent to neglect P and K inputs in the further analysis. However, in some regions P application is controlled via environmental subsidies (e.g. Finland). The regulation determines the maximum amount of P the farmer is allowed to use per field. When soil is rich in P, more P is leached out from the field due to erosion or runoff. PA can be used to lower P content in "hot spots" in the fields. Site-specific P application may be beneficial in certain areas.

Variable lime application
Site-specific application of lime is based on application maps derived from soil maps and directed site-specific soil samples.

An algorithm for variable lime application is determined according to the site-specific soil type and the site-specific pH level. In principle, lime should be added or reduced according to the measured level.

Practical experiences with variable rate liming and the application algorithms provided by advisory services have proven to be very successful on many farms.

The implementation of soil conductivity mapping has also given the farmers a tool to estimate the soil type in a fast and efficient way since soil conductivity is relatively well correlated to clay content in the soil.

Other site-specific application
In principle all plant nutrients can be applied site-specifically. A further study and practical implementation of these techniques depends on the development of efficient sensing techniques and justification of economic viability.

Variable rate irrigation has only received modest interest among North European farmers. In Southern Europe and the Mediterranean countries some trials have been conducted with variable rate irrigation. Variable irrigation techniques could also be relevant in some high value crops and row crops like sugar beets and potatoes in North European countries.

Variable rate sowing can be carried out by reducing and increasing the sowing density and sowing depth on the field. This approach can be relevant if the soil quality and soil compaction various on the field. The sowing density and depth will have an impact on yields, N-application and weed pressure.

Variation in soil cultivation along with seed density might also be relevant in some cultivation practices. The cost of seed is relatively high for some crops, particularly for potatoes and beets. Projects are made to develop technologies that can generate an electronic field-map with geo-spatial co-ordinates for each single seed. The electronic sowing map can thereby be used for high precision application maps of nutrients and chemicals based on the position of each single seed. This approach requires a very accurate positioning system such as RTK-GPS, which is expensive and requires significant computer power.

Variable rate pesticide application
Unlike lime, phosphorus and potassium - weeds and crop infections can hardly be considered as stable factors in the field/soil. An attempt will be made to assess the technical possibilities for variable rate application of chemicals and patch spraying. Variable application of chemicals is not solely emerged with the GPS-system. In fact, farmers have for many years been aware of the potential savings of chemicals within the field.

Full time farmers seem to be risk averse but at the same time aware of the possible savings from using appropriate techniques. The application strategy might also depend on the farm type. For example, livestock farmers seem to have other priorities on the farm than field work. They usually focus on livestock production and may not be as concerned with weeds as for instance arable farmers, probably, because most of the crops will be used on the farms, which reduces the incentives to produce high quality crops (Ørum *et al*. 2001).

In this respect, it is difficult to conclude which farm types that would have the highest benefit from using site-specific application techniques.

Research into **variable application of pesticides** has primarily been focusing on herbicides as indicated previously. However, some research is also carried within the area of fungi detection and variable application of fungicides. Preventive and site-specific treatment with insecticides is complex since insects are difficult to monitor on the field, whereas some weeds and some fungi have a tendency to concentrate in patches.

It is argued that output from a single sensor will be able to give information about more than one crop parameter. Reflectance sensors might enable the farmer to get information about N-status, vegetation index (canopy size) and information related to weed and disease occurrences. In this WP focus will be put on variable rate application of herbicides since most attention have been focusing on weed protection.

Besides some mechanical techniques for organic farming, most conventional systems for controlling crop deceases in cereals are based on conventional boom-sprayers. *Conventional sprayers* are usually constructed with a water tank in which the various chemicals/pesticides are mixed with water. Usually 2-3 different chemicals are mixed in the water tank for each treatment.

In practice, farmers usually “pre-mix” exact amount of water and expected application of active ingredients before spraying. In this matter, they often estimate the precise amount needed for that particular area to avoid emptying the tank after each operation. This common approach conflicts with the idea of variable treatment in which the farmer should strive to reduce the amount of pesticides on areas with no infections. The concept with premixed tanks has been used for many years and requires that the farmer, in advance, is able to assess the exact amount of chemicals that he will apply on the field. To conduct variable rate application, some sprayers are equipped with devices to regulate the amount of chemicals on the run. A GPS-receiver and a tractor-computer can be installed in order to regulate and carry out variable rate application of pesticides.

Due to the practical inconveniences with pre-mixed pesticides for patch spraying it is vital that site-specific spraying systems are followed by some sort of *injection systems* where water and chemicals are separated. With an **injection spraying** system, the various undiluted chemicals are kept in a container, separated from the water tank. The water is pumped through the nozzles and hereafter injected with the chemicals. Commercial injection systems usually have about 5 chemical containers for different chemical ingredients.

With the injection system it is possible to separate chemicals and water during spraying, implying that it shouldn’t be necessary to eliminate any leftovers after the spraying job is carried out. A further advantage is that the system enables the farmer to vary applications of chemicals without any concern of additional chemicals in the water tank.

Other systems

With RTK-GPS it may also be possible to practice a more **precise ploughing, harrowing and harvesting,** which enables the farmer to reduce labour and energy costs.

Many farmers often overlap with about half a meter when harrowing and harvesting. High **precision sowing** techniques could be relevant for row-crops such as sugar beets and potatoes but is likely to be less relevant for cereals.

Below are described a number of techniques that will be investigated further:

Box 1 Automated steering and optimized route planning**

Reference system	Additional equipment	Potential costs	Potential benefit	Benefit level
Conventional/ manual steering	Auto guidance system Mission/operations planning software Reference map Soil samples	Soil map Auto guidance system Reference map Training cost	Save time Save distance (fuel) The tractor pilot/driver can carry out other tasks Increase overall capacity performance Increase work quality	****

** Include a more simple case where automated steering only includes auto-guidance system.

Box 2 Planning of fertilizer application and variable rate application.

Reference system	Additional equipment	Potential costs	Potential benefit	Benefit level
Conventional practices Advisor recommends what to do Farmers distribute fertiliser ones or twice a year with a fixed amount og Nitrogen	Variable rate fertilizer distribution system Integrated GPS system Real time sensing Local weather sensors, Online weather services Soil samples	Variable rate fertilizer distribution system Integrated GPS system Local weather sensors, weather services? Other options: Aerial photos Yield mapping Soil samples Soil map Reference map Soil samples Training costs	Improve yield Save time Save fertiliser	***

** Here, we may compare two approaches to conduct VR fertilization. (1) On-the-go with the use of real-time sensing (e.g. YARA N-sensor system; N-Tech N-sensor system) and (2) Based on application map and soil sampling.

Box 3 Variable herbicide spraying based on weed maps and weather forecast

Reference system	Additional equipment	Potential costs	Potential benefit	Benefit level
Conventional practices Manual weed mapping with GPS Advisor says what to do with chemicals	Integrated Injection sprayer Local weather sensors, weather service Weed mapping with autonomous weed mapping systems Documentation	Integrated Injection sprayer Local weather sensors, weather service Soil samples(soil map Document/stamp Training costs Weed mapping with autonomous weed mapping systems	Save herbicides Traceablity Save time Economic premium for traceability	***

Box 4 Variable rate cultivation of soils based on soil maps

Reference system	Additional equipment	Potential costs	Potential benefit	Benefit level
Conventional soil cultivation practices	Soil maps to identify heavy clay soils Tooth cultivator (Amazone) Front mounted soil structure sensors Other sensors	Soil maps to identify heavy clay soils Tooth cultivator (amazone) Front mounted soil structure sensors Other sensors	Improve yield Energy savings Better route maps – time savings	***

Box 5 Harvest logistics harvest timing with fleet management

Reference system	Additional equipment	Potential costs	Potential benefit	Benefit level
Conventional practices Logistics between barn and field	Integrated New fleet system Yield maps Logistic system	Additional costs of a new fleet system Yield maps Logistic system	Improved yield Optimise harvesting Reduced water content in cereals Time saved from in field logistics	*****

Box 6 Variable rate seeding

	Additional equipment	**Potential costs**	**Potential benefit**	**Benefit level**
Conventional seeding practices	Variable rate seeder Soil maps, Variable rate seeder, depth and density GPS-system	Variable rate seeder Soil maps, Variable rate seeder, depth and density D-GPS systems	Improved yield from better seed density In field logistics Reduce seed costs	**

Box 7 Chlorophyll content measuring before harvesting to optimize harvest procedures

Reference system	**Additional equipment**	**Potential costs**	**Potential benefit**	**Benefit level**
Conventional harvesting procedures	Canopy mapping before harvest Yield mapping Differential GPS-system	Real time sensors for canopy mapping Yield mapping	Improved product quality The farmer may have the possibility to start the combine harvester at the best corner of the field The system may improve quality and water content	***

Information management

Box 8 Management of areal subsidies

Reference system	Additional equipment	Potential costs	Potential benefit	Benefit level
Conventional planning – filling out forms and maps	Software to handle field maps	Software to handle field maps and management of areal subsidies	Reduced time and labour costs	***

In the analysis of different systems we may also have to include the following:

For Precision farming:

1. Variable Rate Pesticides (insects and fungi)
2. Variable Rate irrigation (especially in Southern Europe)

For Information Management we may have to include :

1. Automated farm record keeping
2. Ad-hoc guidance and advice for carrying out organic farming
3. Route-planning for autonomous vehicles in agriculture

For all systems above - a more precise description and definitions of the system will be conducted as the project proceeds.

The above systems will be aggregated in terms of their broader socioeconomic impact

In task 4 we have expanded the model-approach to assess the socioeconomic effects by using the in-house FOI GTAP-model (global trade model and database) for a number of relevant information- intensive and precision farming systems. The new and more efficient technologies (PF and FMIS) are introduced to the GTAP with a change in cost structures and factor productivities estimated in task 1. By using the FOI GTAP model the national and regional socioeconomic effects of PF can be assessed using factor productivity scenarios and slow or fast dissemination of the PF to other regions.

FOI's GTAP global trade model can be used for sectoral studies for PF-relevant crops for PE-relevant EU regions. The FOI GTAP database has 57 sectors of which 12 are primary agricultural sectors (wheat, other cereal grains, oil seeds, sugar beets etc.) and 8 are secondary agricultural sectors. Main components of the model include domestic production, domestic demand, exports and imports and various price variables. In addition, trade policy variables such as tariffs, subsidies/taxes (designed to promote PF) and market price-influencing events are built into the model as price wedges on the produced, consumed, and traded consignments of final products as well as on various inputs in the production process.

We propose application of the GTAP model to FMIS/PF-relevant markets in relevant regions that comprise settings of particular concern or interest to assess the market impacts of policies and incentives designed to promote FMIS and PF. We can reflect PF-augmenting policies on the model's input or/ output sides of the market of focus, and assess the proposed policies on the above-mentioned market variables.

References:

Blackmore S., Griepentrog H.W., Pedersen S.M., Fountas S. (2006): Europe. Chapter in: *Handbook of Precision Agriculture, principles and applications* (ed. Ancha Srinivasan).

Fountas S., Wulfsohn D., Blackmore S.M., Jacobsen H.L., Pedersen S.M. (2006): A model of information flows for information-intensive agriculture, Agricultural systems (87) (2006), Elsevier, p 192-210.

Pedersen S.M. (2003): Precision farming – Technology Assessment of site-specific input application in cereals, Department of Manufacturing Engineering and Management, Technical University of Denmark. Ph.D dissertation, 343 p.

Pedersen S.M., Pedersen J.L. (2003): The economic and environmental impact of site-specific application of nitrogen in cereals. Proceedings of the seminar no. 336, Implementation of Precision farming in Practical Agriculture, 10-12 June 2002, Skara, Sweden., DIAS report No 100 (edited by Lindén B and Olesen S E), pp 156-162.

Sørensen, C.G., Thomsen, F.T. (2006). Synopsis regarding specific and general requirements on fleet management within arable farming. *www.robocluster.dk,* 1-26.

Ørum, J.E., Jørgensen, L.N. (2001): Økonomi og risiko ved forskellige fungicid-strategier i vinterhvede – nogle overvejelser og metoder, indlæg ved Dansk Planteværnskonference 2001.

Ørum, J.E., Noe, E., Jensen, J.E. (2001): Pesticidhandlingsplan 2 i praksis – Landmanden og konsulenten – muligheder og barrierer, Tidsskrift for landøkonomi, Det. Kgl. Danske Landhusholdningsselskab. 188 årgang juli 2001.