American
Society of
Agricultural
Engineers

Paper No. 911040
AN ASAE MEETING
PRESENTATION

FUTURE DEVELOPMENTS FOR FERTILIZING IN GERMANY

by

H. Auernhammer, M. Demmel, J. Rottmeier, T. Muhr
Technical University Munich-Weihenstephan, Germany

Written for presentation at the 1991 International Summer Meeting
sponsored by
THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

Albuquerque Convention Center
Albuquerque, New Mexico
June 23-26, 1991

SUMMARY:

Fertilizing in future will be based on local yield detection, local soil and weather conditions and on use of expert knowledge systems. Position detection will play the key role in a closed loop system for data collection and process control. Engineers have to solve the challenge of the nineties to develop and to implement reliable sensors, actuators and control equipments for practical use. High sophisticated technique will then be able to save costs and to protect environment.

KEYWORDS:

Yields, electronics, fertilizers, satellites, weather

2950 Niles Road
St. Joseph
Michigan
49085-9659 USA
Voice: 616/429-0300
FAX: 616/429-3852

1. INTRODUCTION

Agriculture in the Federal Republic of Germany produces on a high level. Average yields of 69 dt/ha of winter-wheat, 546 dt/ha of sugar-beets and 490 dt/ha of corn-silage require exact scheduled fertilizing. Even if modern distribution techniques are used, over-fertilizing cannot be avoided. This is based on changing circumstances on the fields, mistakes during calibration and on the more psychological sight of the farmer to avoid possible nutrient shortcomings. As a summary of all these facts investigations show the real situation very dramatically. So about 36 % of the phosphorus and about 42 % of the nitrogen in the surface water are coming from agriculture. Phosphorus comes from erosion mainly, where especially corn as a very late covering crop plays a considerable part. In comparison nitrogen comes from over-fertilizing mainly, because very often the organic animal manure is not taken into consideration by the calculation of the required nutrients. From the side of the costs this leads to an enormous financial pressure. For example ISERMEYER 1990 [8] calculates for grassland farms in "Niedersachsen" costs of over-fertilizing of about 286 DM/ha and for cereal farms 125 DM/ha.

Taking into account, that by this over-fertilizing in the very close populated area of the Federal Republic of Germany the ground water and with it the available drinking water is more and more endangered, then it will be understandable that the requirements for a more environmental oriented fertilizing are more and more audible.

2. TECHNICAL OBJECTIVES FOR AN ENVIRONMENTAL ORIENTED FERTILIZING SYSTEM

Fertilizing today is done on a strategy of demand for an expected yield. Based on the yield of the preceding crop and its demand, respectively its crop residues together with the weather in the winter the available nutrients at the beginning of vegetation is defined as the starting position. On this the required basic fertilizing is calculated and according to the weather during vegetation the demand on nitrogen is determined and spread out. The following harvest with its yield allows a balancing afterwards and allows in a feed-back within the whole closed loop the required steps for the following crop.

Nearly all required values in this system are not exactly determined at this moment. Therefore a technique as a necessary aid has to be prepared, starting to provide during harvesting the fertilizing specific values (Fig. 1).

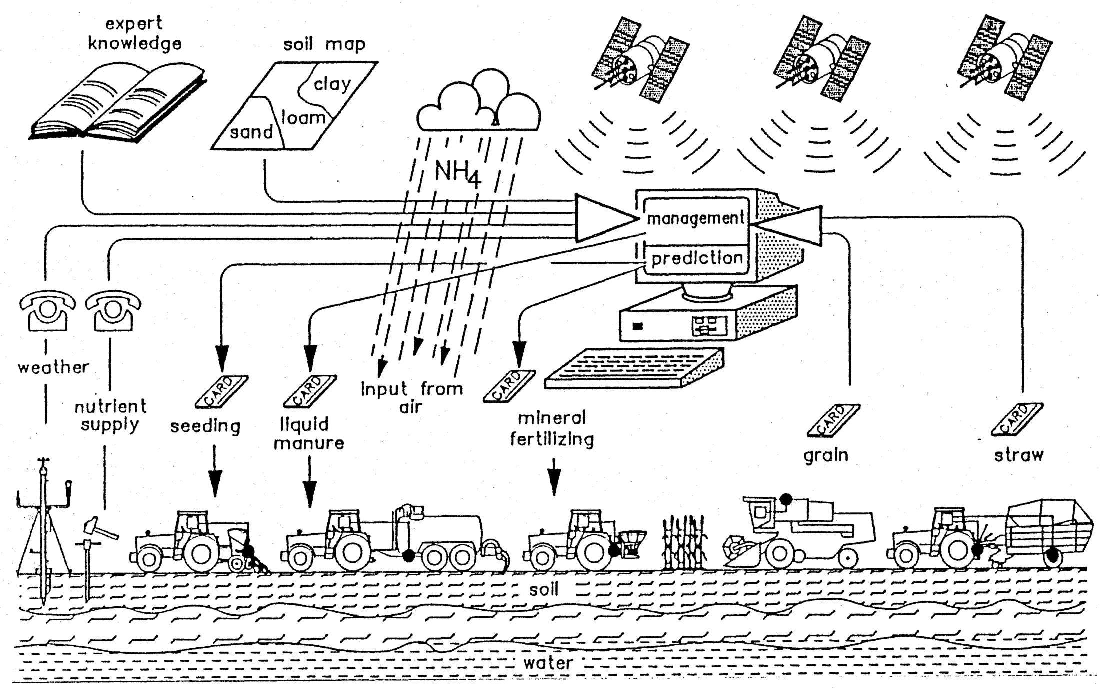

Figure 1: Closed loop system for environmental and yield oriented fertilizing.

This leads to the demand of real yield detection depending upon local situations (spatial variability). For cereals it leads to the requirement for an on-line yield detection in the combine connected to an on-line position detection.

Even grass and in the same way straw as part of all the harvested biomasses have to be detected. For it an onboard-weighing possibility in trailers has to be established, in which again the position detection has to be an undeniable part of it.

Following the above mentioned concept, technical aids for the detection of the climate and of the soil nutrients are to be provided. Thereafter techniques for an exact fertilizing are required, where the distribution of the predicted fertilizer amounts in both longitutional and latitutional directions has to be realized. Also local different needed nutrients with exact dosing of single nutrients have to be taken into account.

For all these steps within the total system an error-free and a simple data transfer has to be established, that all detected data can be brought into a central database. In this data bank, which is connected with soil maps and uses the inclusions of expert knowledge systems, the required predictions can be calculated. These predictions are brought back to the distribution technique and are used for fertilizing itself. Therefore standardization will be an additional part of the required closed loop control and be included in a comprehensive research and development programme (Tab. 1).

Table 1: Activities, sensors, actors, positioning detection and data transfer in a closed loop system of "Environmental and yield oriented fertilizing".

step	task	sensors / actors	positioning	data transfer
yield detection and mapping	cereal harvesting	paddle wheel; x-ray sensors	DGPS	chip card [3]
	grass and straw harvesting	strain gage sensors load cells	GPS	or RAM-box
weather and soil monitoring	local weather conditions	rain fall; wind speed 2 air and 2 soil temperatures humidity; radiation	---	video text network
	soil sampling [1]	hydraulic driven drill or tube with cartridge	DGPS	
controlled distribution	liquid organic manure [1]	hydraulic driven positive displacement pump and slip control	DGPS	chip card [3]
	mineral fertilizing with	slip control together with	DGPS + dead reckoning	or
	- weight control	strain gages in 3 point linkage		RAM-box
	- tramline guidance	--- [2]		
	- variable-rate fertilizing	centrifugal mixing unit		

[1] not under examination [2] future activities [3] DIN and ISO standards under preparation

3. PRESENT SOLUTIONS AND THEIR RESULTS

Starting from these thoughts there have been initiated some research programs during the past.

3.1 ELECTRONIC WEATHER STATION

Beginning in the year 1984 a small electronic weather station has been developed. It was conceptualized for the use on agricultural farms with continuing data logging (Fig. 2).

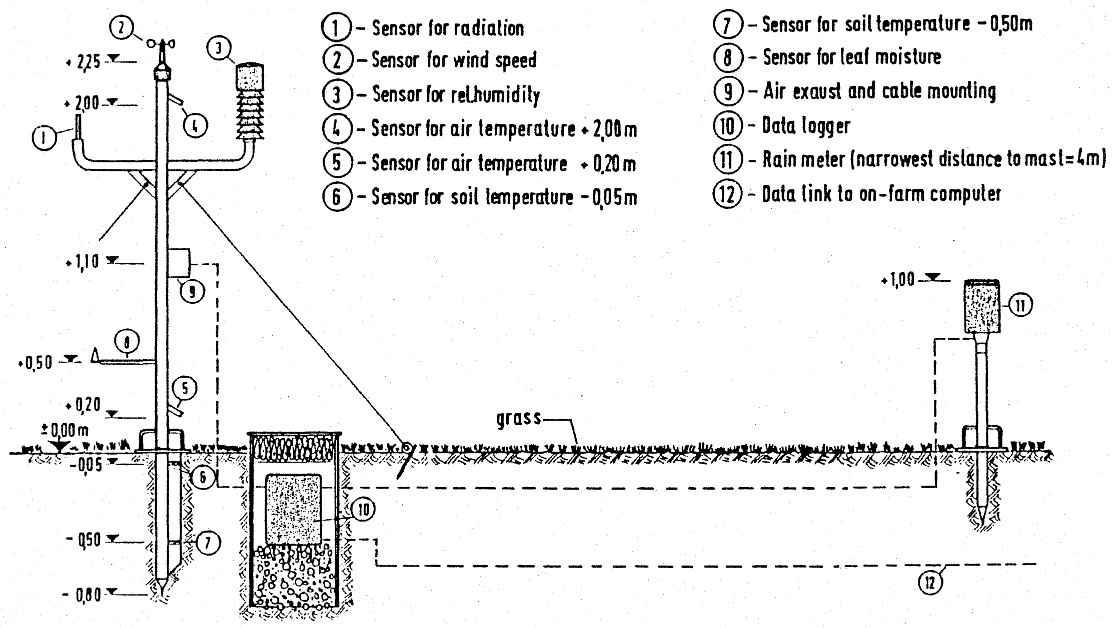

Figure 2: Small electronic weather station as a part of a weather monitoring network for agriculture.

Every night the detected weather data should be transferred by video text to a central host automatically. There the needed prediction models were made to take these data and to offer the results by videotext again to farmers with specific regional proposals.

Currently in Bavaria more then 100 of these small electronical weather stations are installed and connected by video text network. So far in each economic region at least two stations are available. The collected data are used now for irrigation models, and other prediction models with these data are in a period of examination and improvement. Also the data are used for the development of new prediction models on the basis of expert knowledge systems.

3.2 MONITORING OF FERTILIZING

Our own investigations have shown, that also by high sophisticated calibration the used fertilizer distributors cause a relative high over-fertilization and more seldom under-fertilizing in a lot of farms (Fig. 3).

farm	1	2	3	4	5	6	7	8	9	10
number of fields	2	7	4	3	1	3	2	2	2	4
type of distributor	disk	disk	disk	disk	disk	pendulum	pendulum	auger	pendulum	auger
set point (kg/ha)	260	830	600	170	680	425	500	600	300	1500

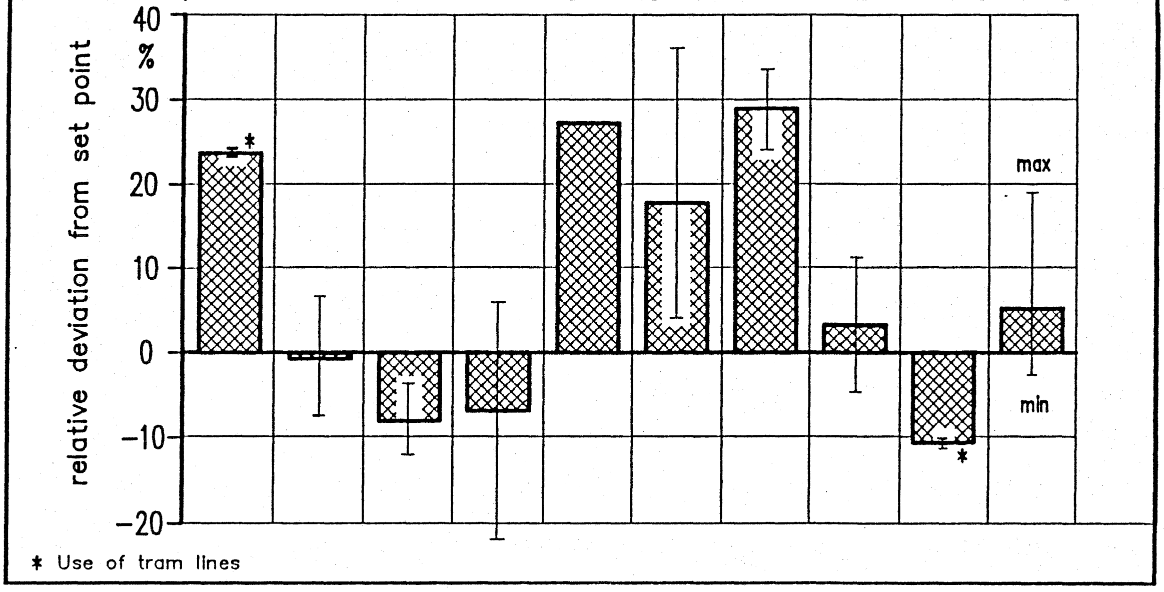

Figure 3: Deviations from the required fertilizer demand after fertilizing (measured on training farms in Bavaria 1989).

As fertilizing in Germany is mainly done with tractor rear mounted distributors, a specific research programme for weighing possibilities in the three-point-linkage of tractors was initiated. More than 20 different systems were investigated with specific sensors in the hydraulic system, on/in the lift arms (rockshafts) and on/in weak lift links. In addition to it specific weighing equipment (weighing frames) between the three-point-linkage and the fertilizer distributor has been tested (Fig. 4).

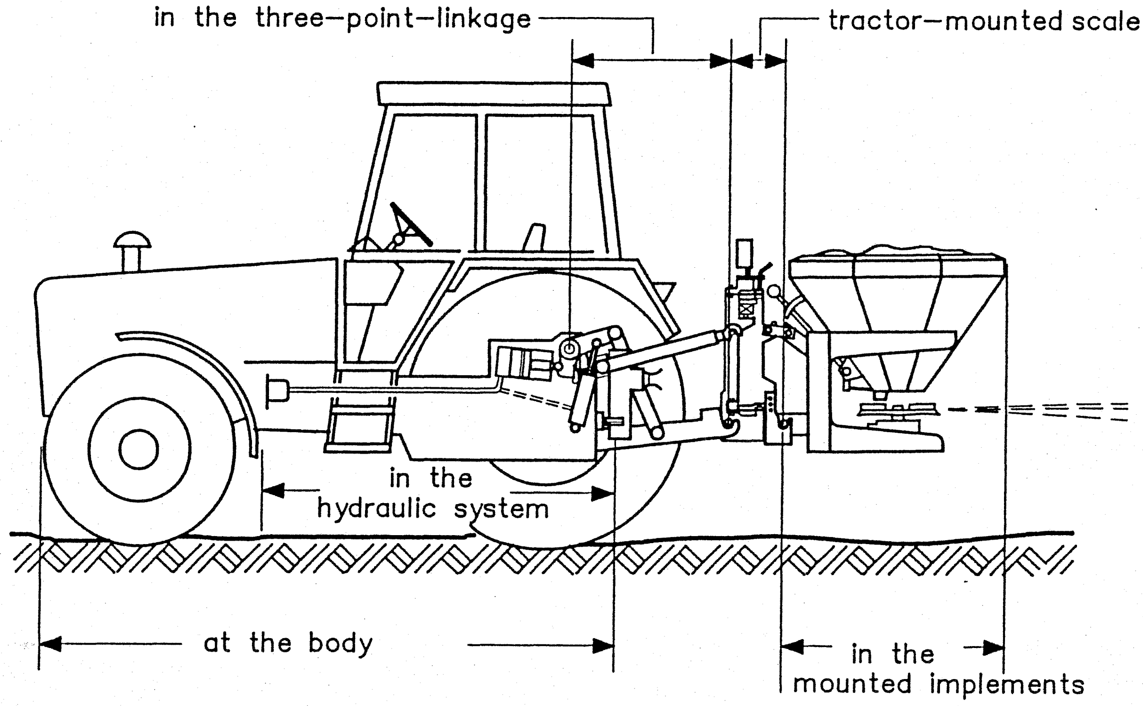

Figure 4: Possibilities for weight detection in a tractor-implement system.

It was shown, that specific weighing frames between the three-point-linkage and the fertilizer distributor can offer best results with an error less than 3 kg. Comparable results are reached also by strain sensors in drill-holes in the lift links.

Integrated sensor systems on the liftarms and on the lift links have higher errors (greater than 6 kg). The errors of pressure sensors in the hydraulic system are between 5 and 20 kg.

In the meantime one company has developed an universal sensor element, which can be placed in the lift links fitted with tractor specific fittings. So on a base of a high number of produced parts with a reasonable price new tractors as well as used tractors can be equipped with a very exact weighing apparatus.

3.3 SITE SPECIFIC FERTILIZING

Looking to the above mentioned situation in Germany, where nearly all fertilizer is spread with tractor rear mounted fertilizing distributors, variable-rate fertilizing on this system will be important in the future. For this reason in the meantime the system will be important in the future. For this reason in the meantime the development and first tests of a variable-rate distributor for three different nutrients have been started. The main investigation objective is the most exact mixing of the different components. For it a centrifugal mixing unit has been realized. For the distribution itself the present usual systems can be used.

3.4 LOCAL YIELD DETECTION IN HARVESTING

In Bavaria more than 40 % of the agricultural land is grassland. Therefore the first investigations for yield detection have been started on selfloading trailers and transport tippers. After that specific investigations on combines were started.

3.4.1 WEIGHING POSSIBILITIES IN SELFLOADING TRAILERS AND TRANSPORT TIPPERS

For yield detection on grassland the selfloading trailer is the central machine on farms. Each farm has at least one of these trailers. Three different systems were investigated (Fig. 5).

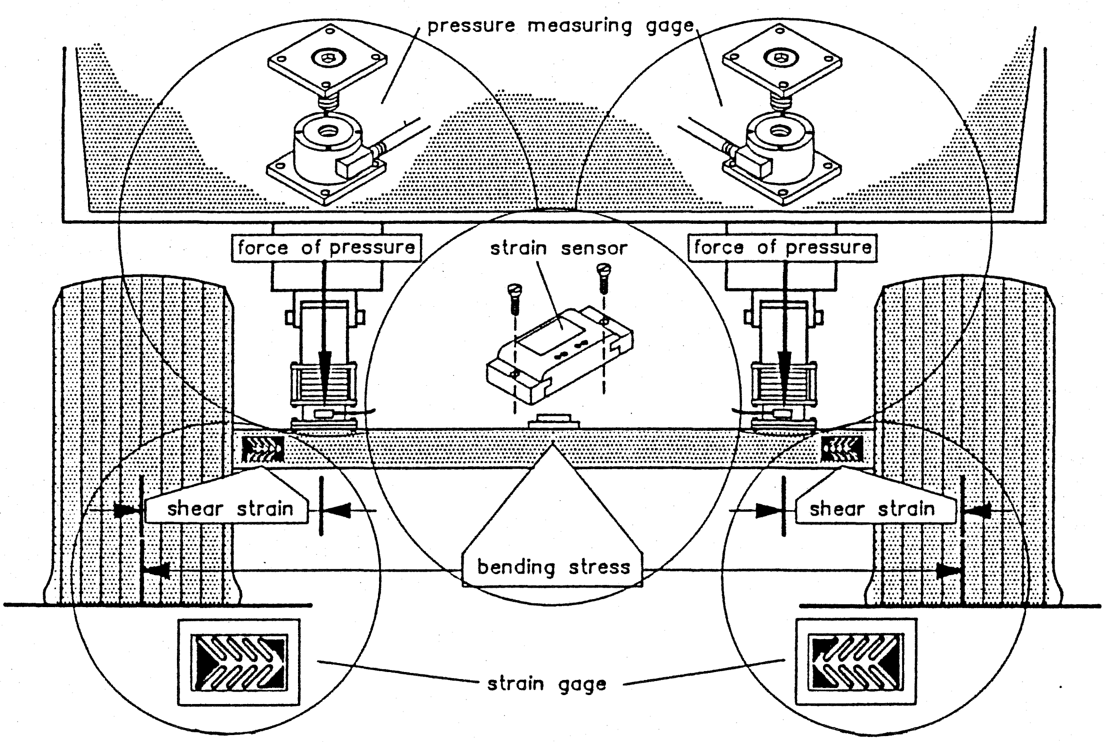

Figure 5: Weighing possibilities in selfloading trailers and transport tippers.

First of all the bending stress on the axles with strain gage sensors was detected. On average it brought an error of about 8 % compared to the real weight of up to 3 tons.

After it the shear strain between axle and frame or spring was detected. Average errors between 1 and 4 % could be reached with this technique.

Last but not least specific pressure sensors from the car industry between axle and frame or spring enabled the best results with an error less than 1 %.

3.4.2 YIELD DETECTION IN COMBINES

For the yield detection a x-ray-sensor was used in a first investigation conducted in 1990 (amarycium 243 with a doses < 35 MBequerel). It shows a very small error (2 to 3 %) and it offers in connection with GPS first yield maps for more than 45 ha of winter-wheat (Fig. 6).

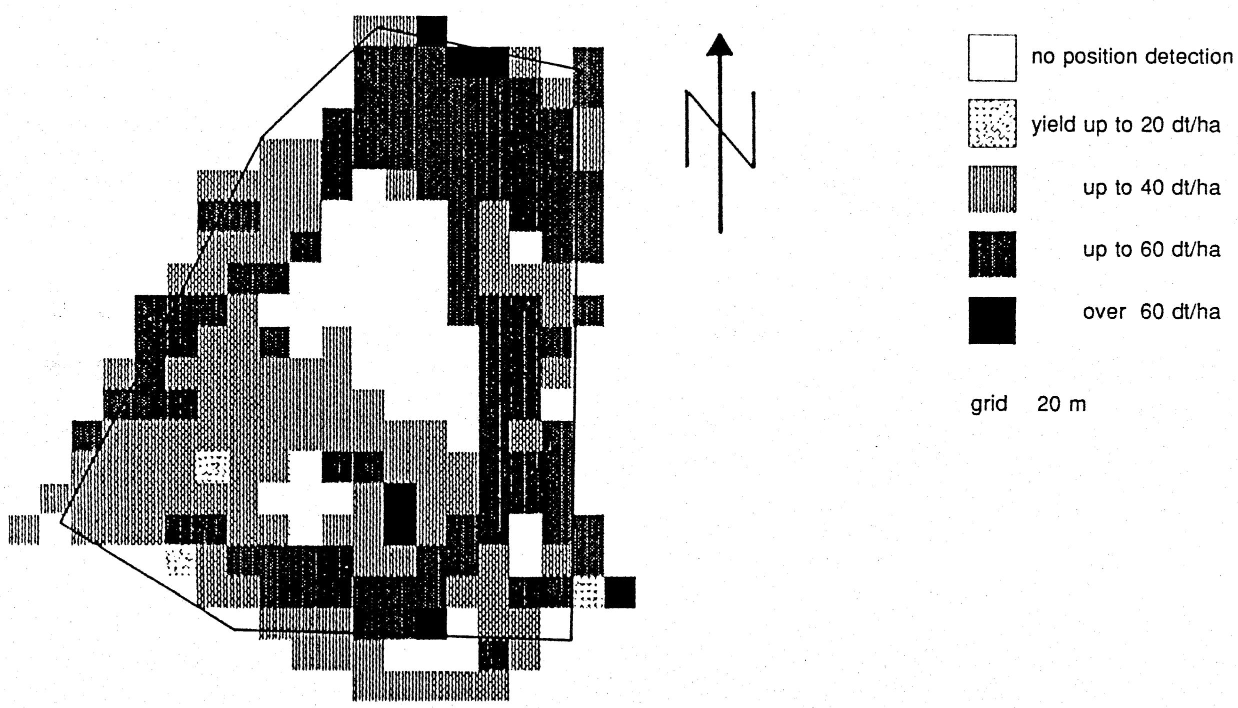

Figure 6: Yield map for winter-wheat on an experimental farm (x-ray sensor and GPS, detection frequency 1 hz. SCHLUETER 1990).

For 1991 two different measurement systems (paddle wheel and x-ray-sensor) shall be used on more than 200 ha (80 ha winter-barley and 120 ha winter-wheat).

3.5 POSITION DETERMINATION OF AGRICULTURAL VEHICLES

Environmental oriented fertilizing as a global objective requires attention to local conditions and local actions. Because of that the position detection of agricultural vehicles will be the crucial center of a closed loop-system.

All investigations in the past dealt with very exact track-measurements to guarantee precise distribution of fertilizer and pesticides. Maximum errors of 1.5 % can be realized by the use of radar-sensors if they are located in the track between the front and rear wheel and if their footprint is directed to the rear wheel. Differences from the required fixing angle (37.5 °) up to 45 ° have only small influences to the exactness and offer in this way more freedom during installation of these sensors for various tractor-types.

In comparison new investigations deal with the usage of GPS, DGPS and dead-reckoning. For the first time DGPS shall be used during harvest to establish comprehensive yield maps for a total farm. In addition to it a dead-reckoning-system has now been installed in a test-tractor.

4. CONCLUSION

In a high yielding agriculture over-fertilizing will lead to environment pollution and to negative influences to drinking water. It can only be avoided if modern technologies in a closed loop control system are used. The loop has to start with yield detection during harvest, it has to include the weather and the nutrients in the soil, and last but not least, it has to offer a local variable fertilizing.

The present available research results promise that this will be possible with technical help. Very soon solutions for the weight detection in selfloading trailers and transport tippers will be available for the use on farms. Also the investigations for weighing possibilities in the tractor three-point-linkage are finished and first tractors will be equipped with it soon. An excellent situation is given after the development and the installation of small electronical weather-stations in Bavaria with a video text networking to the central host with central data processing and central predictions.

In comparison a cheap and highly reliable yield detection system for combines is still not available. Also the error-free position detection is unresolved at the present, dead-reckoning-systems are not even available and tramline-systems require drivers with highest initiative and precise work.

Nevertheless all these techniques together offer a chance to reduce the fertilizer amount at least by 15 % with the same yields and the potential of a 30 % reduction is coming more and more into discussion. But before this, a lot of crop-specific questions must be answered by soil and crop nutrient scientists. Only then the ongoing technical developments in sensors can be used for a better, cheaper and environment-oriented fertilizing.

ACKNOWLEDGEMENTS

The authors would like to thank Prof. J.K. Schueller of the University of Florida, Mr. K. Wild of the Institut für Landtechnik at the TU München, Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten, CASE International, DRONNIGBORG (Denmark), DAIMLER BENZ, X. FENDT & CO., KTBL, K. MENGELE & SÖHNE, MOBA electronic, MUELLER-Elektronik, PFISTER, and SCHARFENBERGER for their assistance.

REFERENCES

1. Auernhammer, H.:
Landtechnische Entwicklungen für eine umwelt- und ertragsorientierte Düngung.
Landtechnik 45 (1990), No. 7/8, p. 272 - 278

2. Auernhammer, H.:
Elektronik in Traktoren und Maschinen.
Munich: BLV - Verlag 1989

3. Auernhammer, H.:
The German Standard for Electronical Tractor Implement Data Communication.
AGROTIQUE 89, proceedings of the second international conference, Bordeaux (France) 1989, p. 395 - 402

4. Auernhammer, H., M. Demmel, H. Stanzel:
Wiegemöglichkeiten in der Schlepperdreipunkthydraulik.
Landtechnik 43 (1988), No. 10, p. 414 - 418

5. Auernhammer, H. and J. Rottmeier:
Weight Determination in Transport Vehicles - Exemplary Shown on a Selfloading Trailer. Technical Abstracts and Poster Abstracts on "International Conference on Agricultural Engineering (AG ENG '90)" Berlin: VDI-AGR/MEG 1990, p. 100 - 101

6. Auernhammer, H., H. Stanzel und M. Demmel (Hrsg).:
Wiegemöglichkeiten im Schlepperheckkraftheber und in Transportfahrzeugen. Schriftenreihe Landtechnik Weihenstephan 1990, No. 2

7. Demmel, M., H. Auernhammer, H. Stanzel
Weighing equipment for the three-point-linkage.
In: Proc. of Int. Conference of Ag. Eng (AGENG) Paris 1988

8.Isermeyer, F.:
Extensivieren bis zum Optimum.
DLG-Mitteilungen 105 (1990), No. 20, p. 55 - 58

9. Petersen, C.:
Precision GPS Navigation for Improving Agricultural Productivity.
GPS World 1991, Vol. 1, p. 38 - 43

10. Rottmeier, J., H. Auernhammer
Gewichtsermittlung in landwirtschaftlichen Transportanhängern.
Schriftenreihe Landtechnik, No. 2, Weihenstephan 1990

11. Schnug, E., S. Haneklaus und J. Lamp:
Economic and Ecological Optimization of Farm Chemical Application by "Computer Aided Farming" (CAF).Technical Abstracts and Poster Abstracts on "International Conference on Agricultural Engineering (AG ENG '90)" Berlin: VDI-AGR/MEG 1990, p. 161 - 162

12. Spinnler, R.
Untersuchungen über Wiegemöglichkeiten in der Schlepperdreipunkthydraulik.
Diplomarbeit: Institut für Landtechnik, Weihenstephan 1987