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Economical and Ecological Aspects of Sensor Use for Plant Protection

The uneven distribution of weeds, pests and insects on arable fields is well known and has been investigated. For this reason pesticides are applied site-specifically. Sensors are needed for site-specific application. With sensors it is possible to detect weeds, pests and insects on arable fields. Pesticides savings potentials vary. In our own tests, herbicide costs were reduced up to 40% and fungicides up to 25%. Sensor costs are not known yet, which makes a monetary assessment of the ecological effects difficult.

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The characteristic of spatial and temporal distribution of weeds, pests and diseases on arable fields proves to be very different [1]. This is true comparing single years, but also single applications. Due to the lack of technical possibilities in the past and for operational reasons a field was treated with an uniform dosage of pesticides when a threshold was exceeded [2]. With the development of site-specific farming new technical possibilities became available, which allow more precise proceedings, also within the plant protection. As a reaction of the described existing heterogeneity parts of the field can be treated with an adapted dose of the pesticide. Stronger infected areas are treated with a higher dose, lower infected areas with a lower dose. To use this technique it is necessary to identify areas to be treated with pesticides correctly. A rating done by hand is out of the question because of labour demand and cost reasons. The technical solution to this problem is the use of sensors. There are two basic possibilities. The first approach is, that during the run they can directly measure the distribution of the wanted features, e.g. weeds and do the pesticide application at the same time. The second possibility is to first determine the heterogeneity and afterwards creating an application map which is used for a later application of pesticides. The first approach is called „online", the second „mapping." It additionally has to be mentioned that sensors for site-specific pesticide application will be more important in the future, if pesticide reduction programmes become reality [3].

Sensors for plant protection

The development stages respectively the application of sensors is very different regarding the fields of work pests, diseases and weeds.

The identification of weeds with sensors is most developed so far [4]. The procedure of sensor driven weed detection differs in accuracy and complexity of the used technique. The mainly important procedures are spectral analyses and image processing,

The safe identification of pests, e.g. fungi, is still in a testing stage.

Another approach to this topic detects not the diseases itself but estimates the need of the application quantity according to the plant mass [5] and the respective crop density. Weaker crop standings gain less, stronger crop standings gain a higher application of fungicides. The aim is an even fungicide distribution at the plant surface.

It is important for all sensor based approaches to identify the characteristics sufficiently, e.g. weeds in the cotyledon stage. But also the time for identification is important, especially when the sensors are used online, because the speed for pesticide application is about 10 km/h.

Economical aspects

The benefit from an economic view will be determined with cost and performance analyses. The aim of sensor use for plant protection is a good performance-costs-ratio.

Costs for machines and labour
The basic machinery costs and the costs for labour will not change in case of online application. This is based on the assumption that the same machinery with constant working speed is used. Using an online approach, additional full costs for sensors and the site-

Table 1: Herbicide and fungicide savings on fields in practice

Jahr	Ort	Fruchtart	Pflanzenschutzmittel	Einsparung %	Einsparung /ha
2000	Ostrau	WW	Fungizide	16,1	9,74
2001	Seefeld	WW	Fungizide	25,0	7,46
2000	Seefeld	WW	Fungizide	7,0	2,63
2002	Seefeld	WW	Fungizide	8,7	2,59
2001	Ostrau	WW	Herbizide	12,7	5,15
2002	Baasdorf	Erbsen	Herbizide	30,0	14,56
2002	Dabrun	Erbsen	Herbizide	40,9	27,56

specific control of the sprayers have to be considered. At present the costs for the sensor are hard to be estimated, because the sensors are only prototypes.

In our own trials regarding fungicide application a so called CROP-Meter was used as a sensor. The CROP-Meter price is about 5,000 Euro. The use of the CROP-Meter is not limited to pesticide application it can be also used for fertilisation. Therefore an exact allocation of costs for plant protection part is very difficult.

The management of the sprayer was done with a so called ìjet gear box (D¸sengetriebe).î This technical solution allows a wider differentiation of the applied quantity. Such a îjet gear boxî has a price of about 25,000 Euro. This means full costs of about 2.6 Euro per hectare if the usage is 1,200 hectares per year. Additional an on-board computer is necessary. The on-board computer can also be used for other tasks. We presume that the farmers have sprayers equipped with on-board computers, so that no additional costs will be chargeable.

Costs regarding environmental damage

The costs for damage to the environment are so far not relevant for business management. These costs are so called „external costs", they are relevant for the national economy. They occur for the cleaning of drinking water, damage in ecological systems etc. In the following they will not be considered because they depend on the specific single situations, are difficult to appoint and not relevant for the farm management at present.

Costs for pesticides

Therefore the main focus lays on the pesticide savings. The pesticide saving is obtainable if the infested areas of a field are treated with recommended dosage.

The attainable saving potentials at plant protection agents depend on different factors, e.g. the infestation pressure.

The potential of saving regarding weed control is broadly investigated. Depending upon operating conditions saving potentials up to 70% were found [6]. These enormous savings could not be confirmed in our own trials. One reason might be that the amount of herbicide applied site-specific was never lowered under 50% of the standard application rate. Our trials showed herbicide savings in peas and winter wheat up to 40%. In monetary terms this means herbicide savings at an average of 15.8 Euro and approximately maximal of 28 Euro per hectare. If the costs of the ìjet gear boxî are subtracted from the average saving effects an average of 13.2 Euro/ha available to cover the full costs of the sensor remains.

In our own trials regarding the saving effects of fungicides in winter wheat, savings up to 25% were determined. The saving effects were lower compared to the herbicide trials. From a monetary view an average of 5.6 Euro and a maximum of 10 Euro per hectare were saved. If the costs of the „jet gear box" are subtracted from the average saving effects a maximum of 7.4 Euro/ha to cover the full costs of the sensor remains.

Ecological aspects

The use of pesticides is a very sensitive area from the ecological view. In the past extensive advancements of pesticides use and the spraying technique already took place and also the dosage needed per hectare was reduced. Nevertheless a further reduction of the applied amount as well as the proof of the aimed and efficient use is desired by the society. Investigations at the specific locations are needed for detailed results about run-off. However on a more general level effects of reduced site-specific plant protection to selected environmental categories can be provided. Therefore the process chain analysis was used.

The process chain analysis allows an assessment of the production and selling of pesticides for selected environmental categories regarding to correlated environmental relevant data [7]. The data is based on our own trials and shows the mean and the standard deviation of the found savings. The savings of primary energy consumption, the greenhouse effect, the acidification effect as well as the eutrophication effect are presented.

With the use of sensor the farmer has access to additional information about his fields. This information helps in further operations to use the means of production purposeful. The management will be able to fulfil the requirements and potentials better.

Discussion

Site-specific farming allows a significant improvement for the use and turnout of pesticides. A prerequisite for an efficient application is the use of sensors. The pesticide reductions identified with trials on arable fields show, that only a limited monetary scope is given for sensor use. For fungicide application slight economic advantages appeared.

For ecological reasons the benefits of pesticide reduction arise among other things in different environmental categories. But ecologically sound factors are economically not relevant for business management so far.

	Primärenergie GJ/ha	CO_2-Äquivalente kg/ha	SO_2-Äquivalente kg/ha	PO_4^{3-}-Äquivalente kg/ha
Herbizide				
Mittelwert	0,268	21,035	0,011	0,084
Standardabweichung	0,180	14,135	0,008	0,057
Fungizide				
Mittelwert	0,162	0,053	4,190	0,002
Standardabweichung	0,097	0,032	2,513	0,001

Table 2: Effects of reduced pesticide input on selected ecological categories

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