GPS IN A BASIC RULE FOR ENVIRONMENT PROTECTION IN AGRICULTURE

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Introduction

Today's crop production techniques and systems need to be reconsidered due to increasing concerns about environmental pollution. Thereby the main focus has to be on environmental friendly production. All actions have to consider the variability of the fields due to different soil fertilities, different soil types and changing soil water resources. Agriculture will leave the paradigm of uniformity and go into a small spaced variability. To technically realize this a simple, safe, always available and inexpensive position detection of the vehicles in the field will have to be guaranteed.

Systematic of position detection in the field

Looking more systematically, position detection of vehicles can be divided into two categories (figure 1).

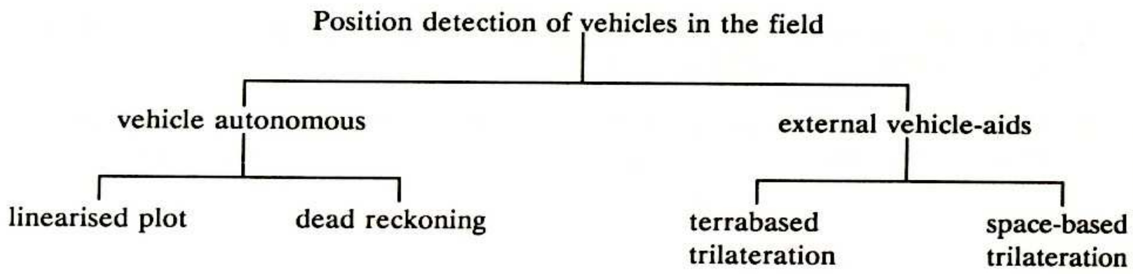

Figure 1: Systematic of position detection of vehicles in the field.

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In the vehicle autonomous system only sensors on the vehicle are used. In a simple case this is realized in a linearised field where each tramline has a known fixed location. For the orientation within the tramline, track measurement is needed. Radar commonly gives this measurement. The use of this type of position detection in the Federal Republic of Germany shows very quickly the limits of this system. It works quite well, if the farmer himself does the job. He has enough expert-knowledge and he takes enough care on it. However, other employees have in most cases not enough diligence or they may not be motivated enough to operate without errors.

Dead reckoning is used in a high number of position determination applications, but until now it is only used in non agricultural traffic, where together with a track travel distance sensor and a steering-angle-sensor or a gyroscope all movements of the vehicle are recorded from a certain initial point. On a calculation basis then the actual position can be defined if there is no slip and no sidedrift.

Terrabased position detection systems use position reflectors or responders which are located on the ground. The position is detected from the travel time of the signals. Use of this technique in small scaled agriculture, like in the western part of the Federal Republic of Germany, puts a very high demand on infra-structure with its need for multiple reflectors and frequencies. Additionally the very many buildings and intensive hilly country in many agricultural areas can cause disturbances.

All these restrictions are not valid for space-based-position-detection-systems. GPS or GLONASS require no structural actions by the farmer. Their use will also be without costs in the future. The needed receivers show heavy decreasing tendencies in price. If a reference-station is utilized, a high precision in position detection can be reached. In addition, a lot of research and development work on these systems is occurring all over the world. Therefore, fast progress in short-time-steps can be expected.

To take all these points into account, the terra-based positioning detection systems will be impractical. Also dead reckoning as the sole system must be rejected, because the often instable driving actions of the vehicles produce too big an error. If non-family-workers should work with a position detection system then also a linearised field comes out of attention because this system can be used only in row-crops and in cereal with tramlines. In the Federal Republic of Germany grassland occupies more than 40 % of the agricultural area. These areas could not be served with such a system.

The usage determines the needed precision

From a present point of view, position detection systems for agriculture can be determined for usage within four different requirement steps. Figure 2 shows three of these steps. Within this list of requirements the first two steps are only monitoring values. Step 3 and 4 lead to navigation and include position detection in it.

The easiest requirements for position precision come from the data acquisition for farm management. Relative to a medium field-size in the Federal Republic of Germany, GPS has only to give an answer to the question: On which field are we working? This field has a medium size of 1 ha, maybe 50 by 200 m. As normally two fields from the same farmer with different crops are not side by side, the precision of position detection is good enough within ± 20 to ± 80 m. In the future, for such a field information on the required working time, the harvested yields or the distributed fertilizers or chemicals must be collected (whether from the farmer's own machinery or from machine-cooperatives / contractors) and attached to the field. These data then are the basis for the field records and with this for the farm management.

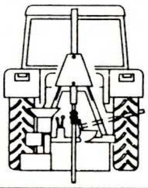
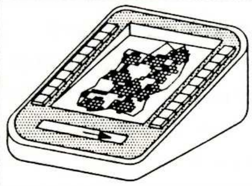
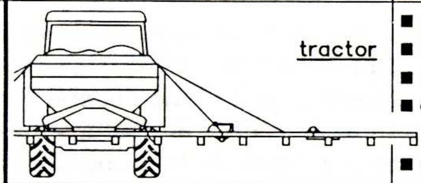
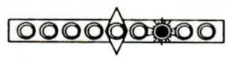
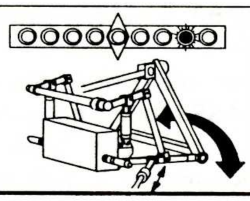
type	kind	examples	navigation aid	required accuracy
rough navigation	 vehicle	■ soil sample aquisition ■ detection of tram lines		± 1 m
fine navigation	 tractor	■ mineral fertilizer spreading ■ liquid manure spreading ■ solid manure spreading ■ application of pesticides ■ soil cultivation		± 10 cm
precise navigation	 Implement	■ drilling ■ hoeing ■ plowing		± 1 cm

Figure 2: Three steps of required precision of position detection in agriculture.

Environment protecting production requires responding to the spacial variability in the natural conditions. During the harvest, as during all distribution works, the borders between the different areas of variability have to be detected. To react to this in a minimum of 10 m the needed precision of position detection should not be worse than ± 1 m.

Additionally requirements are coming from navigation. So besides the distribution of yields and distribution of material, the guidance with bigger working widths will be a more and more increasing problem. Our own investigation shows, that in these cases much higher errors during fertilizer distribution are caused by driving errors then by wrong calibration (figure 3). For this third step a reliable navigation in an area between ± 10 cm is required. But this cannot be offered by DGPS alone. Dead reckoning must therefore be combined into such a system for higher precision.

Quite higher still are the requirements during the planting, if seed guidance in the cm-area is required. And this still can not be realized only together with dead reckoning. Additional tools in form of an implement-exact-guidance and in the form of optical systems could be a solution for this problem.

From all these 4 steps within 3 of them position detection (including navigation) require a precision of less than 1 m. It can be seen that only differential GPS can fulfill the needs of position measurement of agriculture.

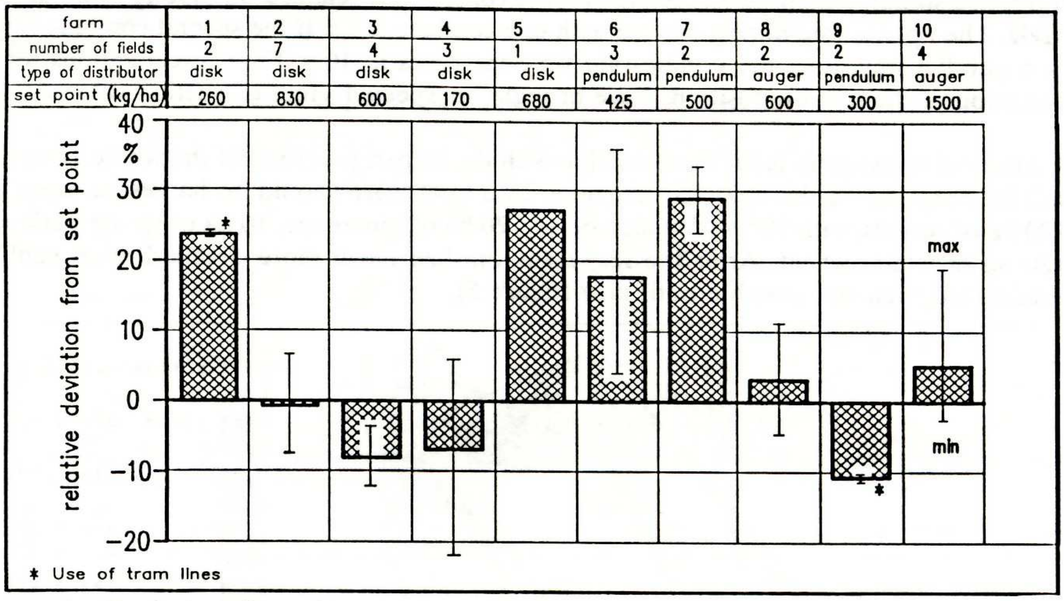


Figure 3: Deviations from the setpoint and guidance errors during fertilizer distributing in training farms in Bavaria.

Environment protection means environment friendly fertilizing

In a system of environment friendly and yield oriented fertilizing, yield mapping will be the initial point of all following fertilizing actions (figure 4).

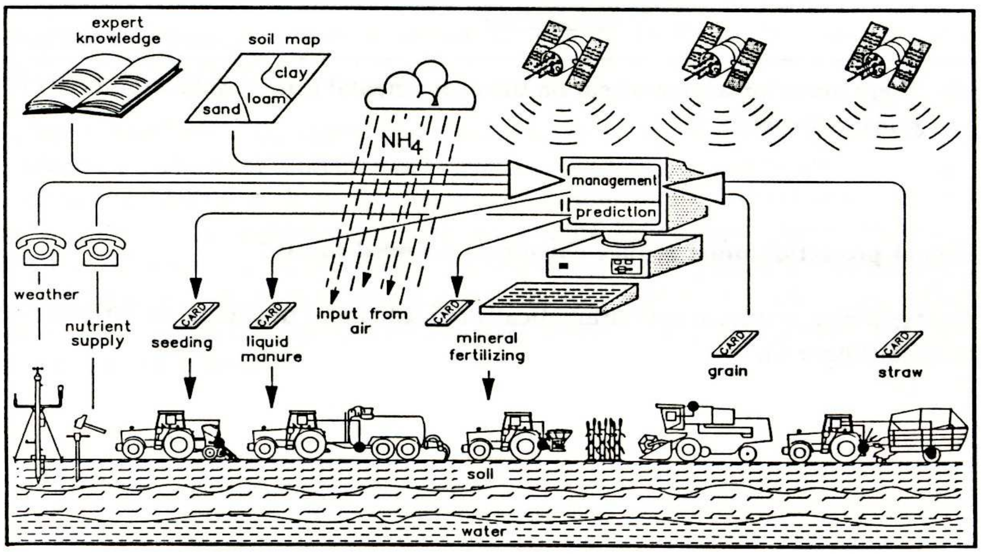


Figure 4: Techniques for an environment friendly and yield oriented fertilizing.

For the first time during the 1991 harvest season a DGPS-system in connection with two combines could be used. This system is divided into 3 units and works by the method of pseudo-positions. All receivers are 6-channel-equipment. The transmission between reference station and mobile receivers on the combines is realized on mobile radio at 160.1 MHz. The update-rate during the use with one combine is 7 s. If the second combine is used in a parallel way, then the update-rate time increases to 10 s. First investigations for the detection of the pseudo-positions have brought unexpected small correction values.

Additional investigations for the detection with the highest precision of the whole equipment will be done during the 1991 harvest time. In a total there should be harvested more than 200 ha of cereals, with 50 ha of winter-barley, 20 ha of winter-rye, 10 ha of spring-barley and 120 ha of winter-wheat. After the harvest is finished much more detailed maps could be established than was possible until now (figure 5).

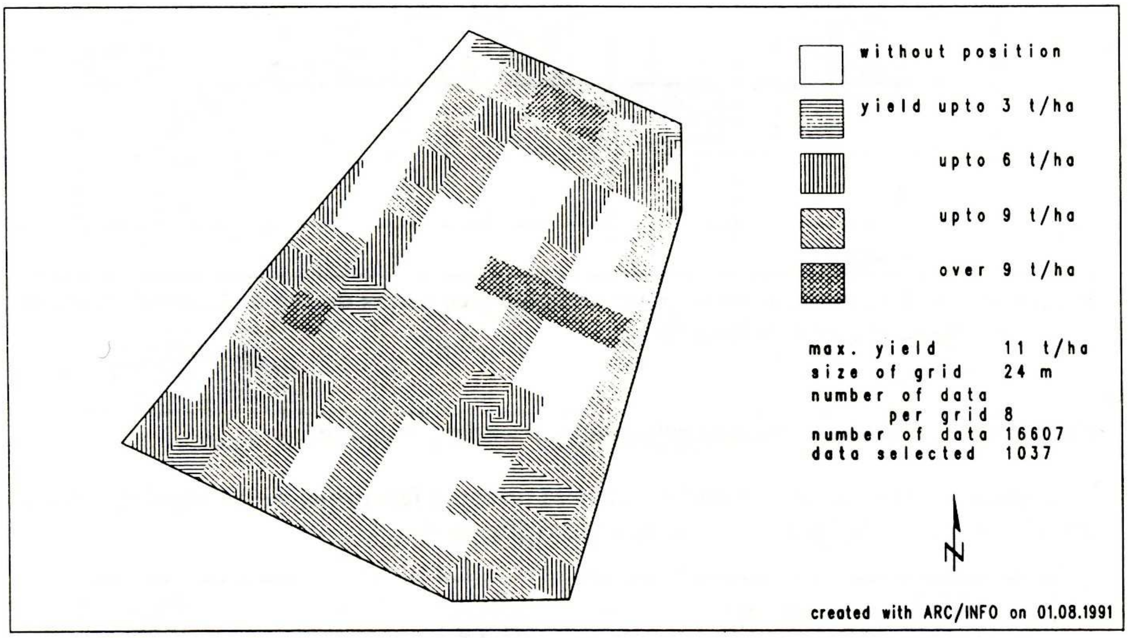


Figure 5: Yield maps for winter-wheat on the experimental station Schlueter 1990 (17.1 ha; gridsize 24 by 24 m).

Environment protection must reduce chemicals for weed control

Similar to fertilizing, a system with dramatically reduced input of chemicals for weed-control is imaginable (figure 6).

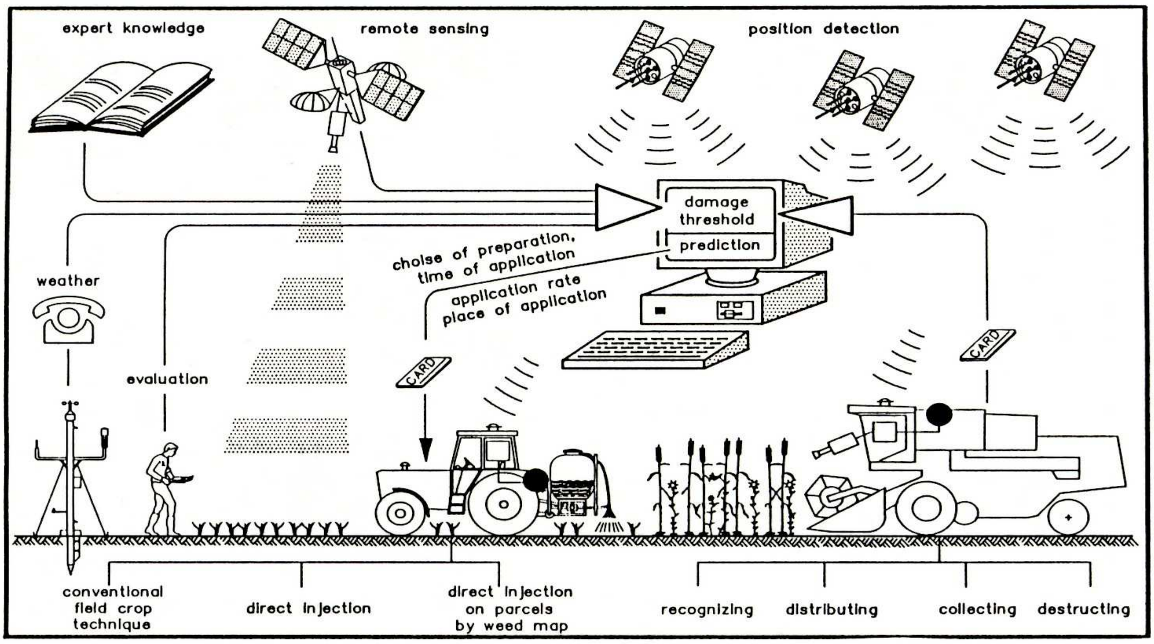


Figure 6: The use of electronics for reducing chemical input in weed-control.

In this the harvest will also be the initial point. Together with suitable detection techniques in the sieves of combines and with an especially developed image analyzing system, the weed amount in cereals could be detected and with the position detection shown locally. As a result, weed-maps in connection with weather-data and expert-systems could then lead to predictions of treatment date, type of chemical and the amount of chemical input. Compared with the whole covering treatment, with such a system about 60 to 70 % of the present expense quantity could be saved. If in a further step the system could be expended to band spraying in row-crops, then even a reduction to only 15 % against the whole covering treatment could be reached.

Mechanical control must be taken as an alternative to totally avoid chemicals for weed-control (figure 7). Then the guidance of tractor and implement will be the main problem. A high performance with a fairly good hoeing-success and small amount of working-time can only be realized if the guidance of vehicles will be automized. Automation has to be complete enough such that in any case the guidance of the implement (hoeing-machine) in a high working-speed guarantees that a good cut, tear and coverwork of the tools will be possible. In this respect the environment friendly weed-control will also be a task for GPS, DGPS and dead reckoning.

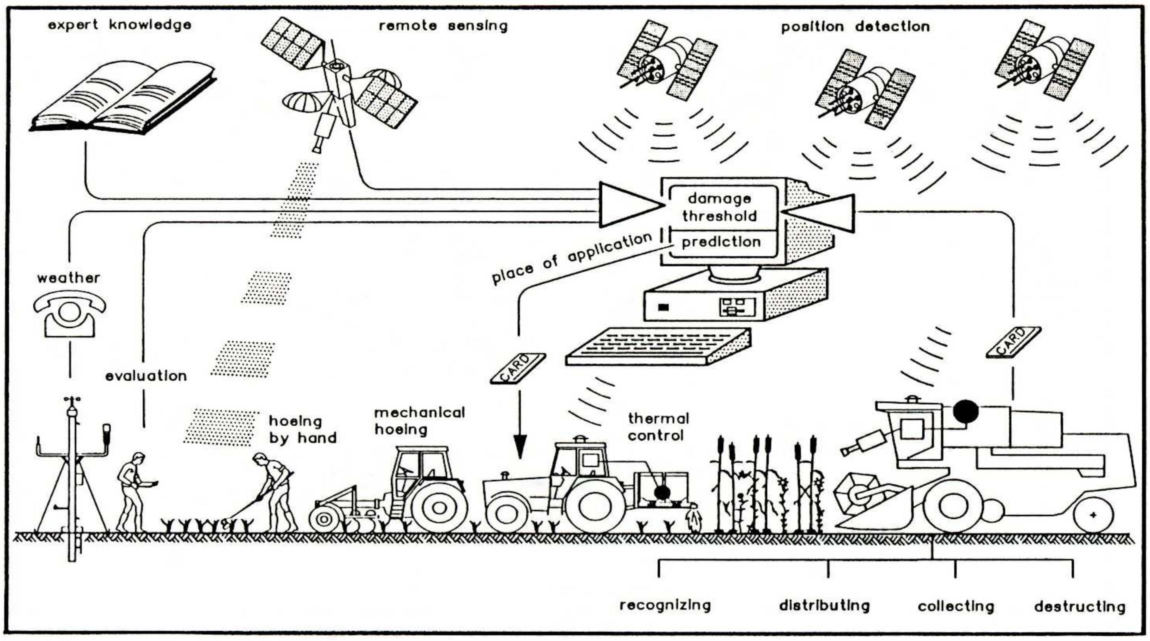


Figure 7: The use of electronics in a closed loop for mechanical weed-control.

Conclusions

Position detection and navigation will be the initial points of all actions within an environment friendly agriculture. Starting from a yield oriented fertilizing in the first step yield mapping has to be made. For this DGPS with an accuracy of ± 1 m is sufficient. If against that during fertilizing an exact guiding is required, then the needed precision increases to ± 10 cm. DGPS alone is not able to fulfill these requirements. A high performance dead reckoning system therefore is indispensable. If increased requirements to get an equal distribution of seed and fertilizing is wanted, then only errors of ± 1 cm can be tolerated. For this DGPS then will be the backbone. High precision dead reckoning systems together with optical systems could be a solution of this problem.

In the same way the requirements for an environmental friendly weed-control are to be seen. Also for this the above mentioned requirements with regards to avoid skips and overlaps and with regards to implement guidance to rows and plants are valid.

Therefore DGPS will be the basic system for the detection of spacial variability and for the distribution of yield-oriented fertilizing and of weed-control. DGPS in this form will be the key of an environment friendly agriculture.

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