Deutsche Gesellschaft für Ortung und Navigation e.V.

EUR NAV 94

3rd International Conference

on

LAND VEHICLE NAVIGATION

14–16 JUNE 1994
DRESDEN

Jointly Organised
by

The German Institute of Navigation
Düsseldorf, Germany

The Royal Institute of Navigation
London, United Kingdom

GPS AND DGPS AS A CHALLENGE FOR ENVIRONMENT FRIENDLY AGRICULTURE

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ABSTRACT

For future-oriented farming, positional information is of extraordinary importance. Out of a multitude of positioning systems, GPS/DGPS is the most suitable one. This system does not require any additional infrastructure and at the same time guarantees complete coverage of all tilled surfaces. The major application of positioning with GPS/DGPS is to be seen in the area of local information and documentation. By generating both planning and process data, it facilitates operation and control of work processes (organical and mineral fertilization, plant protection). In the end, positioning leads to navigation, which in the case of single vehicles and vehicle pools will in turn provide completely new possibilities for development and application. For the first time, vehicles without drivers are conceivable. Thus, the completion of any kind of work on schedule, without time limitations, would become possible, with the slightest imaginable stress for soil and environment.

1 INTRODUCTION

The economies of higher developed countries are marked by industrialization and an increasing range of services offered. As a contrast, the share of the population working in the agricultural sector is decreasing steadily. Remaining agricultural operations try to maintain their competitiveness by upsizing operational units, with growing levels of mechanization and increases in yield. In the past, this tended to result in site-related environmental stress on the one hand and unused resources on the other. Despite or perhaps because of these immense efforts, the public image of both agriculture and environment has suffered in more than one respect.

2 ENVIRONMENTALLY SOUND MEANS "LOCAL"

Plant production always depends on the conditions at the site, i. e., for the most part, on the soil and its local characteristics such as type, nutrient supply and water-bearing qualities. Environmentally sound production aims at integrating the existing, natural factors in order not to induce any lasting changes. In case of nutrient supply this means e. g. fertilization based on nutrient uptake. The quantity of nutrients supplied equals the amount actually uptaked and processed by the plants.

In the past, it was the individual farmer himself, who took into account the above-mentioned factors. As long as the plots were of manageable size, he was likely to be familiar with every square foot of his farm and fields. His daily routine yielded constant feedback to which he could react with his expertise. However, with increasing plot size and the employment of temporary workers, local information was lost at an increasing rate. Farmers were left with having to look at the harvest as a single unit, although, as the acreage to be harvested increased in size, so did the variability within the respective harvests. These disadvantages can only be eliminated through reliable and exact positioning. Thus, position-related soil cultivation with a small-scale orientation would combine the advantages of small farming operations (ecological aspects) with large-scale, cost-efficient cultivation methods (economical aspects).

For agricultural vehicles, a variety of positioning systems is currently available (Fig. 1).

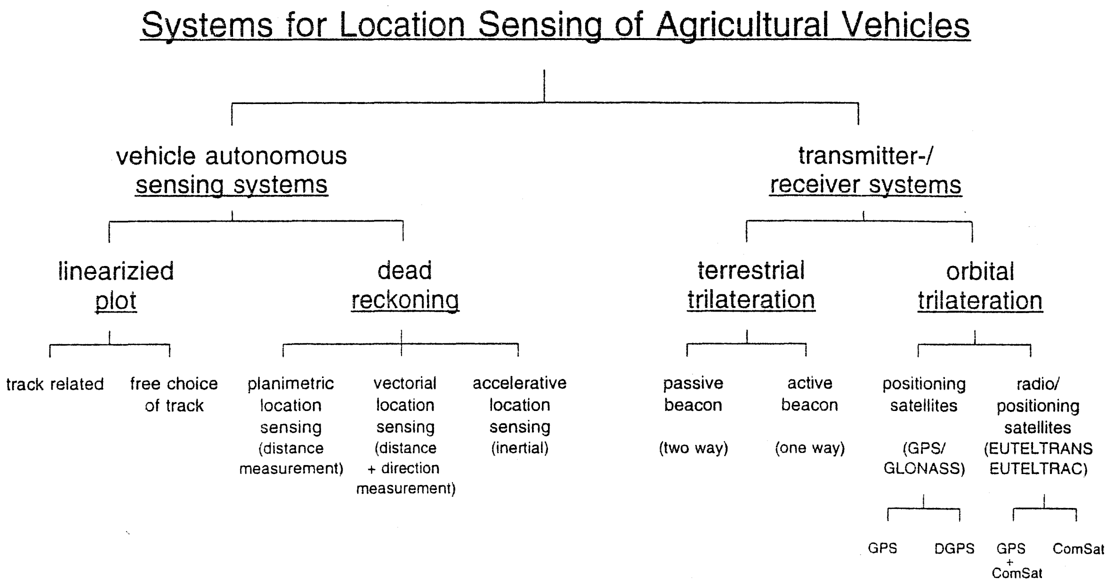


Fig. 1: Systematic representation of positioning of agricultural vehicles.

All systems have inherent advantages and disadvantages (Table 1). However, only the satellite positioning system GPS or DGPS meets the demands for universal application. It is the only system that allows operation 24 hrs/day, independently of weather conditions, without additional infrastructure and at an individual or extra-operational level.

Possibilities of application for GPS/DGPS in agriculture can be divided into two fields: location sensing and navigation (Fig. 2).

Tab. 1: Advantages and disadvantages of positioning systems of agricultural vehicles.

	Vehicle Autonomous Sensing Systems		Transmittier - / Receiver Systems	
	Linearized Plot	Dead Reckoning	Terrestrial Trilateration	Orbital Trilateration
Advantage	→ only 1 sensor needed → error-correction possible at every tramline end → no sensor-infrastructure needed	→ no sensor - infrastructure needed	→ high precision → no farm external actions necessary	→ worldwide high development activity → universal use for high production numbers and low prices → position, time and velocity available all the time → infrastructure build and maintained by the operator
Disadvantage	→ work only possible if starting at the dead point → varying tramline distances cause errors → after a break it is necessary to follow the already worked way starting at the field dead point	→ known starting point (dead point) needed → errors by poor traction (drift of vehicles) → errors remain in the system and sum up till the system is recalibrated at the starting point	→ cost for installation and maintenance → flat area needed → increasing errors close to beacon, may be reduced by 3 or more beacons (higher costs)	→ depending on operator → standardsignals with ± 100 m errors (95 % of all deviations) → for higher accuracy use of DGPS with base station necessary, requires online-radio-connection, higher costs
Error	working width (x) ± 3 - 12 % way length (y) ± 1 - 3 % (by error-correction on tramline end)	≥ ± 1 nautic mile / 8 h (≥ ± 6,4 cm / s) = with 7 km/h ≥ ± 3 %	± 20 cm - ± ∞	± 100 m with GPS ± 1 - 2 m with DGPS
Assessment	for carefully working farmers for the on-farm use fields with row-crops or tramlines suitable	as a single system not satisfying for agricultural use	as an onfarm system it is well satisfying on large and flat areas	nearly unlimited useability with excellent possibilities for the contractor and machinery-ring use and hilly landscapes (using DGPS)

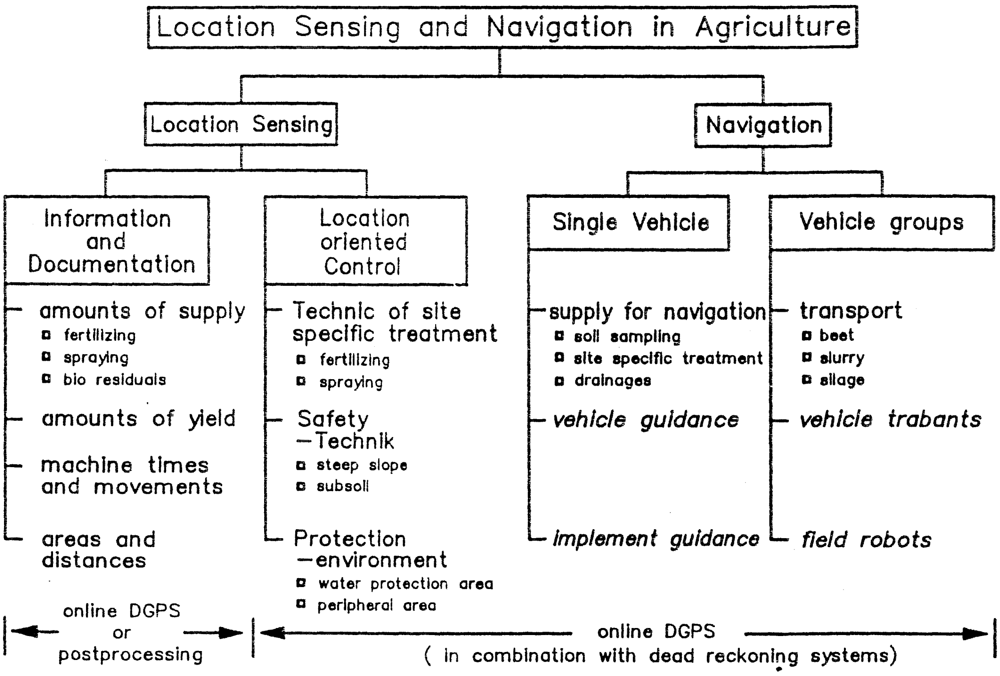


Fig. 2: Applications for location sensing and navigation in agriculture.

3 LOCAL DATA ACQUISITION

Acquisition of local data is divided into four main areas of application:

3.1 AUTOMATIZED DATA ACQUISITION

Improved management techniques need more and better data or information. Location sensing yields geographical information. Location sensing results in "geo-referencing of obtained information (geo-coding)" and therefore supplies all information with its corresponding spatial co-ordinate. The following factors are important in this respect:

3.1 (a) Agent Control

The focus here is information about output of fertilizer and plant-protective agents per plot or part plot. At fertilization, the quantity of fertilizer supplied is the first key variable for the desired balance of supply and uptake. With protective agents, on the other hand, data about "output quantity and means of application" figures as a quality criterion for the buyer.

Additionally, there is the use of an increasing amount of biological refuse from households and industry. For this waste, complete documentation of total output should be required right away, i. e. from its place of origin to its distribution on the fields, as far as location, date and amounts are concerned. In light of a constantly increasing consciousness about environmental issues among the population, this is the only way to ensure future production on surfaces to which such waste materials are currently applied.

3.1 (b) Yield Measurement

It can be assumed, without being in danger of exaggerating, that most grain-producing operations only have an approximate idea about the exact yields of their fields. In the production chain "bulk goods" of today, where the unit "bag" has been eliminated, traditional ways of estimating are no longer possible. However, scales on the farms themselves are still the exception.

Locally measured yield reflects nutrient extraction. This is the second variable in the desirable balance of supply and uptake. Today, local yield measurement is feasible with combine harvesters and thus available on the market (Fig.3). Solutions for yield measurement for tillage, silage corn and potatoes still are to be developed.

3.1 (c) Machine Time and Machine Activities

Almost all agricultural operations use their machines far too little. The machine times or areas processed are often unknown. Purchasing decisions are frequently made on impulse rather than according to real need. This situation is also true for operations with improved management techniques and existing electronic databanks for harvest data. Many of these operations cease recording complete, necessary data already after a rather short time because the required data is either inaccurate or not available at all. Automatized data collection by means of already available sensor devices in tractor and implements is therefore, in connection with positioning, the basis for a potential decrease in operational costs (Tab.2).

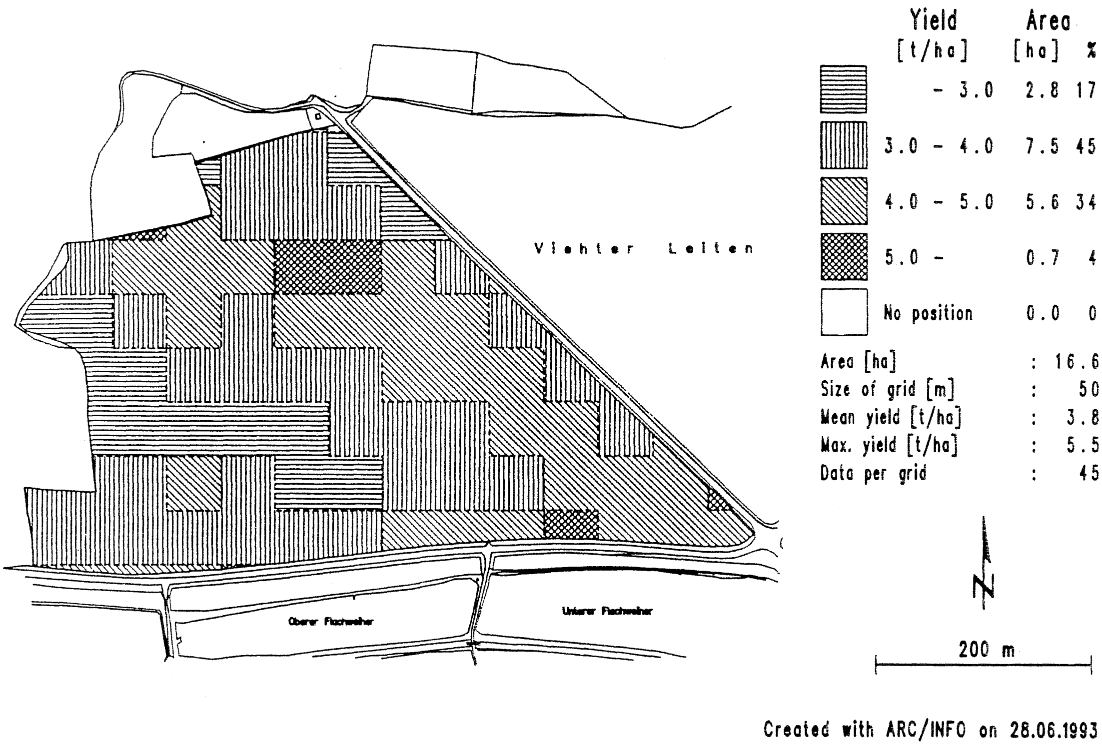


Fig. 3: Yield Map Scheyern "Flachfeld" 1992 (Spring-barley: MF-DGPS; yield detection with DATAVISION-FLOWCONTROL).

Tab.2: Automatic work time acquisition with DGPS and additional sensors.

Plot	Area	Total time	Rel. part of total time			
	ha	hour:min	threshing	bin emtying	idle drive	stand still time
Kehrfeld	25.5	9:56	63.05	6.33	13.00	17.30
Flachfeld	16.6	6:54	72.69	6.10	13.71	7.49
Unteres Hohlfeld	9.9	3:20	62.44	7.58	22.07	7.83
Eulenwies	5.3	2:14	67.37	6.62	19.37	6.58
Unteres Geiswegfeld	3.4	1:25	70.51	7.27	16.66	5.57
Oberes Geiswegfeld	3.3	1:33	68.76	7.58	21.60	2.05
Heubruch	3.1	1:30	71.08	6.09	16.84	5.70
Hopfengarten	2.1	1:02	65.96	4.70	25.04	4.29
Mean (without Kehrfeld and Unteres Hohlfeld)			**69.40**	**6.37**	**18.87**	**5.28**

3.1 (d) Areas and Distances

Every type of work connected with positioning results in surface specification by means of the so-called "plot envelope". Movements in the field can be seen as actual distances travelled. This, in turn, provides direct production data in the form of actually used cutting widths at the harvest as well as at distribution processes and soil cultivation (Tab.3). With regard to potential extra-operational use of vehicles, these are conditions for effective management and staff evaluation, i. e. for effective output and resulting costs.

Tab.3: Calculated threshing distances using GPS for positioning detection harvest Scheyern 1992.

Plot	Plot size	Threshing distance	calculated parameters from the threshing distance	
			working width	rel. deviation from the real working width
	(ha)	(km/ha)	(m)	(work.width = 5,5m = 100%)
Flachfeld	16,6	2,37	4,22	76,73
Eulenwies	5,3	2,25	4,44	80,73
Unt. Geiswegfeld	3,4	2,27	4,41	80,18
Ob. Geiswegfeld	3,3	2,11	4,75	86,36
Heubruch	3,1	2,58	3,87	68,73
Hopfengarten	2,1	1,97	5,07	92,18
Mean		**2,26**	**4,46**	**80,82**

4 LOCAL OPERATION AND CONTROL MECHANISMS

Geo-referenced information means information available at a respective position. Thus, if positioning is available at the vehicle, operational controls may be accessed. A number of intermediate stages are conceivable, starting with the display for the driver only to almost totally automatized processes.

4.1 SITE SPECIFIC TREATMENT

Positioning data available during the working process provides the possibility for incorporating different requirements of fertilizer and plant protective agents via manual adjustment or control circuit (Fig.4). With GPS/DGPS, these activities may be carried out in a reliable and cost-efficient way, and, for the first time, also on an intra-operational basis.

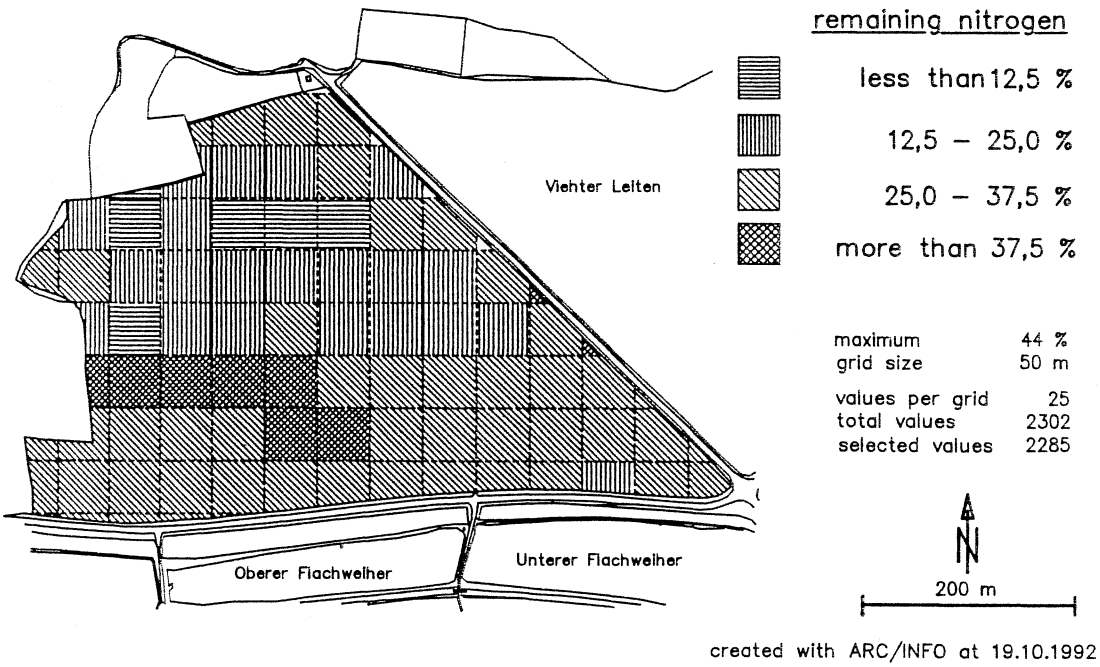


Fig. 4: Remaining nitrogen (by Maidl) Scheyern "Flachfeld" 1991 (winter-wheat; 16,6 ha fertilizing, 160 kg N/ha uniform)

4.2 TECHNICAL SAFETY

Positioning data available during the working process also opens up completely new possibilities concerning the reliability of implement operation and safety of staff in the case of "local dangers". Moist spots on the field may for example be pointed out (to avoid stuck vehicles) as well as crucial inclinations that may pose a problem for certain tractor-implement combinations (to avoid turn-overs). The advantages are obvious: additional, unproductive use of time or possible damages to the technology may be avoided. Reduced safety requirements for staff are also conceivable.

4.3 ENVIRONMENTAL SAFETY

GPS/DGPS helps to avoid unadvertant or careless soil treatment within protected surfaces or areas. Among these are areas governed by special water protection regulations and peripheral area projects, precious biotopes within greater agricultural areas and spaces marked for animal and species conservation. For the first time, active resource protection could already be effected independently at the planning stage and then documented during operation. Since these measures contribute to a general improvement in the environment, they are of topmost priority.

5 NAVIGATIONAL REQUIREMANTA AND POSSIBILITIES

Finally, the target-oriented aspect of positioning, navigation, results in new and promising fields of application. In this respect, two areas are important for agricultural use:

5.1 SINGLE VEHICLES

Currently, navigation of individual vehicles is already being made use of in practice in the form of navigational aids. Focus is on the systematic collection of soil samples (Fig. 5).

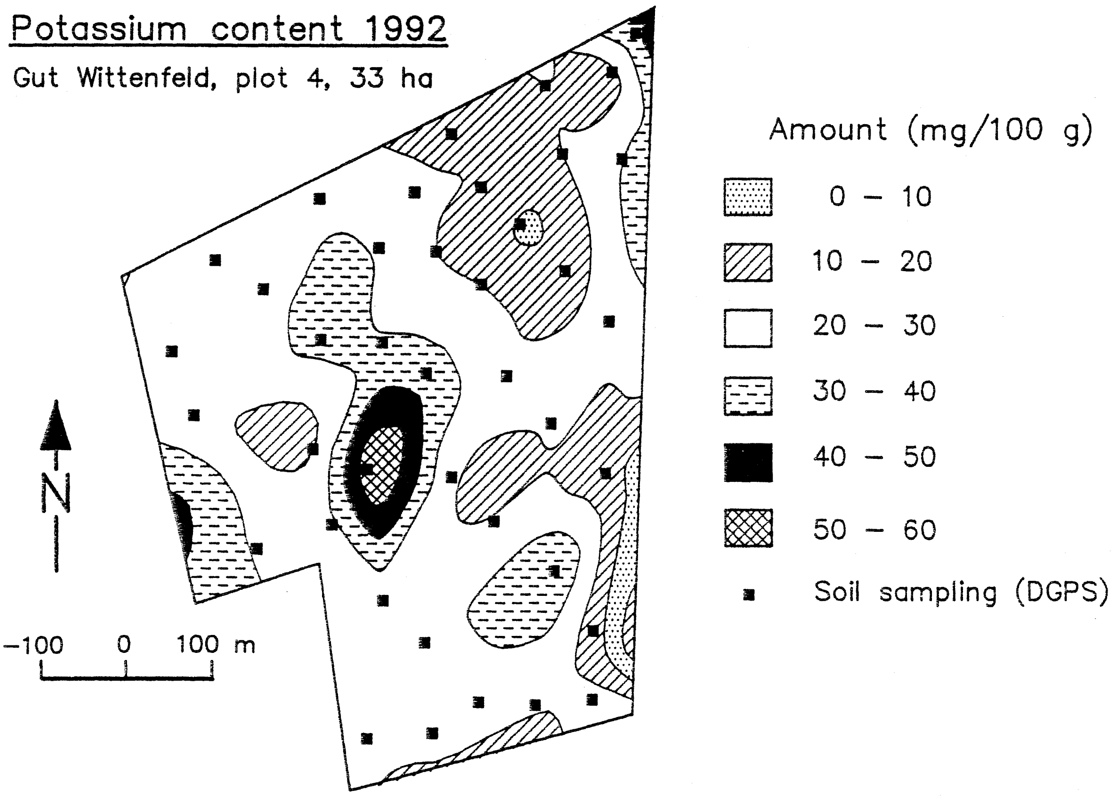


Fig. 5: Graduated potassium supply with respect to geo-referenced soil sampling.

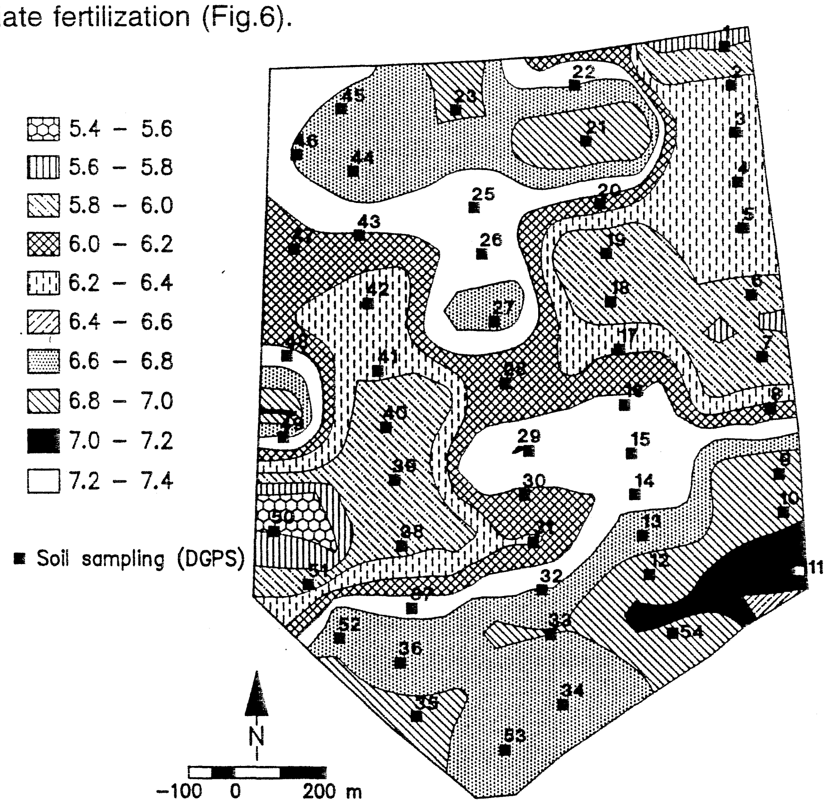
This system incorporates the following steps:

- Marking off the area to be used for testing with DGPS and recording of the plot envelope
- Marking off potentially "excluded areas" (woods, biotopes etc.)
- Calculation of total testing area
- Determination of required sample figure

- Identification and distribution within the available area of points where samples are to be collected
- Approaching chosen points with the aid of DGPS
- Collecting of samples and recording of the corresponding co-ordinate

This process, with the help of geostatistics, yields surface-adjusted charts of available nutrients, thus providing the possibility of a partial, harvest-oriented requirement analysis and appropriate fertilization (Fig.6).

Fig. 6:
Map of pH-Levels on plot 23 (Am Bahndamm) established after DGPS-based soil sampling (by geo -konzept 1993)



Navigational help available from DGPS could also serve to locate geo-referenced supply and disposal devices in the soil (drainage, cables, irrigation ducts e. g.). Moreover, previously defined borders for partial plots may be accessed more easily.

Further features serve to make tractor or vehicle navigation easier for the driver. With respect to mechanical weeding devices this will lead to measures that allow a more careful handling of resources. For this, however, additional investment in a dead INS-55 reckoning system is required, which in turn would enhance the precision of vehicle and implement operation.

5.2 VEHICLE POOLS

As far as transport is concerned, time and volume are the most important factors. Both lead to significant environmental problems, unless appropriate dates and shortest distances are used. For extra-operational transports, this can only be achieved with the help of navigational systems. In the agricultural sector, the transport of sugar-beets is of top priority. Transports from field to plant, centrally organized by the sugar industry and at the same time taking into account appropriate harvesting dates and operational units of different sizes, are a typical problem of vehicle pool management (fleet management). Determining suitable points of departure is a great navigational challenge, since accurate navigation in the range of 10-20 meters is required. Imperfect navigation leads to significant losses of time or undesirable over-extension of badly built up roads. It can also lead to total loss of transport units for a longer period of time.

Similar problems are to be found in the case of extra-operational liquid manure distribution and extra-operational silage harvesting processes, where large combines are concerned.

In the future, navigational management of vehicle pools will lead to discussions about vehicle satellites and driverless field robots. This technology should, however, only receive further attention when positioning has provided an electronical solution to all other above-mentioned tasks and current production conditions have consequently been changed in a way that allows a more careful handling of resources. Then, first useful attempts are conceivable at grain sowing and harvesting.

- At sowing, a manned sowing vehicle (requires manual detail operation) would operate in connection with unmanned vehicles for seedbed preparation on always exactly coordinated surfaces.

- In opposition, at harvest, a manned head vehicle would be followed by one or more unmanned satellites, since the latter have to perform processes determined by the preceding vehicle.

It is entirely possible to imagine further developments if the driver of the vehicle is to be eliminated completely. The machines then would not need any further increases in size. Optimized units could, with less soil pressure and ideal use of traction force, work independently on previously marked areas. In visions of the future, these "herds of robots" would result in team-like conditions, bringing agricultural operations to a point they once already were at - at the time of plough-boys, handmaids and domestics-, i. e. to centrally managed operations with a flock of "servants".

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