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# An On-Farm Communication System for Precision Farming with Nitrogen Real-Time Application

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## Summary:

Precision farming has become a main focus of worldwide agricultural research. Mainly „mapping approaches" are investigated. „Real-time" application technology can be seen in first approaches. Solutions with standardized communication for a cheap realization on the farm are mentioned only theoreticly, although with the Agricultural Bus System LBS a standardized basis technology is available.
The research group „Information Systems Precision farming Duernast" IKB-Duernast has the aim to realize an integrated approach of „realtime application with map overlay" based on LBS in a data collection and analysis concept for farms. The project has startet in September 1998 and will deliver first results at the end of 1999.

## Keywords:

Precision farming, GPS, bus-systems, standardization, communication, data collection, data base, fertilizing, nitrogen.

# On-farm Communication System for Precision Farming with Nitrogen Real-Time Application

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## 1. Introduction

Electronics systems become more and more important in agricultural engineering. With Precision Farming enormous research activities were developed world-wide. New international conferences in Europe and in the United States turn exclusively to this range of topics. Main starting points are situated in closed cycles with yield detection, soil sampling and prediction into fertilization. Approaches for site specific plant protection are in scientific handling (Second European Precision Farming Conference 1999). First attempts refer the different planting densities also into a total system. Two systematically different approaches with emphasis in the USA and in Europe are pursued with fertilization (figure 1).

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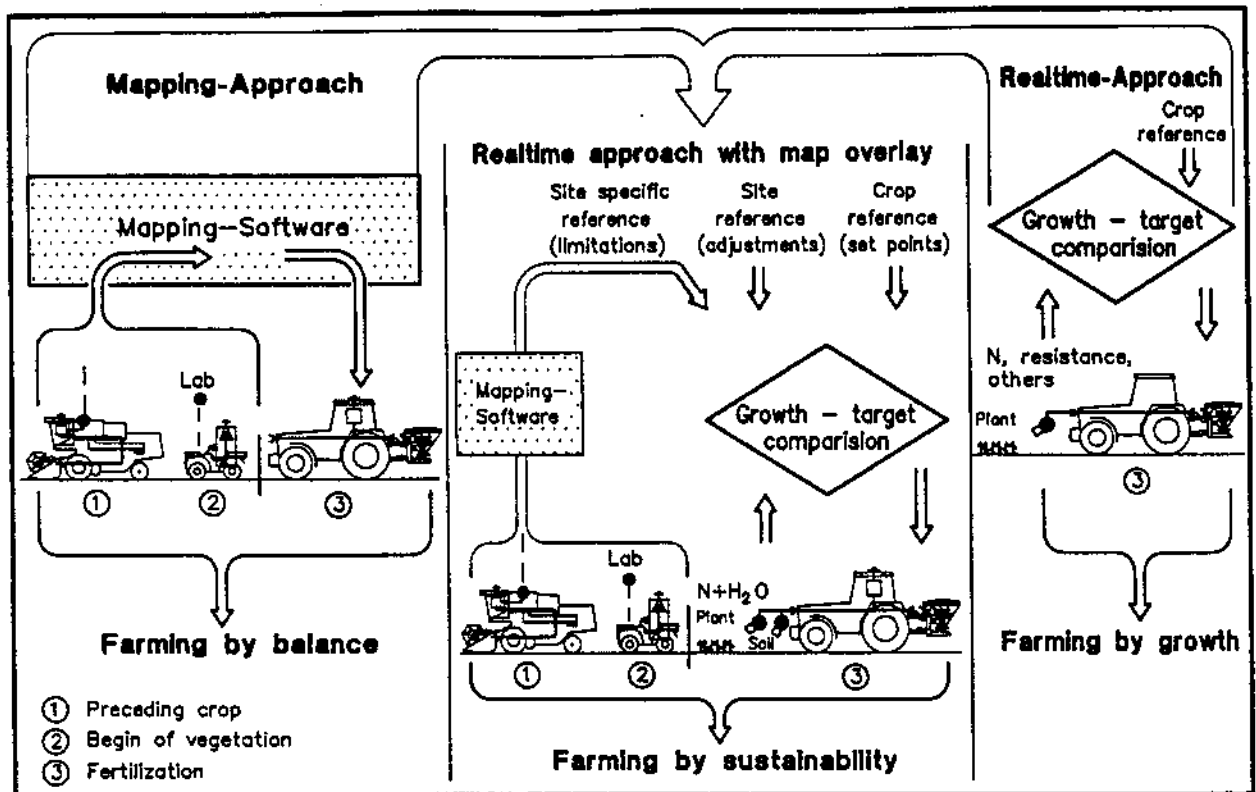
Figure 1: System development for site specific fertilization in crop production

## 1.1 Mapping Approach

Sensors detect geo refereed data of the yield in connection with GPS. Also the soil sampling takes place with GPS. Mapping software creates grid maps or contour maps to zones with uniform yields and same nutrient supply. They serve in connection with soil cards, fertilization requirement rules and expert knowledge to the prediction of nutrients in application cards. These are transferred in connection with GPS over actuators into site specific treatment.

At this beginning one operates theoretically with information exclusively from the past for the needs in the future. Therefore only those parameters can be included into such automatic control loops, which are not subject to large temporal modifications within local areas. In the fertilization therefore the P and K-supply can be adapted to the local request. Also the requirement of micro nutrients is to be integrated into this automatic control loop.

Related to the crop production this approach enables the balance between the application and the uptake of nutrients by the produced crops in an optimal way. It has its strengths, where no or where only less N-fertilization on yield level is needed. A transfer on other applications operations is possible, if these results only become a part once for each growing period, in particular thus like the basic fertilization, in seeding and in planting.

## 1.2 Real-Time Approach

The control loop is structured as an on-line system at the application vehicle. Indirect measuring methods enter the current growth situation (chlorophyll content, plant resistance). The derived application from that effected following standardized growth curves in a realtime control loop. A geo correlation is not necessary. There is no reaction to exceptional cases or there are pre-defined strategies for such events.

The current plant growth of this approach is the initial value as produced biomass. This depends on the past weather situation and the nitrogen quantities available in the soil. The real-time approach therefore depends on the achievement of high yields by a nitrogen application on yield targets. Site-specific differences in growth become balanced. With limited or missing water in the soil, the system leads to spread out more nitrogen than necessary and thus to an intensified danger of washing out nitrogen into the subsoil water.

## 1.3 Consequences

Both approaches system-dependently cannot fulfill the demands of production on high yield level with simultaneous environmental discharge by reduced nitrogen entry. Data from the past (Mapping Approach) describe static statuses and they therefore cannot be assigned at all the weather-related variabilities within the growth period. The exclusive consideration of the up-to-date produced biomass (sensor Approach) must lead however inevitably to problems, where missing subsoil water limits the nutrient feed into the plant or smaller soil fertility cannot furnish the defined yield targets.

# 2. Real-time approach with map overlay

In this approach the two existing approaches are united. The first control input is again a crop reference function. Additional sensors complete the control loop:

- A first adjustment of the crop reference to the real growth situation is done by a site reference. Reflection measurements are used over near and remote sensing methods.

- A second adjustment is done by site specific limitations from the mapping approach, which includes the local soil fertility into the control loop.

- Apart from the online-data recording of plant growth the plant stress is included into the automatic control loop.

- Further the data recording of the available subsoil water and the up-to-date available nitrogen of the soil takes place in the control.

All real-time sensed data are important for the understanding of precision farming. Therefore they must be collected and included into the information pool of the farm and the fields. This requires the creation of a farm related data base system with a simple and reliable connection to the application techniques.

# 3. Research group "Information System Spatially Variable Management Duernast"

The research project with financing by the "German research council (DFG)" is created on a run time of 6 years and is divided into two periods of three years each. In the first 3 years more basically oriented investigations will process the basis for the "Information System Spatially Variable Management Duernast". Afterwards the strategies for the conversion with an integrated verification of the system will be the main goals in the second project period.

In the first period 5 chairs of the faculty are involved in the project. They operate in seven subprojects (SP) on the following problems (figure 2):
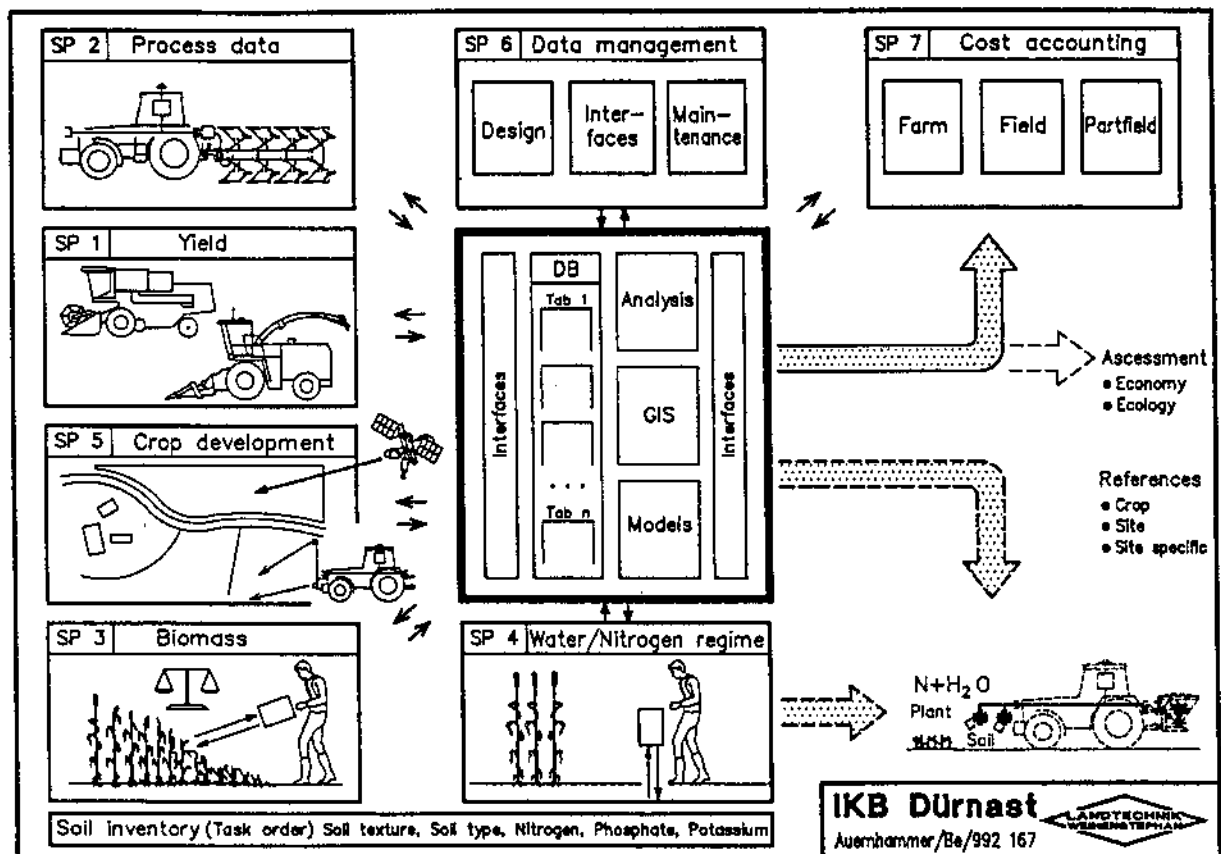
Figure 2:    Cooperating structure of IKB-Duernast

*SP 1 - Yield mapping (Chair of Agricultural Engineering)*
Based on extensive yield detections since 1990 standards for the yield mapping will be developed. Detection errors of the DGPS and measuring errors of the yield measuring sensors have to been respected. Admissible rules for the yield classifying should be derived. They serve as "site specific limitations" in the real-time application system.

*SP 2 – Process Data (Chair of Agricultural Engineering)*
Basis for this subproject is the "Mobile Agricultural BUS-System (LBS)" by DIN 9684. It enables together with GPS an automation of the process data acquisition. The project looks for proof, economical and reliable measuring techniques. All implements of the farm have to be integrated and be addressed with specific data acquisition algorithms at the task controller. As results these influence the design and the necessary gathering rules for the on-farm data base system.

*SP 3 - Biomass formation and N status in plants (Chair of Agronomy and Plant Breeding)*
The objective of this subproject is the development of optical reference values for biomass production of different plant species and cultivars at varied N-fertilization regimes. Therefore reflection measurements in winter wheat and maize are conducted during the growing period. Measurements are accompanied by plant samples to determine dry matter production and N-uptake. The expected correlations serve as "crop input function" for the N-fertilizer system with real time application.

*SP 4 Soil and plant water relations and soil nitrogen status (Chair of Plant Nutrition):*
Input information for optimized cultivation (planting and seeding density, nitrogen fertilization) is obtained by non-destructively measuring relevant soil and plant properties. Site-specific soil properties (soil texture; soil water content) are determined by electromagnetic induction principles and derived from spectral information based on remote sensing techniques. A tractor-mounted sensor is additionally used to characterize the plant water status. Calibration functions are developed based on the relation between non-destructively and destructively obtained information (soil analysis; capacitance principle, tensiometry, pressure chamber, porometry).

*SP 5 - Crop development (Chair for Land Use Planning and Nature Conservation)*
Crop growth and canopy structure development are analysed, evaluating changes of the Bidirectional Reflection Distribution Function (BRDF). Field spectroscopy methods for the approximation of the BRDF as well as remotely sensed data from air- and spaceborne multispectral and "on-track" stereo systems are investigated. The results should be used to optimise canopy reflection models needed to control realtime fertilizer systems in precision farming.

*SP 6 - Data Management (Chair of Operations Research and Information Management)*
All relevant data and information for the twin goals of the project 'Online N-Fertilization' and 'Ecological and Economical Assessment' are to be added to a central data base. To this end, this part of the project develops the necessary data base structure with the interface for the data entries and distribution. In addition tools for the analysis of data and providing data for decision models have to be developed.

*SP 7 - Cost-Accounting (Chair of Operations Research and Information Management)*
The presently developed cost-accounting system is based upon the data structures provided by SP 6, from where it receives the necessary data. Target objects are the whole farm, the individuell fields and the part-field. The outstanding characteristic is the automatic data collection for the cost-accounting system. Manual data entries are not necessary to a great extent. The results to be obtained will be used as a target check for the entire project.

The experimental station Duernast in direct proximity of TUM in Freising-Weihenstephan is the location of the research group.

# 4. On-farm communication system

The targets defined in the project require a global small-scale data acquisition with central data storage. With GPS the respective position and the current time are available everytime and everywhere. If these information is connected with the sensor technology installed in the technique, then an automatically operating process data collection system can be mounted. As universal link for necessary communication in addition the "Mobile Agricultural BUS-System (LBS)" is used. It is characterized by the following features:

· The definition took place in a time interval lasting over 11 years from representatives of science and industry

· LBS is available as a standard since January 1997

· There are real products available on the market

· For use of checking of the standard conformity global test and reference systems exist

· Increasingly low-priced solutions were developed by competitive suppliers

## 4.1 Implement identification

In the definition of LBS own job computers in each machine and implement are expected. These enter the respective on-the-go situations as implement-specific process computers by own sensors and control the implement by own actuators. LBS is appropriate therefore particularly to the application implements for fertilization, plant protection and to seeding and planting techniques. They represent however in an "Agricultural enterprise" the minority and are predominantly surrounded by "stupid machinery" (e.g. plough, harrow, roller, transport unit, ...). Within the research project LBS therefore was extended (figure 3) by an independently operating implement identifier unit "Implement indicator (IMI)".

It fulfills the minimum requirements to LBS job computers with the ability of the implement identification during the initialization procedure and the supply of the cyclic system-alife functions together with:

· A freely programmable implement identification

· An Icon for the representation on the LBS terminal

· The possibility of integration of additional sensors for implement specific data gathering
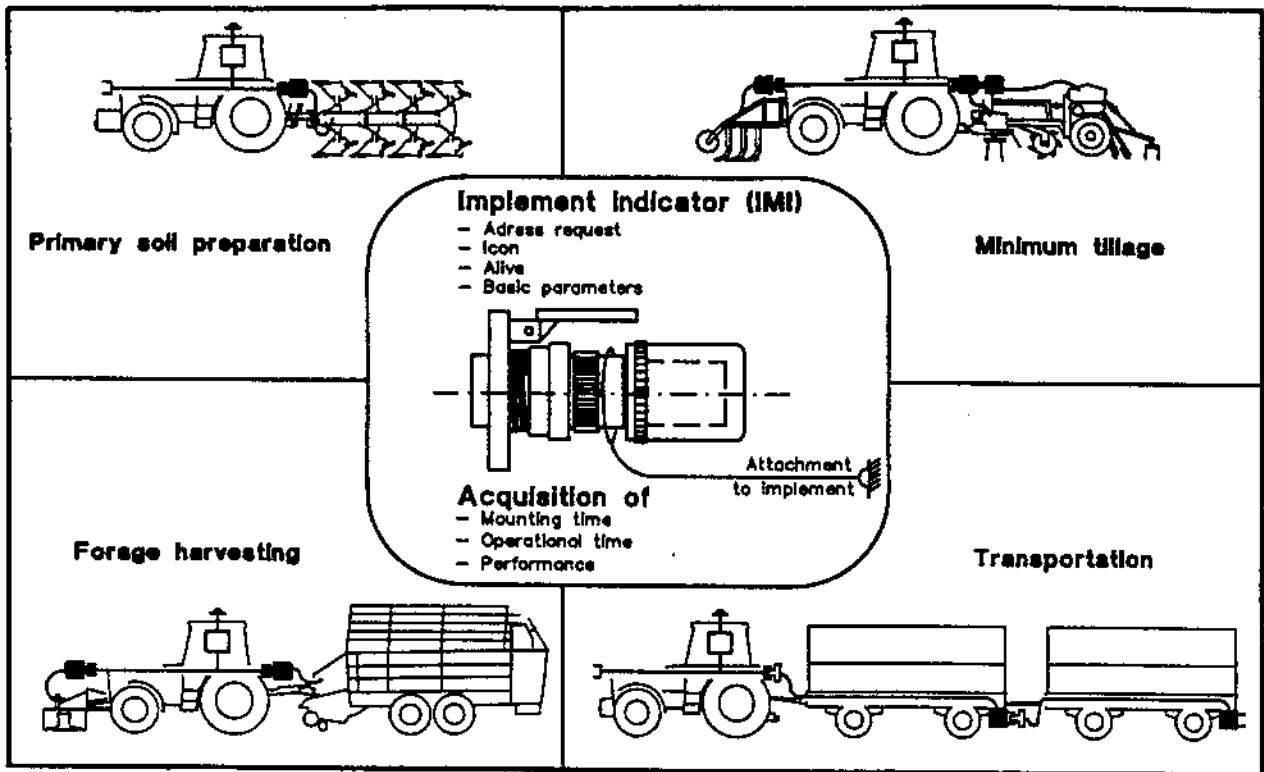
Figure 3: Typical applications of the "Implement indicator (IMI)" in a LBS environment

IMI's are connected firmly after programming with the respective implement by a chain or flexible steel rope. They are able to be integrated in a miniaturized shape directly into the LBS-connector and therefore do not need a "moving bus termination" and an LBS extension socket. Only in transport units and other implements with free combinations the bus extension with LBS connection socket and moving bus termination is required.

## 4.2 Automatic process data acquisition

The automatic process data acquisition takes place with GPS in all tractors of the experimental station. These have three different configurations:

· LBS according to DIN 9684 in the tractor for specific experiments (FENDT Vario 714)

· Signal connectors by ISO 11987 (DIN 9684-1) in the newer tractors. Available LBS terminals are able to use this signals and integrate them into the "Basic data 1 and 2"

· No electronics at all in the older tractors. These tractors will be equipped with a "LBS add-on kit" and work like originally equipped LBS tractors.

With the tractors and the available equipment on the experimental farm three different lines of automated data acquisition systems may be used (figure 4).
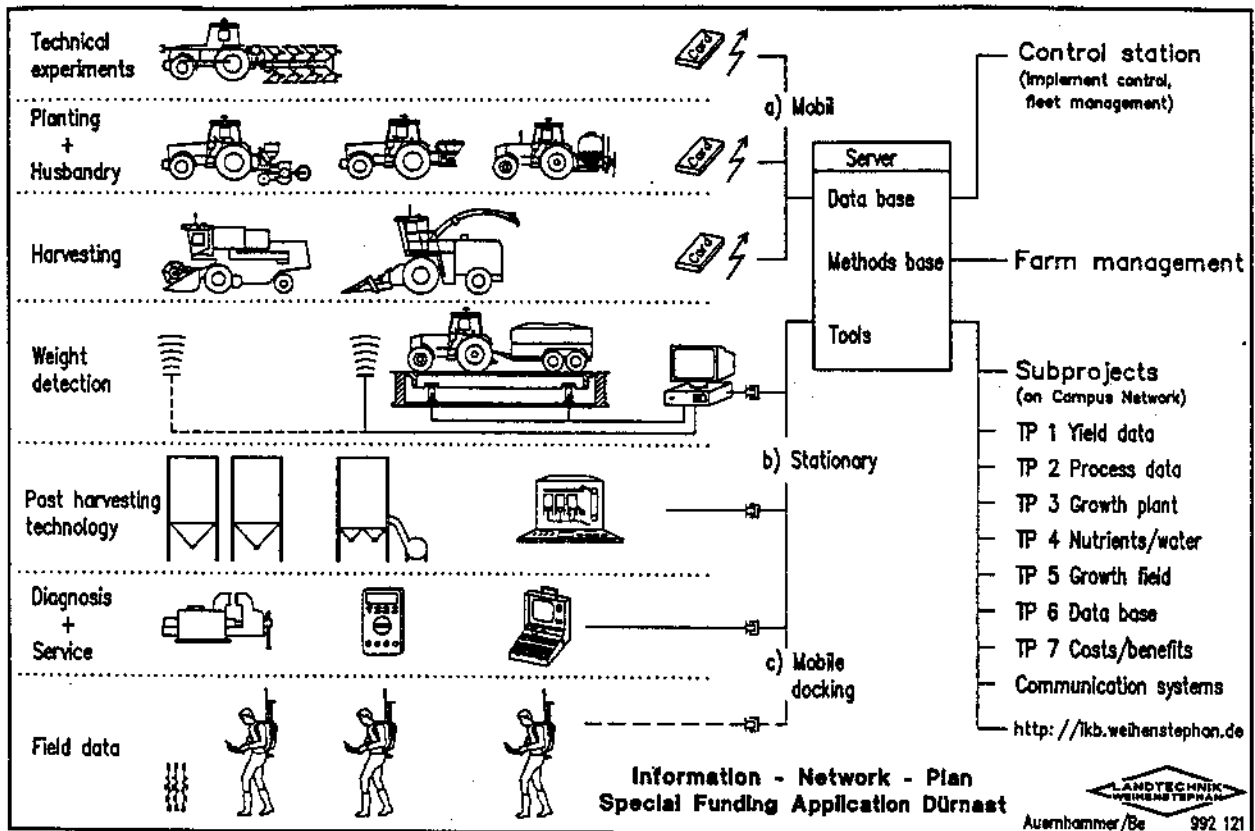
Figure 4: Information network on the experimental farm Dürnast

- IMI's offer in "stupid farm equipment" the implement identification and in some extends additional informations from integrated sensors. New approaches will be taken by different investigations with the experimental tractor. All IMI-signals are processed in the LBS-task controller.

- Job computers in application systems supply the current actual values of these implements to the LBS-task controller. Data processing is similar to the former solution.

- Self-propelled harvesting units have manufactor specific electronics for data acquisition and data processing.

All farm transports will be monitored by the integration of a platform scale into the farm network and with a specific transport identification system. The integration of the in-house drying unit and the workshop for remote diagnostics and new settings of machine internal parameters is planned.

## 4. 3 Integration into the management

Entire data communication between mobile units and management is made by chip card or PCMCIA card. Radio transmission is intended for a later point in time. Data contents are defined according to DIN 9684-5. It is based on ADIS (Agricultural Data Inter-change

Syntax) following ISO 11787.

The definition and the design of the necessary data base represents an emphasis in the research project. This function will be solved by the co-operation of all in the project integrated scientists under the main responsibility of subproject 6. Substantial questions are:
– necessary data
– general and specific data analyses
– interface definition
– supply of necessary tools
– general and specific data analyses


## 4.4 Current development position

To the present status substantial subsystems are compiled:

- The yield determination takes place on the research station since 1995 for grain and mais silage. Over the past time interval continuous sensor technology was used.

- On one experimental field site specific fertilization by grid application was done since 1995 with a LBS prototype. Special investigations were occupied with the LBS operability and with the real bus load.

- The now available tractor with variable transmission is equipped with a standard LBS. Three different LBS terminals take place with it.

- The IMI defined for the process data acquisition is implemented in first prototypes. Field tests are intended starting from the end of July. During maise silage harvest automated data acquisition on all integrated units will take place for the first time.

- The corn planting operations 1999 were done for the first time with a LBS system and with electric powered planters in each planting unit. Site specific planting of maise with 7, 10 and 12 plants/m² was realized.

- The Design of the data base has progressed far. The first test with data integration will take place together with the test of the IMI's.


## 5. Conclusions

Under European production conditions high yields with low environmental impact only can be achieved with time specific and site specific nitrogen fertilization. Mapping approaches as standard solutions in precision farming do not fullfill this requirements. Also exclusive sensor approaches are not suitable. Therefore the solution might consist in an extended combination of both methods. The following problems must be solved:

- Development of reference values (functions) of crop specific nitrogen requirement

- On-line sensing of the nitrogen and water conditions in plant and soil

- Integration of remote sensing for crop development sensing

- Derivation and use of standardized evaluation algorithms of site specific yield data

- Site specific process data acquisition with standardized data transmission for the use of farm, field and partfield cost accounting

- Establishment of an efficient operational data base for the universal use of site specific nitrogen fertilization and economic and ecological evaluation

# 6. Acknowledgements

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