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Based upon national and international databases as well as upon information from research institutes of the Federal Republic of Germany, the Federal States and the universities, an efficient, professional, quick and qualified information from and about special field literature in agricultural science in Germany is safeguarded/ guaranteed.

Key words: Literature Information, Literature Supply, Agriculture, Organisation

Literaturinformation und Literaturversorgung für die Agrarwissenschaften in Deutschland (W. Laux)

Zusammenfassung

In Deutschland wird für die Agrarwissenschaft die Information über Literatur bzw. literaturbasierte Daten durch eine fachübergreifende Organisation, das Fachinformationssystem Ernährung, Landwirtschaft und Forsten (FIS-ELF),

sichergestellt. Es wird vom Bundesministerium für Ernährung, Landwirtschaft und Forsten und von den zuständigen Ministerien der Bundesländer getragen. Es vereint Vertreter der Informationseinrichtungen der verschiedenen agrarwissenschaftlichen Fachgebiete, der fachspezifischen Bibliotheken und der Zentralstelle für Agrardokumentation und -information.

Basierend sowohl auf nationalen und internationalen Datenbanken als auch auf den Informationen aus den Forschungseinrichtungen des Bundes, der Länder und der Universitäten ist eine effiziente, fachspezifische, schnelle und qualifizierte Information aus und über Fachliteratur der Agrarwissenschaften in Deutschland gewährleistet.

Stichworte: Literaturinformation, Literaturversorgung, Landwirtschaft, Organisation

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Hermann Auernhammer

Precision Farming for the Site-Specific Fertilisation

Precision farming has become a main focus of world-wide agricultural research. First systems based on different philosophies can be seen used on farms. Nevertheless, a constant systematics and a "state of the art" do not exist at present.

1 Introduction

"Precision Farming" has become an important topic in agriculture. World-wide this "key word" has caused enormous research activities. Many technical disciplines are taking part in the scientific work and in its realisation. Nevertheless, a constant systematics and a "state of the art" do not actually exist. Therefore in the following article an attempt is made from the view of agricultural engineering, to work out especially site-specific fertilisation.

2 Basic Technology GPS

Precision Farming is inseparably connected with GPS (Global Positioning System). In reality, however, the beginnings were laid at an early stage, because each farmer operates with Precision Farming if he manages his fields himself, knows the local conditions and reacts to the local conditions.

However, the number of these farmers is steadily declining in the highly industrialised countries.

The grain harvest set the first standards for Precision Farming. Today probably more than 70 % of the area with cereals are harvested by contractors or machinery rings throughout the country-side. The contract use of self-propelled forage choppers in the silo maize harvest is even higher. The same machines increasingly take the salvage of the grass silage. Even more, the trend is unmistakable seen to be the large self-propelled six-row sugar beet harvester. A similar development appears for self-propelled harvest techniques with the industrial potato.

Criteria for this technique is:

- Complete work is removed from the farm;
- seasonal workers with often little connection to agriculture take over the (technical) operation of the technique;
- apart from work completion, local information about the

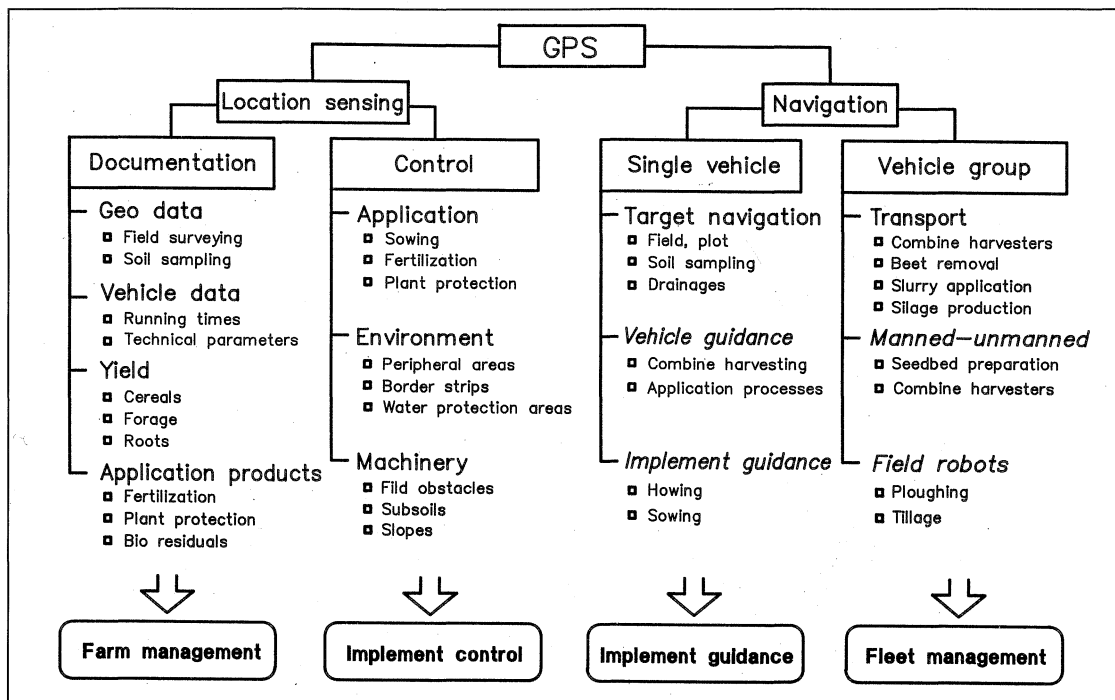


Fig.1: Use of the GPS in agriculture

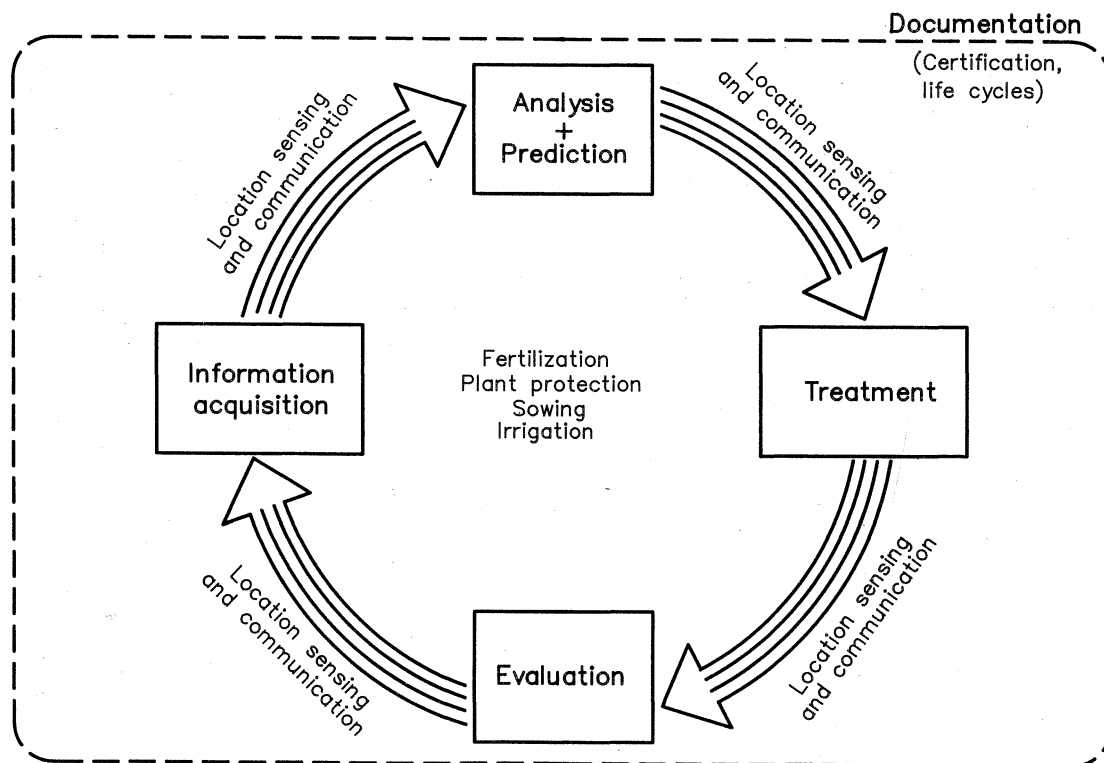


Fig.2: The information cycle of Precision Farming

- success or failure of all preceding work from the farm disappears at the same time;
- the obligation to carry out a homogeneous handling of the areas is irrevocable if new technologies do not eliminate the information loss, and intelligent application techniques are not developed so as to enable a reaction to local conditions.

To that extent GPS is accorded a central relevance. It supplies

- place and time always and everywhere,
- is usable free of charge,
- operates independently of the weather and time of day,
- is subject to miniaturisation,
- becomes ever cheaper with high numbers of units produced world-wide,
- achieves in differential operations the necessary accuracy (Tab.1) for agricultural application, although vehicle guidance and device guidance thereby a future aim ("tool guidance") economically are not yet realisable.

Tab.1: Requirements of the positioning accuracy in agriculture

Required Accuracy	Task	Example
10 m	navigation	- targeting of fields (machinery ring, contractor) - targeting of storage area (forestry)
1 m	job execution information documentation	- local field operations with <ul style="list-style-type: none"> • yield monitoring • fertilizing • plant protection • soil sampling • action in protected areas - automated data acquisition
10 cm	vehicle guidance	- gap and overlay control (fertilizing, spraying) - grain combining
1 cm	implement (tool) guidance	- mechanical weed control

Systematically regarded, GPS enables differential use in agriculture. It can be assigned to the big sectors of position detection and navigation (Fig.1).

Each area of use is characterised by constant requirements.

2.1 Documentation

Basically only GPS technique with position service and time service is used. Resulting from both services characteristic values are calculated for

- points in time,
- total time and section times,
- total travel lengths and section distances,
- speeds.

In connection with one or more sensors in machines and implements it will be possible to document

- transported quantities,
- total expenditure and local expenditure,

- total yield and local yield.

All documented data can be visualised with the local and the time information and can be shown flow-referred.

2.2 Local Guidance

Actors are added to the sensors. From stored (geo-referenced) information and/or from sensor data, reactions are forced by actors in the form of:

- information to the driver for necessary actions,
- site-specific application of seeds, fertiliser and plant protection agents,
- safety-relevant measures for technique and environment up to the "emergency stop" of the used technique.

2.3 Vehicle Guidance

The vehicle guidance addresses the vehicle itself and may be understood as driver discharge or as a back-up for other non-agricultural persons. Executive functions can be used to:

- give punctual target guidance,
- enable parallel swathing by farm works, which directly follows past vehicle passes,
- give guidance along stored guidance lines from preceding, finished measures.

2.4 Fleet Management

Time-adjusted monitoring, leading and assigning several equal units or several different units operating on the same object becomes increasingly important. Fleet management is necessary for

- the interaction of application-, harvesting- and transport units by a steady alignment of positions, quantities, average driving speeds and single quantity units;
- the synchronisation with temporal misalignment of manned leading vehicles and unmanned satellite vehicles (drones);
- the monitoring and guidance of unmanned vehicles, e. g. not yet available field robots.

Within this systematics, GPS is needed for the acquisition of information and for its realisation. For production, information cycles (Fig.2) can be derived which lead in form of Precision Farming to site specific application and which deal with the heterogeneity found in the fields.

Aligned to fertilisation during vegetation growth the following technical measures, with information management in the centre and the services thereof, become necessary (Fig.3).

3 Yield Detection as the Starting Point of Precision Farming

Farming serves to achieve a yield. Yield increase and yield stability are essentially achieved and guaranteed in Europe by means of fertilisation. Thus yield and fertilisation are inseparably connected together. Therefore, Precision Farming addresses in the first developmental stage these two quantities and addresses first the income quantity "yield" with its local development.

3.1 Yield Detection Systems

Five subsystems are required for local yield detection (Fig.4). Problems occur concerning the cut width registration at the combine harvester. Post-processing of the recorded raw

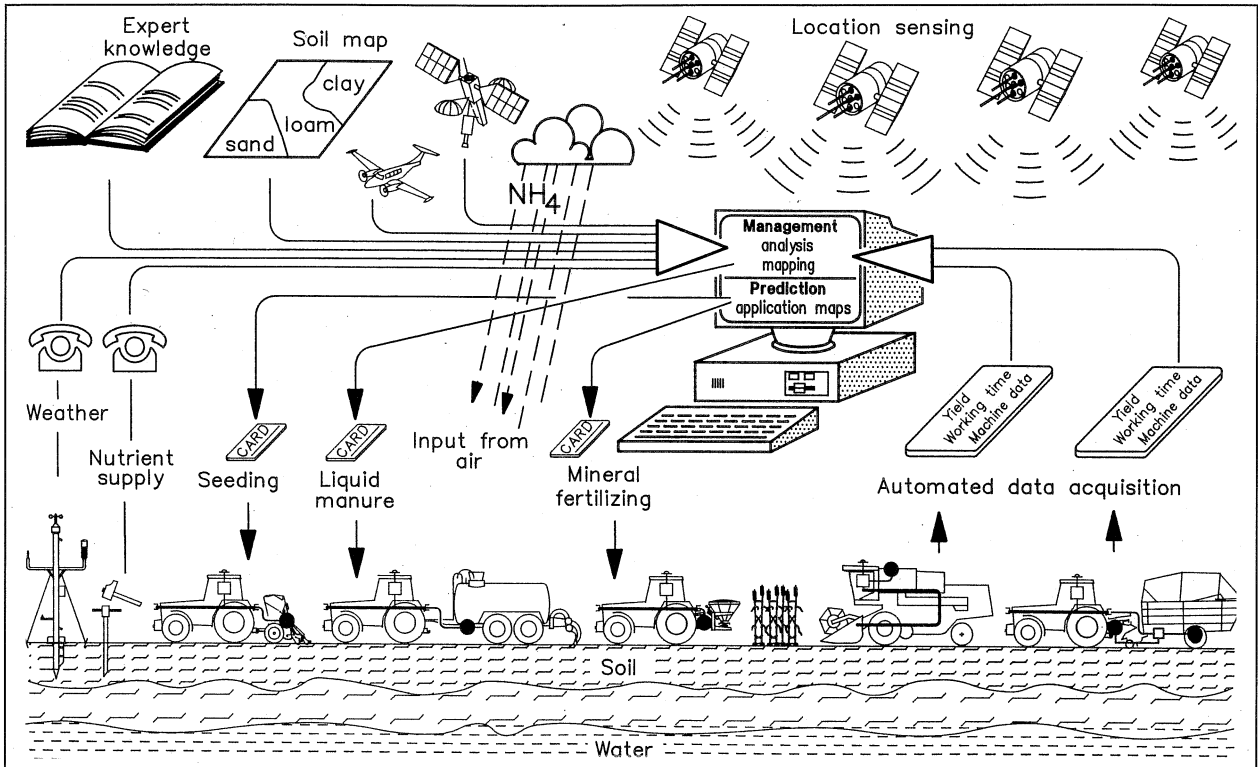


Fig.3: Technique, information and services for the fertilisation in Precision Farming

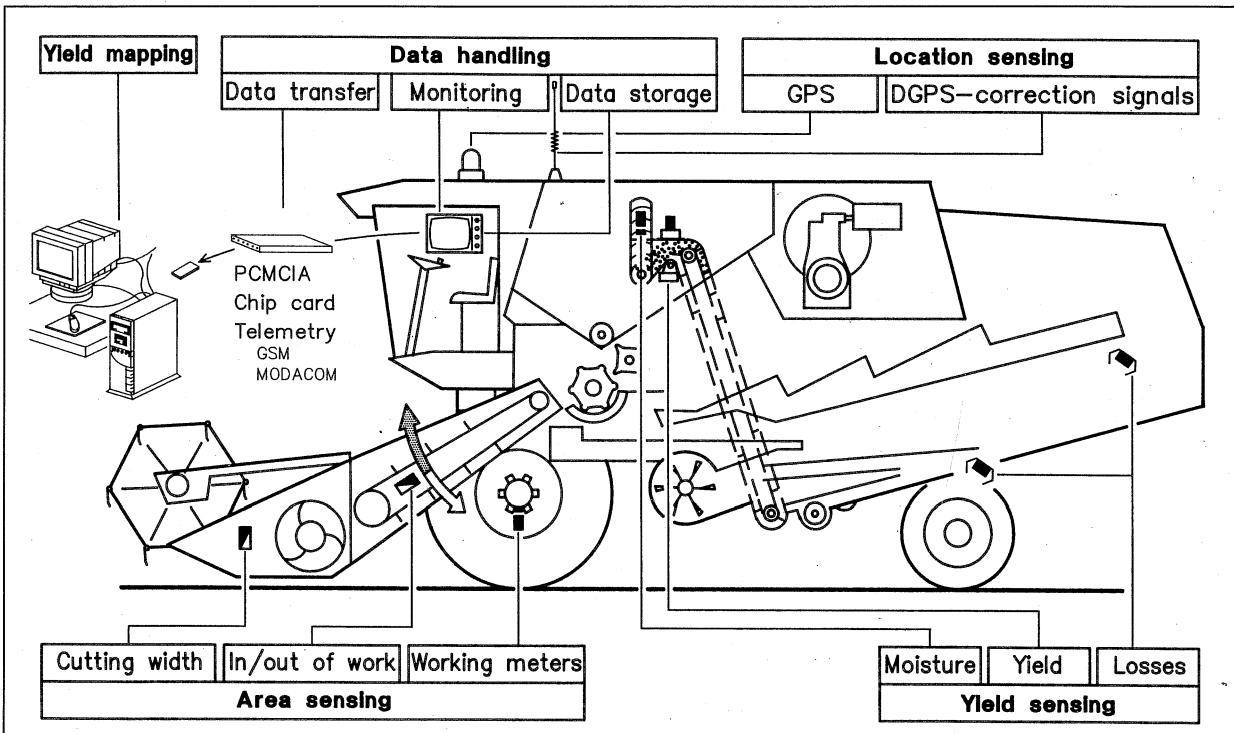


Fig.4: Subsystems for local yield detection

data can create a limited remedy.

For yield measurement various sensors are available. They are characterised by two types of errors:

- individual weights of grain in the tank can be determined with an error of approximately 5 - 7 % (2s-range);
- the deviation of the determined total harvest quantity depend on the calibration. This error can be eliminated, if the raw data are stored and post-calibrated by counter weighing the yield.

First attempts of systems for yield detection in forage choppers, sugar beet harvesters, potato harvesters, forage wagon and big balers are in the developmental stage, or going through their first tests on farms.

3.2 Yield Mapping and Yield Patterns Stability

So far yield mapping has been unsatisfactorily solved. It is effected via firm-specific software according to undocumented analysis algorithms. Standards for statistically secured admissible and meaningful yield class widths are missing as is the case with the optimal patterns differentiation by ranges in contour graphics or by expressive grid sizes.

The first analyses of the stability of yield patterns over time-series increase the certainty of prediction with an increasing number of successive years. Correlations based on grid maps initiate coefficients of determination (r^2) between two harvest years between 0.3 and 0.6. If three successive years are regarded, then in the multiple view the coefficients of determination rise to approximately 0.7-0.8. Yield patterns of grain crops seem to be very stable. For potatoes, however, stronger deviations are seen or developments moving directly in opposite directions are noticeable.

4 Soil Sampling and/or Soil Analysis

Whereas the local yield detection documents the total withdrawal of the harvest of a field and the withdrawal on site specific parts of the fields, soil sampling after harvest determines the nutrient supply in the soil for the next crop.

4.1 Sample Problems

Thus, both variables regarding the production of the current crop are data from the past. Their value is limited, if the temporal distance between the determination of both values increases and if during this time-interval, greatly changing conditions are found (temperature, water conditions by precipitation and inflow or run-off in the soil).

Furthermore, the different density of spatial data is a problem. Yield measurements are made with the usual position determination frequency of GPS receivers every 1 s or 2 s or with average operating speeds of approximately 3 m/s in the distance of 3-5 m (multiplied by the working width of approximately 5 m results in yield measured values for in case each 25-30 m² harvest area).

However, soil samples are collected from cost reasons according to country-wide common standards with approximately 15 cores per hectare as mixed samples. Both pieces of information are therefore not or only limitedly comparable. Ways out of this situation are:

- grid sampling for part-fields between 1 and 3 hectare,
- sample relocation in zones of similar yield levels according to yield mapping,

- geo-referenced single specimen analysis,
- time series analyses on defined sample points with GPS navigation within areas of 1 m².

They can deliver solutions regarding the temporally stable basic nutrients P and K. For the N-supply they are however unsatisfactory because, additionally, temperature and water content in soil and plant overlay the availability and the attainable effect there.

4.2 Geo-Referenced Sample Technique

Soil sample technique uses GPS for several functions for:

- area measuring after driving around to define the necessary number of soil sample points;
- determination of the positions of the soil sample points and navigation to the points;
- accurate position determination at the core point during sample drawing with integrated indication assistance for forwarding to the investigation laboratory and the later integration of the results of analysis into a geo-referenced data record.

In all cases geo-referencing serves for the creation of nutrient supply cards as an overlay for the withdrawal cards. Both enable balancing which is obligatory prescribed according to fertiliser regulations for larger operations in field specific form.

5 Site Specific Application Techniques

In agriculture, electronics was originally introduced in plant production with the application techniques. Industry and practice showed thereby demonstratively and proved the necessity of "high tech" which can and should be used meaningfully and environmentally-friendly, in particular for a more accurate dosage by means of production. Today fertilisation in Precision Farming is seen in three different methodical approaches (Fig.5).

5.1 Mapping Approach

Almost all past work and realised installations refer to this approach. Initial values are the local balance sizes yield and nutrient supply in the soil. They are brought in agreement with the yield target and find their realisation in application cards. Technical solutions pursue three conversion strategies:

- Electronics which up until now is used in the application technique of the operation, has been extended by GPS. For the transfer between management and mobile electronics the medium smart card or PCMCIA card is used furthermore.
- Manufacturers develop integrated, but firm-specific solutions including new communication technologies. Not in production contained techniques are bought by efficient medium-size manufacturers and are company specifically integrated.
- Specialists on the fertilisation sector open up their technique for all manufacturers and users by utilising standardised, universal communication techniques based on the "agricultural BUS system (LBS)".

The application is realised with centrifugal or air spreaders. Different nutrients can be specifically mixed and applied by multiple bin systems on-the-go or a limitation to two nutri-

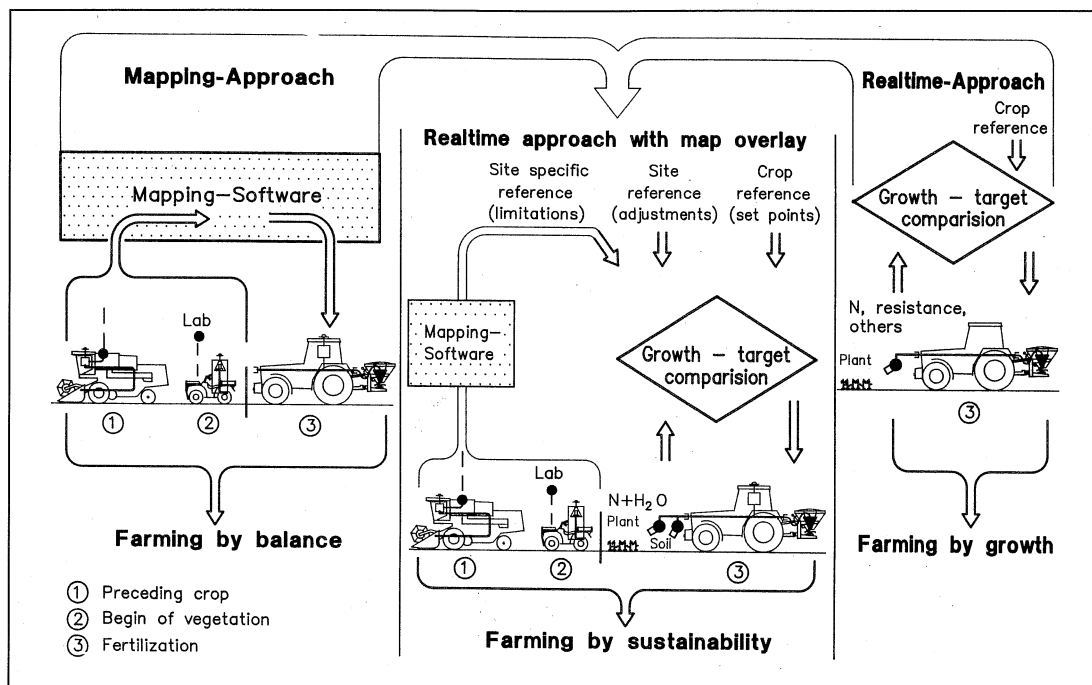


Fig.5: Approaches for site specific fertilisation in Precision Farming

ents is realised by using simultaneously available application technique two times.

Local application is exclusively operated according to grids. These are aligned usually at the north/ south direction and deviate thereby in many cases substantially from the driving lanes. Transitions between the raster specifications are smoothed partly with special control programs. Available section specific controls can be used automatically for spreading non rectangular fields with the help of GPS.

This approach is used in particular for the supply of basic nutrients and trace elements. Also the first N-fertilisation is to be included, in order to give a site-specific start application.

5.2 Real-time Sensor Approach

Due to the not directly foreseeable weather process the N-top-fertilising can be derived only insufficiently from mapping data of the preceding vegetation. Therefore particularly in the case of N-fertilisation, trials were made to determine the current plant growth with on-line sensor technology and to make the necessary N-dosage under real-time conditions. Two approaches are pursued at present:

- Measuring chlorophyll content as a control value which strongly correlates to the N-content in the plant. Calibration is effected via comparative measurement at single plants and company-specific defined supplying values. The control software used calculates the chlorophyll content and fertilises with regard to the defined yield target less developed plants. Generally this approach therefore results in more uniform fields. At present, no dosing limitations dedicated to geographical allocations in the system are contained.
- Recording of the plant growth with the measurement of the plant resistance at a pendulum attached to the tractor front. Comparative measurements showed that the resistance supplies a useful correlation to current plant growth. Realisations in practice were made only in test attempts.

5.3 Real-time Sensor Approach with Map Overlay

With the increasing significance of environmental-friendly production, the mapping approach has therefore to be integrated as an overlay in the sensor approach and has to be amended by an additional control value. Necessary are:

- target sizes for the optimal N-supply of plant types and planting areas according to growth curves and yield level as pre-set value for the necessary cybernetics;
- the on-line detection of current plant growth for the adjustment of the plant-specific regular target size to the field specific conditions;
- a site specific delimitation according to yield mapping of several years for the proof avoidance of over fertilising in less efficient places within the field (characterisation of the field section);
- the additional detection of the water situation stop in plant and soil as in the long run determining control variable for the effectiveness of a possible N-fertilisation in connection with an on-line N-analysis of the available soil nitrogen.

6 "Information System Spatially Variable Management Duernast (IKB-Duernast)"

To be accurate, these objectives are those of the DFG-research group "Information System Spatially Variable Management Duernast (IKB-Duernast)", which is situated at Weihenstephan.

Five institutes of the Technical University of Munich are co-operating to compile the necessary bases for the shown N-fertilising system. These are:

- 1) The Institute for Agricultural Engineering (TUM) with two subprojects:

SP 1 is trying to develop standardised yield mapping algorithms using local yield data of almost ten years. The special consideration in this project is based on the analytic entry of

The development of these systems almost exclusively takes place in Europe with emphasis on Germany. It is a response to the Central European production conditions on high yield level under predominantly humid conditions with locally different conditions concerning precipitation and temperature. The integration of mapping data which is missing actually confines however the application type one and to a large extent excludes the environmental exculpatory component in such a system.

possible errors during the acquisition of information (site detection, yield measurement, moisture test and others) and their consideration with the definition:

- more meaningfully and significantly different yield levels in the field;
- homogeneous grid sizes or admissible ranges of iso-yield areas in contour graphics.

Thereby analyses for yield stability should follow so as to be able to derive a weight of the limiting effect in the intended nitrogen fertilisation system.

SP 2 would like to complete the present site specific vehicle and work time data acquisition in the production process and to transfer onto all those machines and implements which are not explicitly equipped with electronics for the necessary site-specific application. In particular, the soil tilling machines should be included (to this acquisition of information), in order to enter site specific parameters with these machines to register the observed power demand, operating depth, etc. and have them be recognised for the strategic decisions of an on-line nitrogen fertilisation system. In addition, the requirements for the automated and continuous data acquisition should be created which represent the base for cost accountings and operational evaluations.

2) The Institute for Plant Agronomy (TU München) with one subproject:

By this the reference values (calibration curves) for the biomass development are compiled. The examinations concentrate on winter wheat and corn with different variations, in order to address and enter thereby also different growth types and different chlorophyll developments. Nutrient supplying degrees for different yield targets are included into the investigations.

3) The Institute for Plant Nutrition (TUM) with one subproject and three different methodical approaches for two different questions:

Water content in plant and soil is examined with the help of direct and remote sensing. Reflection measurements at defined measuring points are used in the field, in plot trials and in a strip plot trial. The soil water and that soil nitrogen are detected additionally with electromagnetic measuring procedures.

4) The Institute for Land Use Planning and Nature Protection (Ludwig-Maximilians-Universität - LMU):

The subproject tries to penetrate plant development with direct and remote sensing methods. Suitable bandwidths

within the near and further infrared range are examined. As a substantial measured variable, the exposure is included into the investigations so as thus to be able to derive standardised models.

5) The Institute for Operational Research (TUM) with two subprojects:

SP 6 creates the common information platform with the design, the structure and the maintenance of a universally usable operational data base. Great attention is put on the necessary interfaces. The transfer to mobile process technique and the return flow coming from it have high priority.

SP 7 compiles a cost accounting system for the operational, field and site specific referred evaluation. To this extent the subproject promptly furnishes ready results for and over the information system, which should be developed and the desired on-line nitrogen fertilisation.

The required farm information system is structured within the subprojects SP 2, SP6 and SP 7 and completed with a unique investment of an electronic communication system by the research station Duernast (managing director Professor Heissenhuber). This includes all mobile units and also the stationary technique (Fig.6).

It contains a central command control station including a fleet management system, access options of all institutes involved over the university-net, a client for farm management and an Internet link.

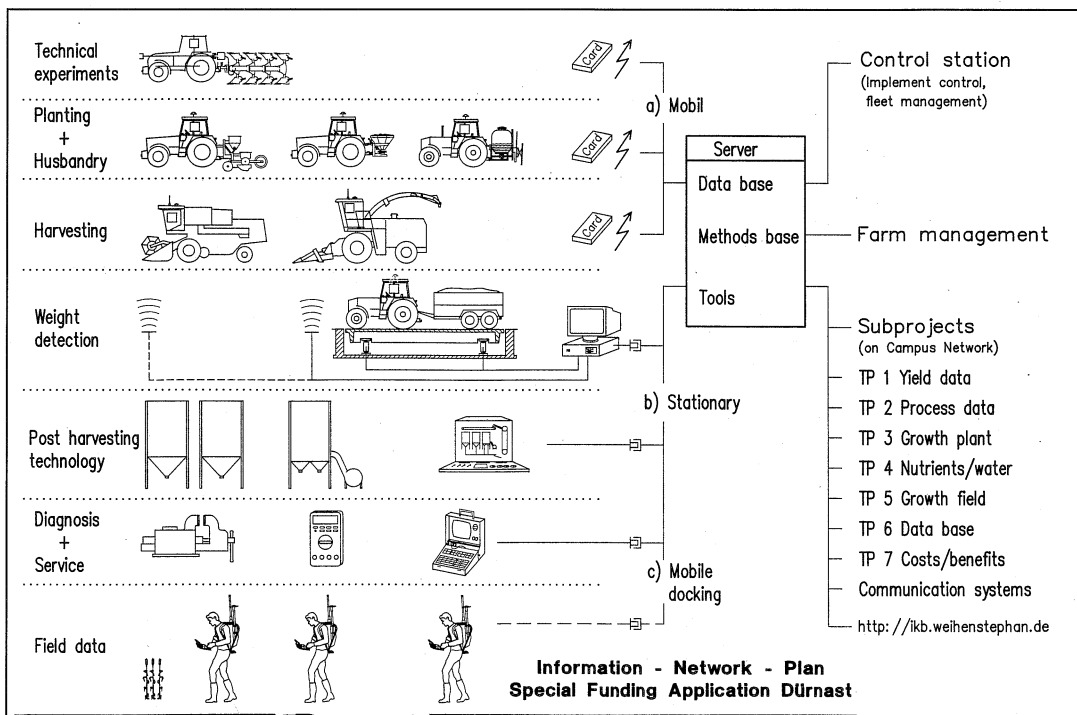


Fig.6: Communication system at the IKB Duernast

7 Communication in a Precision Farming System

Precision Farming means communication. Thus, the availability of an efficient communication system is decisive for its acceptance and possible introduction. For Europe the starting point was already set in the middle of the 80s with the "Agricultural bus system (LBS)"

This enables communication on a standardised base

- between management and mobile technique,

- between drivers and implement electronics,
- between the implements.

With its performance it fulfils the requirements for the integration of the techniques specified above and at the same time creates farmers' independence from the manufacturers. Besides that, the manufacturer, through his own electronic devices, can differ from the competition and make thus a significant contribution to innovations and to steady progress.

With the present continuation of standardisation, efforts on ISO level a connecting system for further-developed and refined techniques will be created for Precision Farming from tomorrow, which can be used globally.

8 Conclusions

With the change to larger farm units and an increasing amount of work done by contractors and machinery rings the farmer loses the direct relationship to the fields on his farm.

Homogeneous applications of seed, fertiliser and pesticides are the result. Over- and less- supplied areas lead to less yield and eutrophication with a multiplicity of negative effects with regard to the expense and the environment. Precision Farming changes this development and enables, without losses of machine power, the management of large fields according to site-specific conditions.

A prerequisite for use in practice is the application of GPS to the geo-referenced acquisition of information and information conversion. For fertilisation the following classification results:

As an entrance technology, local yield detection is available for wide- spread use in the combine. For other harvesting machines scientific solutions are compiled and can be integrated after appropriate adjustment into the available machines. The standardised data analysis is not solved, often problems exist during the data communication into non-firm-specific analysis software.

Geo-referenced soil sampling is suitable as a tool for the optimised supply of basic nutrients. It is usable for N-fertilisation, where continuous growth and climatic conditions are present over the vegetation season.

Not available are scientifically founded strategies from both sources of information for yield-target-oriented site-specific fertilisation measures. N-fertilisation strategies derived from the mapping approach requires high specialised knowledge for its realisation.

Sensor-based on-line N-fertilisation systems are in the first practical application. Firm-specific aligned control electronics operates for uniform yields and leaves environmental friendly criteria without consideration.

With a sensor approach N-fertilisation with map overlay, these disadvantage could be eliminated. The research project IKB Duernast, created on a longer term basis is aiming to close the gaps for it.

The actual introduction of Precision Farming for the fertilisation into practice is, however, handicapped by the not yet realised use of the available communication standard LBS. Farmers therefore, hesitate rightfully with embracing the new technology, particularly since the economical use is monetarily modest by low nitrogen prices. In contrast to this, the actual performance of Precision Farming, environmental discharge, is only sizeable with difficulties, a remuneration of these performances is not in view.

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Precision Farming for Site-Specific Fertilisation

(H. Auernhammer)

Summary

Precision farming has become a main focus of world-wide agricultural research. Mainly "mapping approaches" are investigated. "Real-time" application technology can be seen in first approaches. Solutions for geo-referenced documentation, vehicle guidance and fleet-management are discussed. Solutions with standardised communication for a cheap realisation on the farm are mentioned only theoretically, although with the Agricultural BUS System LBS a standardised basis technology is available.

The research group "Information System Spatially Variable Management Duernast" IKB-Duernast aims to realise the integrated approach of "realtime application with map overlay" based on LBS in a data collection and analysis concept for farms.

Key words: Precision farming, GPS, bus-systems, standardisation, communication, data collection, data base, communication, fertilisation, nitrogen

Precision Farming für die teilschlagspezifische Düngung (H. Auernhammer)

Zusammenfassung

Precision Farming ist ins Zentrum der weltweiten landwirtschaftlichen Forschung gerückt. Hierbei werden jedoch überwiegend die auf der Kartierung basierenden Ansätze untersucht. Mit dem Hydro-Agri System ist die erste Umsetzung einer Real-Time Applikationstechnik verfügbar. Ebenso werden erste Lösungen der georeferenzierten Betriebsdatenerfassung, einer GPS-gestützten Fahrzeugführung und von auf GPS basierenden Flottenmanagementsystemen diskutiert. Demgegenüber bleibt der Einsatz genormter Elektronikkomponenten, Grundlage für eine kostengünstige Realisierung der vorgestellten Möglichkeiten, nur Theorie, obwohl mit dem "Landwirtschaftlichen BUS System LBS" eine genormte Basistechnologie zur Verfügung stehen würde.

Die Forschergruppe "Informationssysteme Kleinräumige Bestandesführung Dürnast", IKB Dürnast, hat das Ziel den integrierten Ansatz einer "Real-time Stickstoffdüngung mit Map-Overlay" auf Basis des LBS und mit einem Betriebsdatenerfassungs- und Analysekonzept zu realisieren.

Stichworte: Teilschlagbewirtschaftung, GPS, BUS-System, Normung, Kommunikation, Datenerfassung, Datenbank, Düngung, Stickstoff

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