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A typology of PF-technologies suitable for farms in the EU-nations

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Contents

Abstract

Deliverable 7.1 “A typology of Precision Farming Technologies suitable for farms in the EU-nations” focuses on the development of a typology that summarizes and structures the broad and diverse set of techniques constituting precision farming technology. The typology should be applicable to EU-farms. Main characteristics of typologies were extracted and applied to PF. The typology has to cover and is restricted to relevant crops of the EU. Analysis of statistical data from the EU-27 determined cereals and forage plants with about 75 % of arable land to be dominant for EU-farms (reference year 2005). The relevant driving variables PF technologies, farming system (intensity),·cultivation measurements, collection of machine data, time slice for availability of the technique, Global Positioning System (GPS) level and information load for the FMIS (Farm management information system) were identified by a literature review and were used to discriminate and structure PF-technologies. For the application of the typology different starting levels (min, compact, combi) were set up. The typology focuses on two general farm types with different PF application level: Type I is using GPS but no Variable Rate Technology (VRT) technique and type II is using VRT technique. General farm type I has three subtypes (regarding the usage and quality of GPS and the use of robots). General farm type II has five subtypes (regarding the usage and quality of GPS, the usage of sensors, maps or both and the use of robots).
The subtypes of the general farm types are dissected into definite segments regarding the relevant driving variables.

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1 Introduction

This paper focuses on the question of the development of a typology of Precision Farming Technologies (PFT) suitable for farms in the EU-nations. The developed typology will zoom onto the usage of PFT on arable land. Therefore the agricultural land use in Europe has taken into consideration. In this case it is important to note that this paper gives just an example for a possible typology for PFT in cereals and forage plants in the EU 27.
Furthermore this paper is important basis knowledge for the work on the next deliverables in Work package 7. For deliverables 7.2 and 7.3 it is necessary to generate the current knowledge about Precision Farming in Europe and to present the results of the FutureFarm Project.
Deliverable 7.3 "Typology of farms and regions in EU states assessing the impacts of PF-technologies in EU-farms and Regions" is about the dissemination and distribution of PFT in Europe related to the different regions in the EU 27. Therefore this paper will show one possible approach for a typology of PFT in coherence to different regions in the EU.

As conditions for the agricultural production process differ in space and time, fields therefore should obtain appropriate treatments in regard to the heterogeneous natural conditions (s. PEDERSEN, S.M., 2003. p.9, DEUTSCHER BUNDESTAG, 2006. p.25 and HÜTER, J. and KLÖBLE, U., 2007). As the water and soil conditions, which are the main pre-requisites for the plant growths, vary on small scales in space but also in time, the treatment and application has to consider these aspects for an optimized land use. "PF is designed to provide data and information to assist farmers when making site-specific management decisions" (ARNHOLT, M. et al., 2001. p.1) on sub-field level to improve in average on the one hand the returns and economical profitability and on the other hand reduces environmental impacts for a more sustainable agriculture (s. ARNHOLT, M. et al., 2001. p.1, DEUTSCHER BUNDESTAG, 2006. p.4, PEDERSEN, S.M., 2003. p.9, FOUNTAS, S. et al., 2005. p.121 and GEMTOS, F. et al., 2002. p.1, see below).
Furthermore, it is important to recognize PF as a systemic approach (s. FOUNTAS, S. et al., 2005. p.121). Therefore, it is not only focussing on the variable rate application or site-specific application.
PF is considered to be a holistic management system of the agricultural process rather than an assessment of individual technologies (s. KUTTER, T., et al., 2009. p.2, PEDERSEN, S.M., 2003. pp.10, 172, REICHARDT, M. and JÜRGENS, C., 2008b. p.74 and REICHARDT, M. and JÜRGENS, C., 2007a. p.843). A lot of spatial high-resolution information is necessary for the right decision making and suitable applications on-field (s. DEUTSCHER BUNDESTAG, 2006. p.4, PEDERSEN, S.M., 2003. p.20 and SYLVESTER-BRADLEY, R., et al., 1999. p.1).
PF is an application of spatial information technologies, which have been being available since about two decades (s. GRIFFIN, T.W., et al., 2004. p.1 and GRIFFIN, T.W. a. LOWENBERG-DEBOER, J., 2005. p.20).
Starting at the early 1990s Precision Farming was introduced in agricultural business (SRINIVASAN 2006). Since that time many efforts have been done to:

(i) help the farmers with this new technology
(ii) get information about techniques and procedures which have already been adopted by farmers and
(iii) classify and characterise different Precision Farming technologies.

The bullet point (i) has been handled in different scientific projects, in Germany for example the *pre agro* project (www.preagro.de), the DFG Research Group FOR 473 "Information System for Site Specific Crop Management - Duernast" (http://ikb.weihenstephan.de/) or the PIROL project (http://www.pirol.fh-osnabrueck.de/). This small enumeration is of course not complete. There are many other projects all around the world focusing on different topics.

Furthermore, bullet point (ii) has been carried out by many studies (e.g. REICHARDT and JÜRGENS 2007; REICHARDT and JÜRGENS 2006; PEDERSON ET AL. 2004; FOUNTAS ET AL. 2004, FOUNTAS ET AL. 2005). Within EU the adoption of Precision Farming varies from country to country. In some countries like UK, Denmark or Germany Precision Farming has an appreciable dispersion, but in other countries little or even no Precision Farming is used.

Finally, the third bullet point (iii) was early recognised in the scientific community (AUERNHAMMER 1994). There are different classifications of Precision Farming technologies. Figure 1 shows one possible classification from AUERNHAMMER (2001), who considers PF as a collection of techniques and specific equipment as well as integrated concepts and is providing a wealth of data and tools for information management. For this paper it is necessary to restrict the classification on tools for crop production.

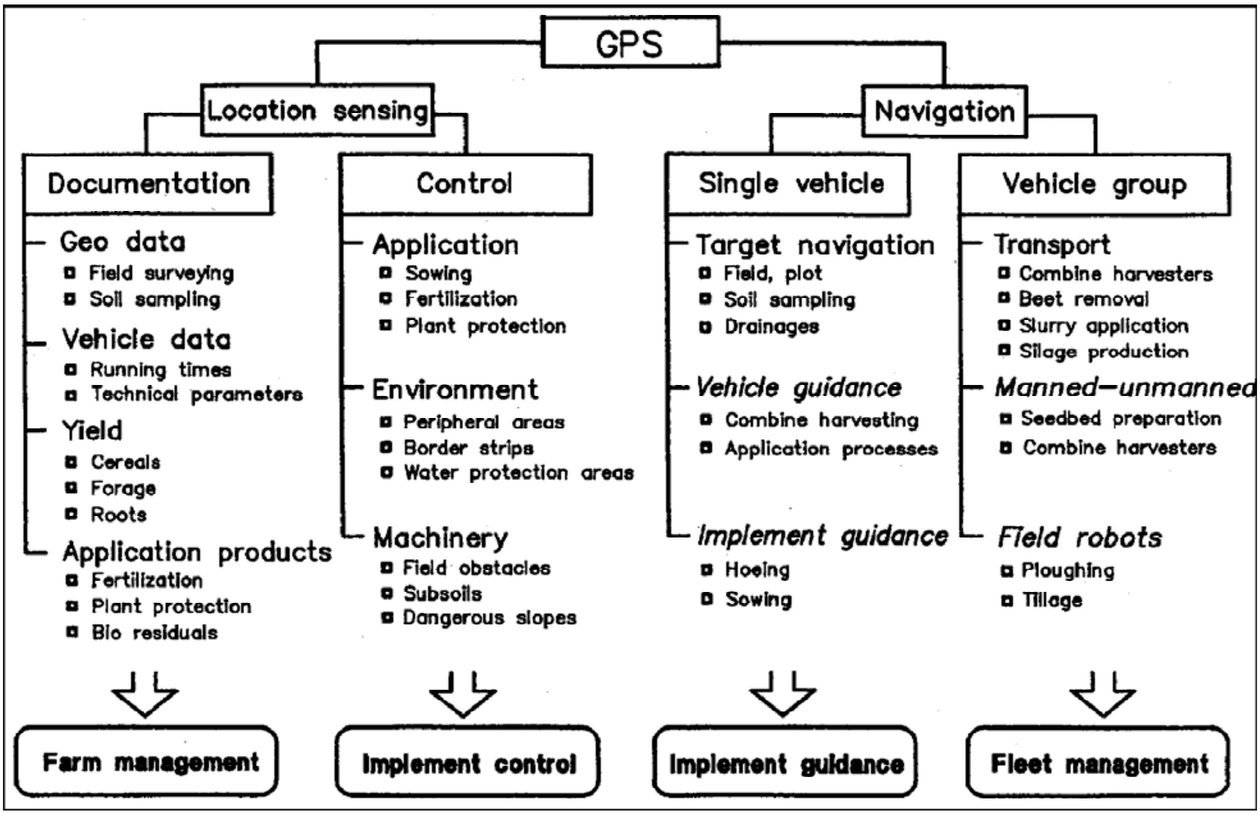

Figure 1: GPS in agriculture (Source: AUERNHAMMER, 2001)

The question at which level farming can be called Precision Farming was discussed and is still under discussion in a controversial way. For some GPS use is a prerequisite for PF, for others is variable rate technology. For this typology bringing more accuracy in agricultural measurements and/or the usage of GPS is defined as Precision Farming.

2 Material and Methods

2.1 A web research was done to clarify the exact meaning of `*typology*`. A suitable definition was found at the web page Wiktionary (http://en.wiktionary.org/): "The systematic classification of the types of something according to their common characteristics." (http://en.wiktionary.org/wiki/typology).

2.2 Additional literature was examined to get an overview about some general characteristics of typologies (CABALLERO 2001, KOENZEN 2005, VALBUENA ET AL. 2008).

2.3 An explicitly literature collection was evaluated to gather the scope of existing PF – technologies around the EU-27.

2.4 Relevant procedures for agricultural farming and also for Precision Farming were identified through literature review (HUFNAGEL et al. 2004, SRINIVASAN 2006).

2.5 Statistical data for the relevant agricultural data were provided from EuroStat. For each country statistical data regarding the farm structure were supplied. The data have the base year 2005. Table 1 gives information about which publication belongs to each country.

The percentages of relevant crops (like cereals and forage plants) were calculated by dividing the sum of the total arable in the EU-27 by the sum of the land of the according crop. Hence, these values are a weighted average.

Table 1: Statistical references for the farm structure in the EU (alphabetic order, Source: Eurostat, 2009)

Country	Reference
Austria	Statistics in focus - agriculture and fisheries - 11/2007
Belgium	Statistics in focus - agriculture and fisheries - 26/2007
Bulgaria	Statistics in focus - agriculture and fisheries - 43/2007
Cyprus	Statistics in focus - agriculture and fisheries - 21/2007
Czech Republic	Statistics in focus - agriculture and fisheries - 21/2006
Denmark	Statistics in focus - agriculture and fisheries - 18/2007
Estonia	Statistics in focus - agriculture and fisheries - 14/2006
Finland	Statistics in focus - agriculture and fisheries - 19/2006
France	Statistics in focus - agriculture and fisheries - 42/2007
Germany	Statistics in focus - agriculture and fisheries - 5/2007
Greece	Statistics in focus - agriculture and fisheries - 59/2007
Hungary	Statistics in focus - agriculture and fisheries - 22/2006
Italy	Statistics in focus - agriculture and fisheries - 22/2007
Latvia	Statistics in focus - agriculture and fisheries - 16/2006
Lithuania	Statistics in focus - agriculture and fisheries - 12/2006
Luxembourg	Statistics in focus - agriculture and fisheries - 15/2006
Malta	Statistics in focus - agriculture and fisheries - 13/2006
Netherlands	Statistics in focus - agriculture and fisheries - 13/2007
Poland	Statistics in focus - agriculture and fisheries - 10/2006
Portugal	Statistics in focus - agriculture and fisheries - 24/2006
Romania	Statistics in focus - agriculture and fisheries - 60/2007
Slovakia	Statistics in focus - agriculture and fisheries - 7/2007
Slovenia	Statistics in focus - agriculture and fisheries - 11/2006
Spain	Statistics in focus - agriculture and fisheries - 24/2007
Sweden	Statistics in focus - agriculture and fisheries - 17/2006
United Kingdom	Statistics in focus - agriculture and fisheries - 20/2006

3 Results

3.1 General characteristics of typologies – with a focus on Precision Farming

Typologies have in common that they try to provide a generalisation into sets of specific things. Typologies should be as universal as possible, but it is necessary to always have in mind that many individual cases still exist. In addition, typologies should allow the assessment of procedures in different directions, e.g. economical or ecological.
The typology of PF-technologies suitable for farms in the EU-nations focuses on (i) relevant crops (cereals and forage plants) on arable land in the EU-27 (ii) relevant procedures for agricultural farming/PF and (iii) technologies at present and in the near future. That will lead to a critical point, because the technologies in PF are changing. For example the RTK-GPS is widespread used for auto-steering systems, but was not so commonly used 10 years ago. New sensors, e.g. soil sensors (MOUAZEN 2007) may lead to a continuous progress in agricultural procedures.

3.2 Statistical data

Statistical data of the arable land from the EU-27 were considered. The following figure 2 shows main crops of arable land for the EU-27 in the year 2005.

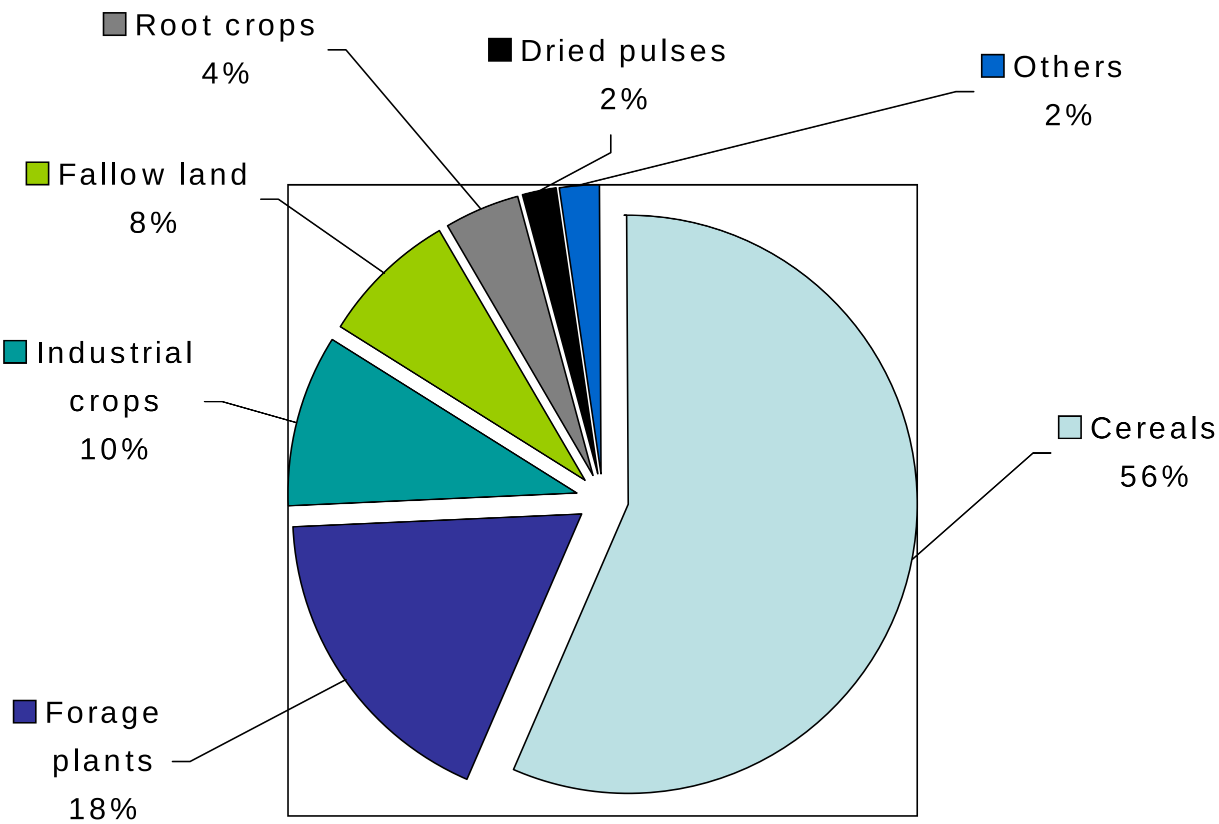

Figure 2: Main crops of arable land for the EU-27 (numbers rounded, Source: Eurostat, 2009)

The following enumeration gives more detailed information about the crops planted on arable land.

- **56.5 % cereals and in more detail**
  - Common wheat and spelt 21.7 %
  - Barley 13.7 %
  - Grain maize 7.5 %
  - Oats 4.2 %
  - Durum wheat 3.6 %
  - Rye 2.4 %
  - Others (e.g. Triticale, Rice) 3.3 %

- **17.7 % forage plants**, which means all "green" arable crops intended for animal feeding; Examples: temporary grass, vetches, green maize; fodder roots and brassicas are excluded

- **9.8 % industrial crops and in more detail**
  - Rape and turnip 4.8 %
  - Sunflower 3.3 %
  - Cotton 0.4 %
  - Soya with 0.4 %
  - Tobacco 0.2 %
  - Others 0.7 %

- **7.7 % fallow land**

- **4.2 % root crops and in more detail**
  - Potatoes 1.9%
  - Sugar beet 2.2%
  - Fodder root 0.1%

- **1.8 % dried pulses**

- **2.3 % others and in more detail**
  - Fresh vegetables, melons and strawberry 1.7%
  - Flower and ornamental plants 0.1%
  - Others 0.5%

As depicted in Figure 2 and explained in the enumeration 74.2 % of the cultivated crops are cereals and forage plants on over 100 million ha arable land in the EU-27 (Source: Farm Structure Survey 2005, own calculation).

Table 2 indicates Cereals in % having the highest amount of all crops in all EU – countries, except for Ireland and the Netherlands. Here the Forage Plant production is highest. Noticeable are Portugal and Sweden, these two countries have a similar percentage amount on cereals and forage plants.
For the typology presented in this document, cereals and forage plants will be taken into consideration, representing the main cultivated crops in the EU-27. Therefore the cultivated area with these crops is particularly suitable for PFT.

Table 2: Statistical data for the frequency (percentage) of selected crops in the EU-27 (Source: Eurostat, 2009)

Country	Cereals	Industrial crops	Forage plants	Fallow land
EU-27	*56.5*	*9.8*	*17.7*	*7.7*
Austria	57.8	8.3	17.1	7.0
Belgium	38.1	5.0	29.7	3.3
Bulgaria	65.9	28.7	2.5	1.2
Cyprus	44.6	0.4	28.7	16.1
Czech Republic	59.5	15.9	17.2	1.2
Denmark	60.6	4.6	18.3	7.4
Estonia	49.7	8.4	34.6	4.3
Finland	53.1	4.6	27.9	10.8
France	49.2	11.5	24.9	7.5
Germany	57.5	12.0	15.2	6.6
Greece	58.6	19.6	9.6	5.7
Hungary	65.9	18.4	7.5	3.7
Ireland	24.6	0.3	68.3	1.4
Italy	56.1	3.9	25.5	5.9
Latvia	46.2	7.1	32.3	8.0
Lithuania	56.4	6.7	21.4	7.7
Luxembourg	47.6	7.8	38.1	3.2
Malta	0.0	0.0	52.9	11.4
Netherlands	19.4	1.1	40.6	3.1
Poland	74.3	5.9	7.2	1.3
Portugal	31.2	0.8	32.1	28.8
Romania	65.7	16.1	8.6	3.6
Slovakia	59.2	16.9	17.9	0.7
Slovenia	54.3	4.5	31.0	1.1
Spain	60.0	5.6	5.4	20.9
Sweden	39.3	3.5	39.3	12.1
United Kingdom	47.8	10.5	21.1	8.2

3.3 Relevant driving variables for the typology and their explanation

The literature research and own knowledge led to the following variables for the typology of PFT:

a) **PF -technologies**
b) **Farming system (Intensity)**
c) **Cultivation measurements**
d) **Collection of machine data**
e) **Time slice for availability of the technique**
f) **PF -starting levels**
g) **GPS level**
h) **Information load for the Farm-Management-Information-System (FMIS)**

a) The PF -technologies:

In Comparison to Figure 1 (Auernhammer, 2001) we tried to simplify the description of PF-technologies. The huge amount of PFT can be split up in three main segments, if you put all information based technologies into mind (s. SCHELLBERG, J. et al., 2008. p.60).
The following three parts of PF-Technologies all need some kind of geographical positing system (GPS), which is called the backbone of PF and supplies the required accuracy (s. PEDERSEN, S.M., 2003. p.19 and AUERNHAMMER, H., 2001. p.41), when they are used with sensor approach (online).

Firstly, the recording technologies for data collection, like field surveying, yield mapping and soil sampling. Secondly, the reacting technologies, the Variable Rate Applications (VRA) or also named as Variable Rate Technologies for site-specific application, especially for seeding, fertilizers and pesticides. This technique doesn't need GPS for the direct application, but the GPS is necessary for analyzing and creating maps. Furthermore, the guidance systems are the third considerable part of the PF-technologies including parallel tracking systems and automated guidance systems (s. Figure 3).

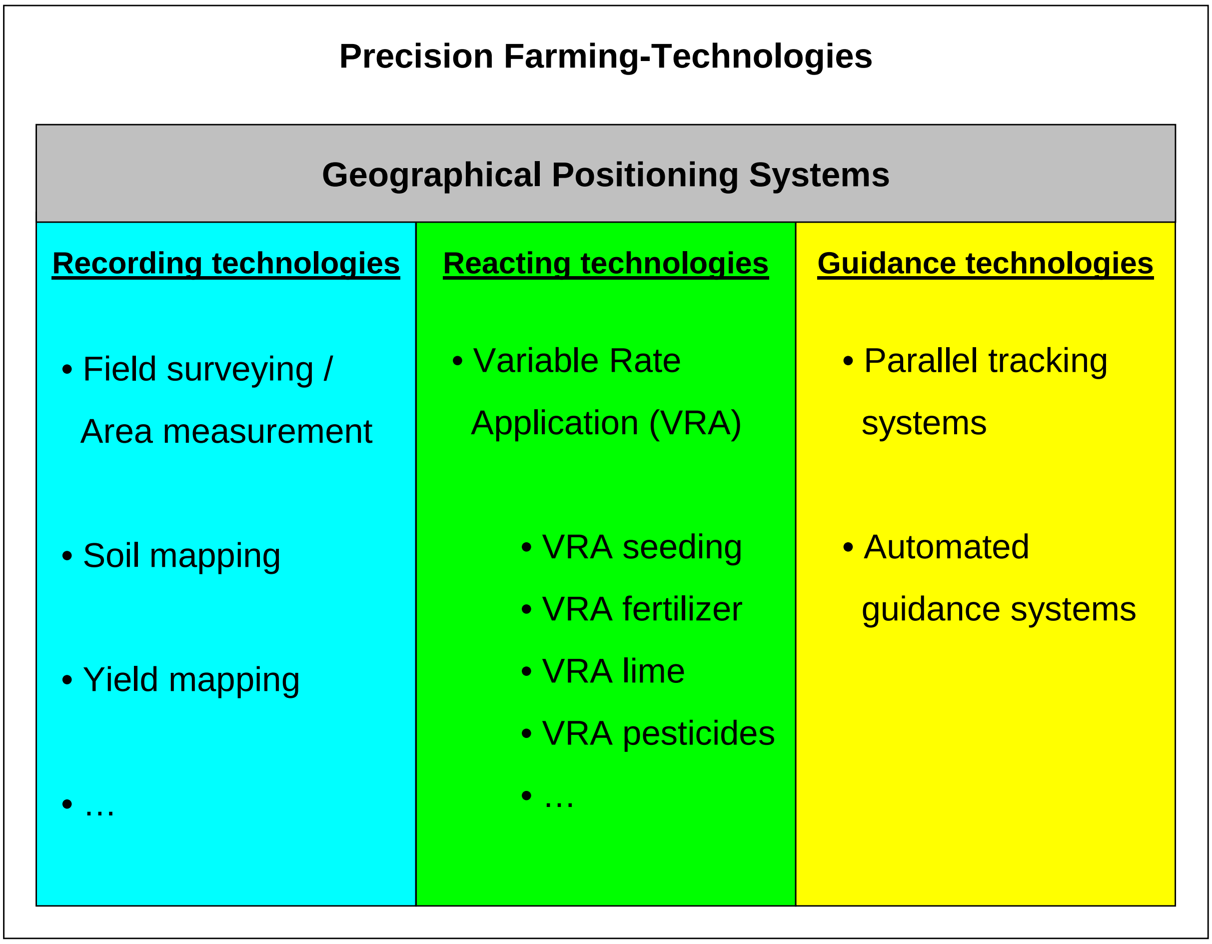

Figure 3: Precision Farming -technologies (own illustration)

In general the **recording techniques** GPS field surveying and GPS soil mapping have the largest distribution of all technologies worldwide, build the basis and are the background for a precise data acquisition and information winning, which is necessary for subsequent site-specific application (s. DEUTSCHER BUNDESTAG, 2003. p.58, REICHARDT, M. and JÜRGENS, C., 2008a. p.587, HÜTER, J. and KLÖBLE, U., 2007, BLACKMORE, S. et al., 2003. p.455 and MARKINOS, A.T. et al., 2005. p.166). Hence, the recording technologies GPS field surveying, GPS soil mapping and GPS yield mapping are the first, which were being commercial available and are introduced by the majority of PF-users at the starting level.

The first stage in the PF process is the measurement of important factors that indicate and affect the efficiency of crops with yield maps and soil parameters as the two main approaches (s. BLACKMORE, S.M. et al., 2006. pp.582f.). The recording technique GPS yield mapping is providing valuable basis data estimating the need for inputs considering space and time (s. BLACKMORE, S.M. et al., 2006. p.573f.). Yield mapping systems play an important role in the decision making process to adopt PF and are indispensable to aim local treatment by precision farming practices (s. GODWIN, R.J. et al., 2002. p.4, AUERNHAMMER, H., 2001. p.34, HÜTER, J. and KLÖBLE, U., 2007 and BLACKMORE, S., 2000. p.38). As the seasonal weather conditions and on smaller scales the soil compositions are changing in time yield maps show significant differences from year to year (s. SYLVESTER-BRADLEY, R. et al., 1999. pp.1ff.). Hence, it is important to conduct yield mapping for several years. Consistent yield patterns over years are mainly referred to soil conditions. Soil mapping is also an important tool to indicate the moisture available for the plants, the soil nutrients, the organic matter and the pH-level, which are important data for the subsequent site-specific application with lime and fertilizers. Gathering soil samples and the data acquisition with analyses is expensive and time consuming, but provides valuable information for following treatments (s. PEDERSEN, S.M., 2003. pp.21, 83ff.). An easy method for soil texture assessment is soil conductivity mapping, whereas EM-38 and Veris are the most common techniques used for soil conductivity mapping.

It is important to result in useful information for reacting technologies and not to stay on the stage of data collection for more than a decade with yield mapping, soil mapping and other recording technologies. Recording and mapping the in-field variability are the main pre-requisites for the use of VRA, which allows farmers to analyze and decide applications site-specific (s. BRASE, T.A., 2006. pp.4ff.). It is still a big challenge for farmers to convert the obtained data into useful knowledge for site-specific treatment (s. SORENSEN, C.G. et al., 2002. p.10). This fits to the main order with the implementation of reacting systems (VRA) as second step following the recording systems, which are required for a better information and knowledge level as well as for the calculation and mapping of reacting techniques.

Variable Rate Applications “are made to achieve an optimized use of inputs” (SORENSEN, C.G. et al., 2002. p.2). Some tools of VRA are dividable, like VRA of nitrogen, phosphorus and potassium, VRA of lime, VRA of pesticides and VRA seeding (s. PEDERSEN, S.M., 2003. p.12 and SCHNEIDER, M. and WAGNER, P., 2008. p.404). A suitable treatment of land via VRA allows the farmers "to place a specified amount of product on a particular area of a field" (BRASE, T.A., 2006. p.5). In contrary to place average rate amounts the efficiency is increasing. Most Variable Rate Applications are nowadays based on the recording yield mapping and sometimes soil mapping systems (s. PEDERSEN, S.M., 2003. p.20 and FOUNTAS, S. et al., 2005. p.127). Variable Rate Applications are meant to be the prime benefit of PF. The site-specific application of inputs is required for savings in time, cost and fuel as well as for the sparing use of resources for a sustainable agriculture (s. HÜTER, J. and KLÖBLE, U., 2007). The VRA of seeding is just rarely adopted and used, especially because experiences are being very few so far (s. SCHNEIDER, M. and WAGNER, P., 2008. pp.403ff.). The VRA of fertilizers need analysed soil samples in a close pattern or on-the-go determination, which have been being market-ready since a few years (s. HÜTER, J. and KLÖBLE, U., 2007). Samplings in sufficient amounts for site-specific treatments are uneconomic, so that online-/on-the-go-/real-time-applications are an inevitable need for a wider distribution of variable applications of nutrients. Determination of nutrients in real-time eases and betters the site-specific application of fertilizers. The VRA of nitrogen is the most common VRA, because it is the most important nutrient for crops (s. PEDERSEN, S.M., 2003. p.96). The Yara N-Sensor, the Greenseeker, the MiniVeg N-Lasersystem, the SoilDoctor and the Crop-meter are some on the market available and widely distributed online-systems for VRA of nitrogen (s. DEUTSCHER BUNDESTAG, 2006. pp.5, 30). Yield responses usually on large scale to applied nitrogen amounts (s. SYLVESTER-BRADLEY, R. et al., 1999. p.4). The demands of nitrogen by the crop and the soil-ability to supply nitrogen are the two sources to assess the VRA nitrogen application. Therefore, the nitrogen supply of nitrogen is spatially variable and requirements are changing referring to this. Other fertilizers are not as important as nitrogen, but also necessary for viable and productive plants, like phosphorus, potassium and lime. The precise treatment with pesticides requires sensors for a differentiated on-the-go weed combating (s. SCHNEIDER, M. and WAGNER, P., 2008. p.406). "There are likely to be significant savings in herbicides through the adoption of successful precision application techniques" (SYLVESTER-BRADLEY, R. et al., 1999. p.6). Furthermore, the possible site-specific variation of online irrigation and tillage are new segments of the VRA, which are being in its infancy. In the long term, the main requirements should be oriented on the development of improved systems for sensing on-the-go, e.g. chlorophyll and protein sensors, to ease the Variable Rate Applications (s. SYLVESTER-BRADLEY, R. et al., 1999. p.7 and PEDERSEN, S.M., 2003. p.11).

Besides, the parallel tracking systems and automated **guidance systems** basing on GPS-positioning technologies are becoming more important for decreasing time consumption and minimising costs for labour and fuels within the on-field-work (s. JÜRGENS, C., 2006. p.47 and NEUE LANDWIRTSCHAFT, 2008. p.49). Accurate GPS-

Technologies allow better navigation by men and even full-automated navigation on-field (s. AUERNHAMMER, H., 2001. p.32). The RTK (Real-Time-Kinematic)-stations provide information in an accuracy of centimetre, which is the requirement for correct guidance and also for VRA (s. PEDERSEN, S.M.,2003. p.74). The auto-guidance and parallel tracking systems avoid the over-application of inputs and allow also work in darkness, which is another important issue (s. NEUE LANDWIRTSCHAFT, 2008. pp.49f. and REICHARDT, M. and JÜRGENS, C., 2008b. p.90). As these technologies are relatively inexpensive, the distribution is growing sooner than other PF-Technologies. The auto guidance systems are perceived to be the "door opener for farmers and contractors to the use of PF technologies" (KUTTER, T. et al., 2009. p.13).

Regarding the Variable Rate Technology different approaches are possible. The decision for doing e.g. a different nitrogen application can be based on (i) maps; the off-line approach, (ii) sensors; the online approach or (iii) a combination of a map with an online sensor; the so-called hybrid approach.

The maps for VRT application should have a relationship to the cultivation's measurements. It might be possible to create maps for nitrogen application with respect to last years yield maps but not to create maps for pest management regarding insecticides. The creation of those maps should be reasonable and cost-effective. Maps for VRT technique can have different sources, e.g. aerial images, satellite data, soil maps or yield maps.

The three segments (recording, reacting and guidance technologies) include a wide approach of PF-Technologies considering more than just the site-specific application, as it is partly mentioned in literature. Nevertheless, the site-specific application (VRA) forms the core area of the whole PFT, because these techniques are the only ones, which react site-specific with regard to the heterogeneous differences in-field. Nevertheless, the guidance systems and recording technologies are also elements of PF in a wider view and coherent system. Data collections, data processing and variable rate application of inputs are the main activities within PF (s. FOUNTAS, S. et al., 2005. p.121). The huge amount of different PF-technologies allows farmers to change their production process "in an optimal way at the respective plots in the field" (VIRGIL, M. et al., 2007). Most of the technologies, which are available nowadays, are used on arable land, but not on grassland (s. SCHELLBERG, J. et al., 2008. pp.59ff.). The low economic value of grassland hinders the application of expensive technologies. It is considerable that in temperate climates relative intensively used grassland sums more than 80%, e.g. some parts of central Europe or Northern America, and substantially supports the beef and milk production.

Remote sensing, satellite images and aerial photography are also possible technologies for sub-field treatment in agriculture, especially in areas with low cloud amounts, e.g. the Mediterranean area during the summer time (s. PEDERSEN, S.M., 2003. pp.87ff.). Historical, weather and climate maps as well as other information can also be implied in the use of PF and help to improve the treatment (s. DEUTSCHER BUNDESTAG, 2006. p.16).

b) The farming systems (intensity)

In this paper the farming system or farming intensity is split into three main systems:

a) Organic farming
b) Extensive farming / low energy input
c) Integrated farming ("conventional farming")

a) Organic farming (at least EU-Eco-regulation 2092/91) is the form of agriculture that relies on a wide crop rotation, green manure, compost, biological pest control, and mechanical cultivation to maintain soil productivity and control pests, excluding or strictly limiting the use of synthetic fertilizers and synthetic pesticides, plant growth regulators, livestock feed additives, and genetically modified organisms (Directorate General for Agriculture and Rural Development of the European Commission).

b) Extensive farming or low energy input farming is an agricultural production system that uses small inputs of labour, fertilizers and capital, relative to the land area being farmed. Yields per hectare are very low, but the flat terrain and very large farm sizes mean yields per unit of labour are high. Nevertheless is a large-scale growing of wheat, barley and other grain crops in areas like Australia, USA possible. In the EU extensive farming is primary disseminated on the poor soil in Middle and South Europe, but also on heather and moor areas (Lueneburg Heath, Germany), nature reserve areas (where an intensive agriculture is not possible) or on hill pastures like in the alps. Generally speaking the abandonment of heavy soil cultivation, e.g. ploughing, is just not possible, neither because of the costs or because of the difficult cultivation conditions (soil, climate, relief, or others). Because of the restricted land use we put seeding and tillage together as one work step for further explanations.

c) Integrated Production/Farming is a farming system that produces high quality food and other products by using natural resources and regulating mechanisms to replace polluting inputs and to secure sustainable farming (good agricultural practice).
Emphasis is placed

• on a holistic systemic approach involving the entire farm as the basic unit,
• on the central role of agro-ecosystems,
• on balanced nutrient cycles, and
• on the welfare of all species in animal husbandry. (s. Boller, E.F., et al; 2004. p.4)

In this paper the term "conventional farming" will not be mentioned. It seems to be obvious that farms using the good agricultural practice and PF, even on a low level, can be named as integrated farming.

c) The cultivation measurements are divided into:

- Tillage
    - Ground cultivation
    - Seed bed preparation
- Seeding
    - Sowing
    - Planting
- Fertiliser
    - Base
    - Nitrogen
    - Liming
- Weed control
    - Mechanical treatment, e.g. hoeing,
    - Herbicides
- Pest and disease management
    - Fungicides
    - Insecticides
- Spraying growth regulators
- Harvesting
    - Quantity
    - Quality (moisture, protein, oil, …)

The above cultivation measurements are required indeed for cereals and forage plants, but they are not required in every other crop.
What is more, the farming systems have an influence on the measurements or their design, e.g. nitrogen fertilisation in an organic farming system only with organic manure.

Precision irrigation is not taken into consideration because of its low dispersal and its rare use in the selected crops. For 2005 the agricultural area of the EU-27 was about 172,000,000 ha and the area irrigated at least once was 10,500,000 ha or about 6 % of the total agricultural area (source: Eurostat, table ef_lu_ofirrig).

d) The collection of machine data is divided into:

- Yes
- No

Collecting machine data means the data gathering of geographical positions or the geographical positions with sensor values or geographical positions with the applied amount (VRT).

e) The time slices for availability of the technique are divided into:

- Now available
- Next 5 years
- In the future (> 10 years)

“Now available” means that the technique is ready to be used by farmers. This could either be sensors already available from commercial companies or ready to use modules or procedures.

The availability in the “next 5 years” is given to sensors or procedures which are currently under development but their implementation in agricultural practices can be scheduled.
“In the future” means that these technologies are in an experimental stage in labs or research institutes.

f) PF Starting levels:

To assess the typology the following staring levels for PF were identified:

- “Mini”
- “Compact”
- “Combi”

“Mini” means a low-cost alternative, e.g. minicomputers: palms, PDA, manual or automatic control of application, parallel guidance with light bars

“Compact” is a mid-cost alternative, e.g. on-line sensors combined with direct controlling, on-board computers or terminals, parallel guidance with terminals.

“Combi” is the high-end alternative, e.g. complex software (farm management systems, GIS, div. databases), documentation (Cross Compliance, QS etc.), parallel guidance (very precise, automatic steering).

g) GPS level

- GPS
- DGPS
- RTK-GPS

GPS is defined as a simple GPS without any improvements for precision and an accuracy of about 3 - 10 m
DGPS has a differential signal for improving its accuracy which is normally less than a meter.
RTK –GPS is a GPS system with accuracy of up to a few centimetres.

h) Information load for the FMIS

- No
- Low
- Medium
- High

The information load is an important parameter for the development of the farm management information system (FMIS).

No information load means that no data are recorded or that the accuracy of the GPS is not sufficient enough, e.g. simple GPS.

Low information load is set to e.g. DPGS positions or other data with not much information content.

Medium information load includes for example accurate GPS positions and data for plant or soil parameters. Also the VRT techniques only with maps bring a medium information load.

The high information load is given e.g. for VRT sensor systems or hybrid systems (maps and sensors). Therefore the information density is high and also the possibility of as-applied maps with underlined dense advance information is given.

3.4 Typology in a nutshell

General farm type I: Using **no** VRT

- subtype 1: Using GPS for “work” (GPS, DGPS, RTK)
- subtype 2: Using GPS for “work” and sensors for data gathering
- subtype 3: Using GPS and robots for data gathering

General farm type II: Using VRT

- subtype 1: Using **no** GPS, using sensors for VRT, no recording of positions and their amounts (no as-applied)
- subtype 2: Using GPS for “work” and maps for VRT
- subtype 3: Using GPS for “work” and sensors for VRT
- subtype 4: Using GPS for “work”, maps and sensors for VRT
- subtype 5: Using GPS for “work”, robots for VRT

The mentioned levels in the typology are at least the minimum requirements. For example in the case of the GPS level the usage of RTK systems instead of DGPS system is possible but not necessarily required.

4 Discussion and Conclusion

Discussion

The developed typology of PF-technologies represents a general, not a detailed or case specific view. It summarizes and structures the very broad and diverse set of these techniques. Demand for such a typology is related to the need to have a clear description of the applicable PF-techniques for impact assessments of farming systems or in the design of information management for farms likely to use PF in the future.

With the help of this typology in a next step farms in the EU-27 can be classified according to a general farm type and relevant subtypes. Also the typology could help to find the demand on information flows in a FMIS and to identify the starting level that probably a predefined farm is likely to apply.

The typology can to be slightly different, if other crops like root or tuber crops or other types of production - e.g. horticulture - will be taken into consideration.

Intentionally in this typology specific sensors of certain machinery were not addressed. The sole existence of a sensor in a crop management system does not determine the usage and is therefore not suitable for developing a typology.

In addition to the restrictions of the developed typology mentioned above internal problems of PF-technologies are still existing. For instance some PF-techniques are staying within development and are not being in commercial use or market-ready up to now, while other techniques have been in use for some years (SCHNEIDER, M. and WAGNER, P., 2008. pp.401ff. and PEDERSEN, S.M., 2003. p.95). Besides Precision Farming requires a huge amount of comprehensive, usable, information intensive technologies, which are also cost-intensive. Therefore, the profitability of PF-adoption is an individual question for each farm. “In principle, it is now possible to set up a complete Decision Support System for precision farming. This would include a GIS system at the core, with a sensor linked to data processing software to analyse the incoming measurement, a decision support structure to interpret the data and propose treatments and programs to turn the resulting decisions into instructions for variable treatment using a GPS system” (SYLVESTER-BRADLEY, R. et al., 1999. p.3).

Conclusion

Precision Farming covers a wide range of technologies for different sectors in agriculture. They differ in techniques, equipment and procedures. The PF-typology for European farms is a necessary precondition to reduce the number of possible combinations of Precision Farming situations for impact analysis and scenario modelling. Precision Farming can be characterised as information oriented production. These information are part of the farm management information system. In the next step of the project it will be discussed with the developers of FMISs (WP 4), if a further aggregation of types is necessary. The PF-typology for European farms could also be used to transfer the project's results from one or few prototypes of the FMIS developed for normative farming situations to special or future situations of farms in the Europe. Not all situations can be analyzed directly. With the help of such typologies general principles can be developed. The four pilot farms of the FutureFarm project serve as a basic framework for generalisation procedures.

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6 Appendix

Detailed typology – some remarks

The detailed typology refines the typology in a nutshell. All mentioned relevant driving variables are taken into consideration and the assessment with the starting levels of each branch is done. Furthermore the GPS level is outlined.

The mentioned levels in the typology are at least the minimum requirements. For example in the case of the GPS level the usage of RTK systems instead of DGPS system is possible but not necessarily required.

Robots are not a homogenous group. They differ in size, knowledge and mode of action. No further diversification will take place at this project phase. Maybe some changes will occur due to the further work with WP 6.

For the general farm type II (using VRT) subtype 2 and subtype 4 maps are used for the decision of the dosage at a predefined area. These maps can be created on different single data source or by combination several data sources together. Aerial images, satellite data, yield maps, crop density, soil samples, etc. are possible source.

The typology tries to work with appropriate maps. Some data analysis works theoretically only, some sources produce very comprehensive data for VRA application in farm management. This procedure can be supply appropriately in the future. So for some part of chemical crop protection management the time slice for on-line sensors realisation is in the future.

6.1 general farm type I:

Using GPS but no VRT technique

<u>subtype 1</u>: using GPS for guide work

GPS level: simple GPS – Examples: Logistic
Faming system: Organic farming; Extensive farming; Integrated farming

Cultivation measure-ments	Collection machine data	Time slice	PF Start-ing levels	Information load for the FMIS
-	No	Available	"Mini"	No

GPS level: DGPS – Examples: grid soil sampling, light bars
Faming system: Organic farming; Extensive farming; Integrated farming

Cultivation measure-ments	Collection machine data	Time slice	PF Starting levels	Information load for the FMIS
-	Yes	Available	"Mini"	Low

GPS level: RTK GPS – Examples: auto-steering
Faming system: Organic farming; Extensive farming; Integrated farming

Cultivation measure-ments	Collection machine data	Time slice	PF Start-ing levels	Information load for the FMIS
-	Yes	Available	"Combi"	Low

general farm type I: Using GPS but no VRT technique

Subtype 2: Using GPS and sensors for data gathering for crop stands or soils or others

Faming system: Organic farming; Extensive farming; Integrated farming

Cultivation measurements	Collection machine data	Time slice	PF Starting levels	GPS level	Information load for the FMIS
Tillage e.g. logging soil properties (clay content)	Yes	Next 5 years	“Compact”	DGPS	Medium
Seeding e.g. logging soil properties (clay content)	Yes	Next 5 years	“Compact””	DGPS	Medium
Fertiliser – lime e.g. capture of pH-value	Yes	Next 5 years	“Compact”	DGPS	Medium
Fertiliser – base e.g. capture of need for phosphorus and potassium	Yes	Next 5 years	“Compact”	DGPS	Medium
Fertiliser – nitrogen e.g. capture of need for nitrogen	Yes	Available	“Compact”	DGPS	Medium
Weed control e.g. capture of weeds	Yes	Next 5 years	“Compact”	DGPS	Medium
Pest and disease Management e.g. capture of pests	Yes	Next 5 years	“Compact”	DGPS	Medium
Spraying growth regulators e.g. capture of crop density	Yes	Available	“Compact”	DGPS	Medium
Harvest e.g. capture of yield quantity and quality	Yes	Available	“Compact”	DGPS	Medium
Monitoring biotic data	Yes	Next 5 years	“Compact”	DGPS	Medium

<u>general farm type I:</u> Using GPS but no VRT technique

Subtype 3: Using GPS and robots for data gathering

Faming system: Organic farming; Extensive farming; Integrated farming

Cultivation measurements	**Collection machine data**	**Time slice**	**PF Starting levels**	**GPS level**	**Information load for the FMIS**
Robots are used for detecting soil or plant properties with **no** reference to cultivation measurement	No	Next 5 years	“Combi”	DGPS	Medium
Robots are used before specific cultivations measurements take place with regards to these cultivation measurements e.g. before seeding, fertilising, harvesting	No	In the future	“Combi”	DGPS	Medium
Robots are used for monitoring biotic data	No	In the future	“Combi”	DGPS	Medium

6.2 general farm type II:

Using VRT technique

subtype 1: using **no** GPS for work (only online sensors)

Faming system: Organic farming

Cultivation measurements	**Collection machine data**	**Time slice**	**PF Starting levels**	**GPS level**	**Information load for the FMIS**
Tillage	No	Next 5 years	“Compact”	DGPS	No
Seeding	No	In the future	“Compact””	DGPS	No
Fertiliser – lime	No	Next 5 years	“Compact”	DGPS	No
Fertiliser – base	No	Next 5 years	“Compact”	DGPS	No
Fertiliser – nitrogen	No	Next 5 years	“Compact”	DGPS	No
Weed control	No	Next 5 years	“Compact”	DGPS	No
Pest and disease Management					
fungi – crop density	No	Available	“Compact”	DGPS	No
fungi – direct detection	No	Next 5 years	“Compact”	DGPS	No
Pest and disease Management					
insects	No	In the future	“Compact”	DGPS	No
Harvest	No	Available	“Compact”	DGPS	No

general farm type II: Using VRT technique

subtype 1: using **no** GPS for work (only online sensors)

Faming system: Extensive farming

Cultivation measurements	**Collection machine data**	**Time slice**	**PF Starting levels**	**GPS level**	**Information load for the FMIS**
Tillage and Seeding	No	In the future	“Compact”	DGPS	No
Fertiliser – lime	No	Next 5 years	“Compact”	DGPS	No
Fertiliser – base	No	Next 5 years	“Compact”	DGPS	No
Fertiliser – nitrogen	No	Available	“Compact”	DGPS	No
Weed control	No	Next 5 years	“Compact”	DGPS	No
Spraying growth regulators	No	Available	“Compact”	DGPS	No
Pest and disease Management					
fungi – crop density	No	Available	“Compact”	DGPS	No
fungi – direct detection	No	Next 5 years	“Compact”	DGPS	No
Pest and disease Management					
insects	No	In the future	“Compact”	DGPS	No
Harvest	No	Available	“Compact”	DGPS	No

general farm type II: Using VRT technique

subtype 1: using **no** GPS for work (only online sensors)

Faming system: Integrated farming

Cultivation measurements	**Collection machine data**	**Time slice**	**PF Starting levels**	**GPS level**	**Information load for the FMIS**
Tillage	No	Next 5 years	“Compact”	DGPS	No
Seeding	No	Next 5 years	“Compact””	DGPS	No
Fertiliser – lime	No	Next 5 years	“Compact”	DGPS	No
Fertiliser – base	No	Next 5 years	“Compact”	DGPS	No
Fertiliser – nitrogen	No	Available	“Compact”	DGPS	No
Weed control	No	Next 5 years	“Compact”	DGPS	No
Spraying growth regulators	No	Available	“Compact”	DGPS	No
Pest and disease Management					
fungi – crop density	No	Available	“Compact”	DGPS	No
fungi – direct detection	No	Next 5 years	“Compact”	DGPS	No
Pest and disease Management					
insects	No	In the future	“Compact”	DGPS	No
Harvest	No	Available	“Compact”	DGPS	No

general farm type II: Using VRT technique

subtype 2: using GPS for guides work and **maps** for VRT

Faming system: Organic farming

Cultivation measurements	**Collection machine data**	**Time slice**	**PF Starting levels**	**GPS level**	**Information load for the FMIS**
Tillage	Yes	Next 5 years	“Compact”	DGPS	Medium
Seeding	Yes	Available	“Compact””	DGPS	Medium
Fertiliser – lime	Yes	Available	“Compact”	DGPS	Medium
Fertiliser – base	Yes	Available	“Compact”	DGPS	Medium
Fertiliser – nitrogen	Yes	Available	“Compact”	DGPS	Medium
Weed control	Yes	Next 5 years	“Compact”	DGPS	Medium
Pest and disease Management					
fungi – crop density	Yes	Available	“Compact”	DGPS	Medium
fungi – direct detection	Yes	In the future	“Compact”	DGPS	Medium
Pest and disease Management					
insects	Yes	In the future	“Compact”	DGPS	Medium
Harvest	Yes	Available	“Compact”	DGPS	Medium

general farm type II: Using VRT technique

subtype 2: using GPS for guides work and **maps** for VRT

Faming system: Extensive farming

Cultivation measurements	**Collection machine data**	**Time slice**	**PF Starting levels**	**GPS level**	**Information load for the FMIS**
Tillage and Seeding	Yes	Next 5 years	"Compact"	DGPS	Medium
Fertiliser – lime	Yes	Available	"Compact"	DGPS	Medium
Fertiliser – base	Yes	Available	"Compact"	DGPS	Medium
Fertiliser – nitrogen	Yes	Available	"Compact"	DGPS	Medium
Weed control	Yes	Next 5 years	"Compact"	DGPS	Medium
Spraying growth regulators	Yes	Available	"Compact"	DGPS	Medium
Pest and disease Management					
fungi – crop density	Yes	Available	"Compact"	DGPS	Medium
fungi – direct detection	Yes	In the future	"Compact"	DGPS	Medium
Pest and disease Management					
insects	Yes	In the future	"Compact"	DGPS	Medium
Harvest	Yes	Available	"Compact"	DGPS	Medium

<u>general farm type II:</u> Using VRT technique

subtype 2: using GPS for guides work and **<u>maps</u>** for VRT

Faming system: Integrated farming

Cultivation measurements	Collection machine data	Time slice	PF Starting levels	GPS level	Information load for the FMIS
Tillage	Yes	Next 5 years	“Compact”	DGPS	Medium
Seeding	Yes	Available	“Compact””	DGPS	Medium
Fertiliser – lime	Yes	Available	“Compact”	DGPS	Medium
Fertiliser – base	Yes	Available	“Compact”	DGPS	Medium
Fertiliser – nitrogen	Yes	Available	“Compact”	DGPS	Medium
Weed control	Yes	Next 5 years	“Compact”	DGPS	Medium
Spraying growth regulators	Yes	Available	“Compact”	DGPS	Medium
Pest and disease Management					
fungi – crop density	Yes	Available	“Compact”	DGPS	Medium
fungi – direct detection	Yes	Next 5 years	“Compact”	DGPS	Medium
Pest and disease Management					
insects	Yes	In the future	“Compact”	DGPS	Medium
Harvest	Yes	Available	“Compact”	DGPS	Medium

general farm type II: Using VRT technique

subtype 3: using GPS for guides work and **sensors** for VRT - corresponding to subtype 1

Faming system: Organic farming

Cultivation measurements	Collection machine data	Time slice	PF Starting levels	GPS level	Information load for the FMIS
Tillage	Yes	Next 5 years	"Compact"	DGPS	High
Seeding	Yes	In the future	"Compact""	DGPS	High
Fertiliser – lime	Yes	Next 5 years	"Compact"	DGPS	High
Fertiliser – base	Yes	Next 5 years	"Compact"	DGPS	High
Fertiliser – nitrogen	Yes	Next 5 years	"Compact"	DGPS	High
Weed control	Yes	Next 5 years	"Compact"	DGPS	High
Pest and disease Management					
fungi – crop density	Yes	Available	"Compact"	DGPS	High
fungi – direct detection	Yes	In the future	"Compact"	DGPS	High
Pest and disease Management					
insects	Yes	In the future	"Compact"	DGPS	High
Harvest	Yes	Available	"Compact"	DGPS	High

general farm type II: Using VRT technique

subtype 3: using GPS for guides work and **sensors** for VRT - corresponding to subtype 1 – FMIS high

Faming system: Extensive farming

Cultivation measurements	**Collection machine data**	**Time slice**	**PF Starting levels**	**GPS level**	**Information load for the FMIS**
Tillage and Seeding	Yes	In the future	“Compact”	DGPS	High
Fertiliser – lime	Yes	Next 5 years	“Compact”	DGPS	High
Fertiliser – base	Yes	Next 5 years	“Compact”	DGPS	High
Fertiliser – nitrogen	Yes	Available	“Compact”	DGPS	High
Weed control	Yes	Next 5 years	“Compact”	DGPS	High
Spraying growth regulators	Yes	Available	“Compact”	DGPS	High
Pest and disease Management					
fungi – crop density	Yes	Available	“Compact”	DGPS	High
fungi – direct detection	Yes	In the future	“Compact”	DGPS	High
Pest and disease Management					
insects	Yes	In the future	“Compact”	DGPS	High
Harvest	Yes	Available	“Compact”	DGPS	High

<u>general farm type II:</u> Using VRT technique

subtype 3: using GPS for guides work and **<u>sensors</u>** for VRT - corresponding to subtype 1

Faming system: Integrated farming

Cultivation measurements	Collection machine data	Time slice	PF Starting levels	GPS level	Information load for the FMIS
Tillage	Yes	Next 5 years	“Compact”	DGPS	High
Seeding	Yes	In the future	“Compact””	DGPS	High
Fertiliser – lime	Yes	Next 5 years	“Compact”	DGPS	High
Fertiliser – base	Yes	Next 5 years	“Compact”	DGPS	High
Fertiliser – nitrogen	Yes	Available	“Compact”	DGPS	High
Weed control	Yes	Next 5 years	“Compact”	DGPS	High
Spraying growth regulators	Yes	Available	“Compact”	DGPS	High
Pest and disease Management					
fungi – crop density	Yes	Available	“Compact”	DGPS	High
fungi – direct detection	Yes	In the future	“Compact”	DGPS	High
Pest and disease Management					
insects	Yes	In the future	“Compact”	DGPS	High
Harvest	Yes	Available	“Compact”	DGPS	High

general farm type II: Using VRT technique

subtype 4: using GPS for work and maps and sensors for VRT (**hybrid**) -corresponding to subtype 1 and 3

Faming system: Organic farming

Cultivation measurements	**Collection machine data**	**Time slice**	**PF Starting levels**	**GPS level**	**Information load for the FMIS**
Tillage	Yes	Next 5 years	"Combi"	DGPS	High
Seeding	Yes	In the future	"Combi""	DGPS	High
Fertiliser – lime	Yes	Next 5 years	"Combi"	DGPS	High
Fertiliser – base	Yes	Next 5 years	"Combi"	DGPS	High
Fertiliser – nitrogen	Yes	Next 5 years	"Combi"	DGPS	High
Weed control	Yes	Next 5 years	"Combi"	DGPS	High
Pest and disease Management					
fungi – crop density	Yes	Available	"Combi"	DGPS	High
fungi – direct detection	Yes	In the future	"Combi"	DGPS	High
Pest and disease Management					
insects	Yes	In the future	"Combi"	DGPS	High
Harvest	Yes	Available	"Combi"	DGPS	High

<u>general farm type II:</u> Using VRT technique

subtype 4: using GPS for guides work, maps and sensors for VRT **<u>(hybrid)</u>** -corresponding to subtype 1 and 3

Faming system: Extensive farming

Cultivation measurements	Collection machine data	Time slice	PF Starting levels	GPS level	Information load for the FMIS
Tillage and Seeding	Yes	In the future	“Combi”	DGPS	High
Fertiliser – lime	Yes	Next 5 years	“Combi”	DGPS	High
Fertiliser – base	Yes	Next 5 years	“Combi”	DGPS	High
Fertiliser – nitrogen	Yes	Available	“Combi”	DGPS	High
Weed control	Yes	Next 5 years	“Combi”	DGPS	High
Spraying growth regulators	Yes	Available	“Combi”	DGPS	High
Pest and disease Management					
fungi – crop density	Yes	Available	“Combi”	DGPS	High
fungi – direct detection	Yes	In the future	“Combi”	DGPS	High
Pest and disease Management					
insects	Yes	In the future	“Combi”	DGPS	High
Harvest	Yes	Available	“Combi”	DGPS	High

general farm type II: Using VRT technique

subtype 4: using GPS for guides work, maps and sensors for VRT **(hybrid)** -corresponding to subtype 1 and 3

Faming system: Integrated farming

Cultivation measurements	Collection machine data	Time slice	PF Starting levels	GPS level	Information load for the FMIS
Tillage	Yes	Next 5 years	“Combi”	DGPS	High
Seeding	Yes	In the future	“Combi””	DGPS	High
Fertiliser – lime	Yes	Next 5 years	“Combi”	DGPS	High
Fertiliser – base	Yes	Next 5 years	“Combi”	DGPS	High
Fertiliser – nitrogen	Yes	Available	“Combi”	DGPS	High
Weed control	Yes	Next 5 years	“Combi”	DGPS	High
Spraying growth regulators	Yes	Available	“Combi”	DGPS	High
Pest and disease Management					
fungi – crop density	Yes	Available	“Combi”	DGPS	High
fungi – direct detection	Yes	In the future	“Combi”	DGPS	High
Pest and disease Management					
insects	Yes	In the future	“Combi”	DGPS	High
Harvest	Yes	Available	“Combi”	DGPS	High

<u>general farm type II:</u> Using VRT technique

subtype 5: using GPS for robots for VRT FMIS high

Faming system: Organic farming; Extensive farming; Integrated farming

Cultivation measurements	**Collection machine data**	**Time slice**	**PF Starting levels**	**GPS level**	**Information load for the FMIS**
Tillage	No (only robot data)	In the future	“Combi”	RTK GPS	High
Seeding	No	In the future	“Combi”	RTK GPS	High
Fertiliser – lime	No	In the future	“Combi”	RTK GPS	High
Fertiliser – base	No	In the future	“Combi”	RTK GPS	High
Fertiliser – nitrogen	No	In the future	“Combi”	RTK GPS	High
Weed control	No	In the future	“Combi”	RTK GPS	High
Spraying growth regulators	No	In the future	“Combi”	RTK GPS	High
Pest and disease Management	No	In the future	“Combi”	RTK GPS	High
Harvest	No	In the future	“Combi”	RTK GPS	High