PESTICIDE APPLICATION MANAGER (PAM) - DECISION SUPPORT IN CROP PROTECTION BASED ON TERRAIN-, MACHINE-, BUSINESS- AND PUBLIC DATA

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ABSTRACT

Pesticide Application Manager (PAM) is a project co-funded by the German Federal Ministry of Food and Agriculture (BMEL) that aims to develop solutions for automating important processes in crop protection by using ICT. PAM is implemented by a consortium of public and private organizations under the lead of the Central Institute for Decision Support Systems in Crop Protection (German acronym: ZEPP).

One of the focal points of the project is the development of a Decision Support System (DSS) that automates pesticide application and the protection of adjacent natural and aquatic ecosystems by using GIS-created, machine readable application maps, that include legal buffer zones where spraying is prohibited.

In the first year of the project the focus has been put on identifying data and methods that can be integrated into the DSS. Geodata play important roles in this process. To be able to create machine readable application maps information about the location of fields as well as water bodies and terrestric structures like hedges are necessary. These are the base for identifying and creating the legal buffer zones.

To avoid unnecessary survey work for farmers, the first approach was to check if geodata in adequate quality and quantity is publicly available or if not, easy to create via digitizing from areal views. A baseline survey was conducted on pilot farms. The main result was that geodata available for farmers in Germany does not meet the requirements in accuracy or completeness necessary to be useful for the purposes of the PAM-Project. This means that in most cases a separate survey done by the farmer is necessary. A technical procedure how to conduct such surveys is being developed using a GNSS-RTK based approach.

Keywords: Crop protection**,** precision agriculture**,** automatic pesticide application, GIS, DSS

INTRODUCTION

Due to a series of rules and legal requirements for planning, implementation and documentation, crop protection is one of the most information intensive activities in modern agriculture. One example is the legal obligation to leave buffer zones at field boundaries to protect adjacent natural and aquatic ecosystems. In agricultural day-to-day reality the planning and implementation of crop protection measures as well as the compliance with laws, rules and any sort of documentation are mostly due to the responsibility of the operator who is conducting the action. Much of this work is still done manually and without the support of information technology which results in high workloads as well as an increased error-proneness.

The objective of the PAM project is to develop different tools to automate and therefore optimize the processes mentioned above. An internet based Decision Support System (DSS) is being developed to make the different tools available to the public. PAM aims to integrate data available online from different private and public sources using up-to-date ICT-technologies including mobile technologies. This will make crop protection measures less error-prone and easier documentable as well facilitate a reduction of pesticides. The result is a reduction of costs for farmers as well as an improved pollution control.

One of the focal points of the DSS developed in PAM is to automate the spraying process and the protection of adjacent natural and aquatic ecosystems by using GIS-created, machine readable application maps, that include legal buffer zones where spraying is prohibited. This article is focused towards this part of the DSS. Figure 1 describes the underlying concept:

Data Integration Application Map

Fig. 1. Concept of creating application maps

Pesticide Application Manager (PAM) is a project co-funded by the German Federal Ministry of Food and Agriculture (BMEL). PAM is implemented by a consortium of public and private organizations under the lead of the Central Institute for Decision Support Systems in Crop Protection (ZEPP).

Project partners are:

- Association for Technology and Structures in Agriculture (KTBL),
- Julius Kuehn-Institut (JKI), Federal Research Centre for Cultivated Plants,
- BASF SE
- John Deere GmbH & Co. KG, Intelligent Solutions Group
- ISIP – Information System for Integrated Plant Production

The project duration is three years, from 2013 to 2016.

MATERIAL AND METHOD

The part of the DSS that creates application maps consists of six steps. Data from the farmer as well as public information and geodata are integrated (Fig.2). Each step will be described in detail in the following:

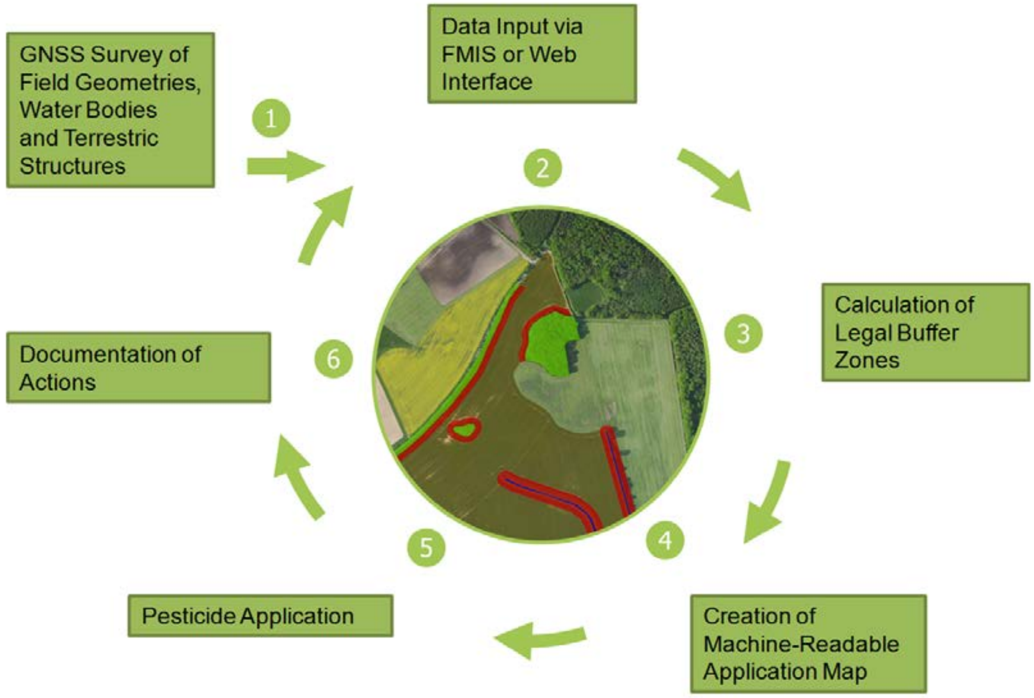

Fig. 2. PAM - Decision Support System

Step 1: GNSS Survey of Field Geometries, Water Bodies and Terrestric Structures

Geodata from water bodies and terrestric structures like hedges or skirts of the forest are necessary to calculate the required buffer zones. Field tests using available public geo-data of rivers, forests and hedges have shown that this data is often incomplete or doesn´t meet the location accuracy necessary for precision farming processes (see chapter RESULTS).

Because of a lack of existing geodata the DSS-process starts with the mapping of field geometries and sensitive landscape areas adjacent to the field

A technical procedure how to conduct such surveys is being developed. A GNSS-RTK based approach is promoted, which reaches an accuracy of up to just a few centimeters. The procedure allows the farmer to map the applicable landscape elements during a tractor ride using an off-set method. It is being developed in cooperation with German supervising authorities to promote that data recorded are officially accepted.

Step 2: Data Input via Farm Management Information System (FMIS) or Web Interface

To allow field specific advice, data from the farmer are necessary. This includes information about cultivated crop, geographic coordinates of the field (e.g. from Step 1) and spray nozzle used (drift reduction class). Data input can either be done using a direct connection of the FMIS system or via a web interface on www.isip.de. The PAM project cooperates with Landdata Eurosoft and HELM Software to assure the integration of its services. Open interfaces are being developed to allow the integration in other systems.

Step 3: Calculation of Buffer-Zones based on Legal Regulations

In a third step zones inside the field are being identified, where spraying pesticides is not allowed under the specific conditions. The following factors are included in the process:

- Pesticide specific buffer zones to water bodies or other landscape structures deserving protection based on information from the pesticide database of the German Federal Office of Consumer Protection and Food Safety (Bundesamt für Verbraucherschutz und Lebensmittelsicherheit 2013)
- Buffer zones that arise from the slope of a field (e.g. >2%)
- Buffer zones that arise from spray nozzles used (drift reduction class)
- Buffer zones to water bodies depending on which German state the field is in
- Buffer zones to terrestric structures deserving protection based on the index of small landscape features by the Julius Kühn-Institut (JKI), Federal Research Centre for Cultivated Plants

The calculation of the buffer zones is carried out by an online-GIS-application. Within the scope of a complex geoprocessing service information and geodata from the sources mentioned above are intersected to identify zones in the field where pesticide spraying is prohibited. The result is a map that defines application zones and legal buffer zones (Fig.1). The farmer has the possibility to edit this map.

Step 4: Creation of the Machine-Readable Application Map

The application map is provided using the non-proprietary ISO-XML format (ISO 11783-10 2009) which can be applied to terminals of different manufacturers. The file format ISO-XML is becoming more and more established in agricultural engineering.

Step 5: Application

Provided that a tractor with GNSS and a pesticide sprayer with section control are available, an automated application is possible. Once the sprayer moves into an area of the field that is a buffer zone, the respective section is switched of automatically (Fig.3).

Fig. 3. Crop Protection Application (Photo: John Deere)

Step 6: Documentation

Modern terminals are able to record data about pesticide applications. This considerably facilitates the documentation process. The protocol file can be used as justification towards public authorities or purchasers. The compliance with legal buffer zones can be proven. Furthermore the information generated can be used for consecutive treatments.

Besides the creation of application maps there are some more concepts being followed in the curse of PAM. The two main examples shall be described in brief as follows:

Development of an electronic system to read bar code labels of crop protection product (CPP) containers and connect to different public and private databases to get related information

Information about crop protection products is mostly only human-readable, e.g. labels on CPP-containers. This poses the risk, that information is not considered in the right way or even not at all. Manual transfer into FMIS is error-prone as well. Using electronically readable crop protection product information helps users to avoid errors and make sure all relevant information is being considered.

In the project PAM a system for electronically readable bar-code-labels is being developed in cooperation with the project partner BASF. By connection to different private and public databases product specific information is being made accessible on site. Examples are:

- Information about miscibility of different crop protection products
- Information about legal regulations

Development of a web service for profitability analysis

Another web application is being developed to analyze economical aspects based on changes induced by legal buffer zones. Reduction of fuel as well as changes in wear of application machines will be shown. The project partner KTBL provides data on cost, working times and fuels usage that will be used additional to the calculated pesticide application area.

The profitability analysis will be based on machine type, recorded field geometries including not treated buffer zones, working width, driving speed and further parameters.

RESULTS

In the first year of the project the focus has been put on identifying data and methods that can be integrated into the DSS. Geodata play important roles in this process. To be able to create machine readable application maps information about the location of fields as well as water bodies and terrestric structures like hedges are necessary. These are the base for identifying and creating the legal buffer zones.

To avoid unnecessary survey work for farmers, the first approach was to check if geodata in adequate quality and quantity is publicly available or if not, easy to create via digitizing from areal views.

To be able to test if data meets the PAM requirements, in a first step a reference baseline was created. On pilot farms in the states Rhineland-Palatinate and Mecklenburg-West Pomerania adequate fields have been identified (Fig.4). On these fields the field geometries as well as slope tops of water bodies and terrestric structures have been surveyed. High accuracy GNSS with RTK and a tachymeter were used to achieve the highest possible accuracy (Fig.5).

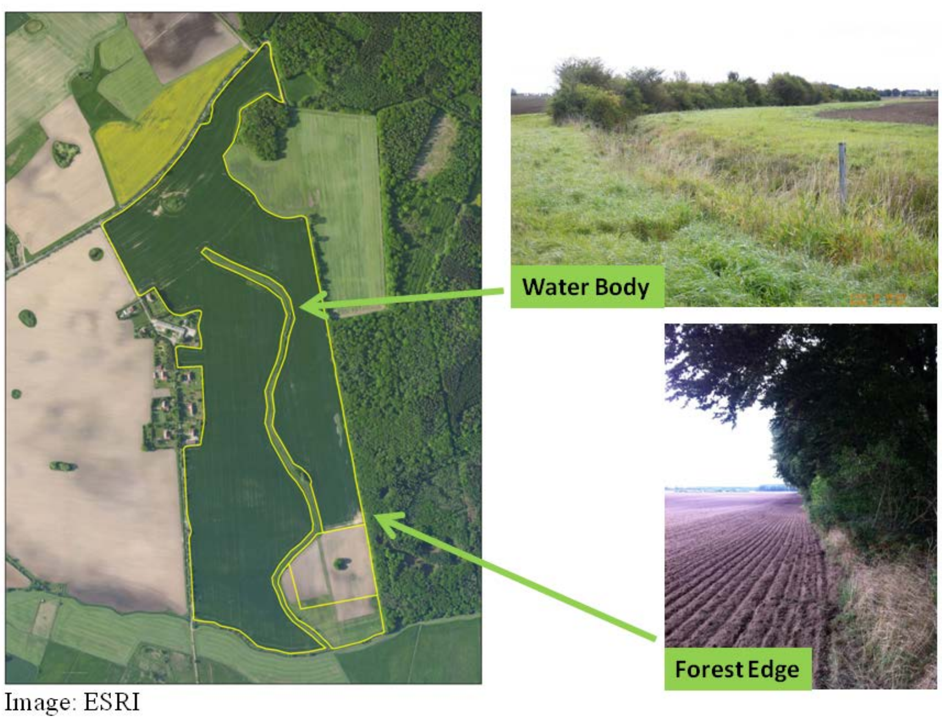

Fig. 4. Field with structures, which require keeping legal buffer zones

Fig. 5. Baseline survey to create high precision geodata

To check their accuracy and completeness publicly available geodata and data digitized from areal views were compared to the reference data using Geographical Information Systems (GIS). Figure 6 illustrates this process by showing an overlay of different datasets.

The following datasets were compared to the surveyed reference data:

- **ATKIS:** Digital Landscape Model of the Official Topographic Cartographic Information System (ATKIS) managed by the Federal Agency for Cartography and Geodesy (BKG). ATKIS includes geodata about vegetation and water bodies on a national scale. Those were used for the analysis.

- **Land Register Map (LIKA)**: Even though differing in certain details, Land Register Maps are available on a national scale. They are mainly created to document land parcel ownership, but also include information about water bodies, which are available as a special category of land parcels. The baseline survey data for water bodies was compared with those land parcels.

- **Digital Orthophotos (DOP):** The BKG offers DOP as Web Mapping Services (WMS) with a resolution of 20/40 cm. Geodata about water bodies and terrestric structures was extracted from the DOP by manual digitizing in a GIS system.

- **Field Boundaries:** German farmers can use digital field boundaries offered by public institutions. These field boundaries were compared to the agriculturally worked area surveyed in the baseline study.

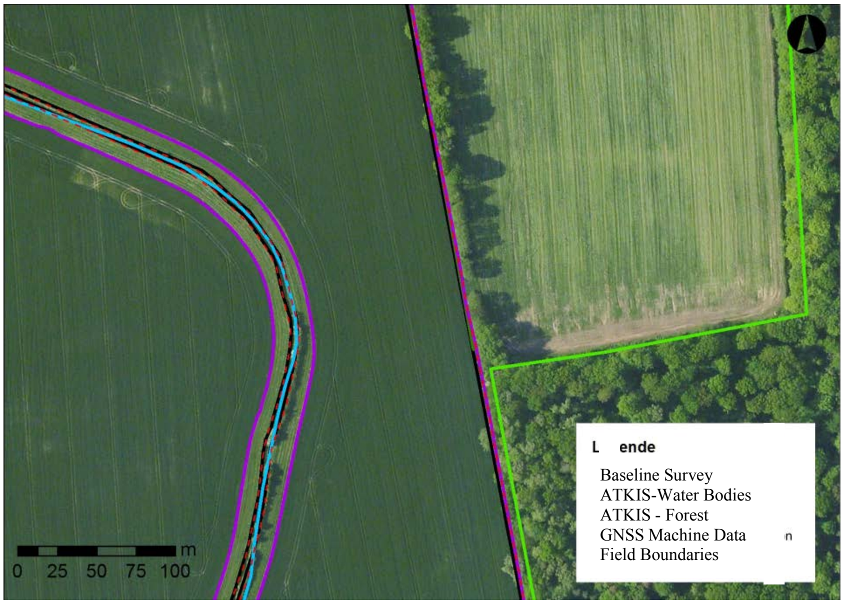

Image: ESRI

Fig. 6. Comparison of different geodata with baseline survey

- **Machine Data:** GNSS position data from tractor GNSS-systems with RTK correction signal (accuracy +/- 2cm) were used for comparison with the baseline survey. The GNSS data was recorded during regular agricultural processes like drilling or crop protection spraying.

The results of the comparison are illustrated in Table 1. The second column shows the average difference between the respective geodata and the reference data from the survey:

Table 1. Offset between different geodata and survey data

	Average Offset [m]	Source
ATKIS	3,1	BKG
LIKA	1,0	WMS
Pesticide-Application	0,9	Machine GNSS
Field Boundaries	1,7	Public Institution
DOP	1,3	WMS

The BKG states that **ATKIS** data reaches an accuracy of up to 3 meters. This could be verified during the comparing measurements. Unfortunately this is not sufficient for PAM purposes. Additionally it was shown that ATKIS data are not always complete especially regarding small terrestric structures like hedges.

Geodata for water bodies from the **Land Register Map (LIKA)** showed nearly everywhere a high accuracy from up to 1 meter or better. Unfortunately the focus of this data is not mapping water bodies or terrestric structures but delimiting field plots. In cases where fields plots end at a water body the data could be used for PAM purposes, but a laborious data preparation using GIS would be necessary to separate the necessary data from the rest. Additionally the data is not everywhere available without cost and terrestric structures are not part of the data. Because of these objections the use of LIKA data is seen as not practicable.

Given good visibility of water bodies (little vegetation) and knowledge of the local situation, manual digitizing of structures in **Digital Orthophotos (DOP)** was coming to good results. But in case of heavy vegetation, slope tops of water bodies are not indentificable anymore. The same applies for terrestric structures. Large treetops at the edge of a forest make it impossible to identify the borderline between forest and field. Because of these restrictions the method is not usable for PAM.

Machine Data (log data) recorded during regular tractor rides with high-precision GNSS systems showed very high accuracy even though the purpose of the tractor ride was not to map aquatic or terrestric structures. It seems that machine data reaches the necessary accuracy to map structures deserving protection even if there is an offset. Consequently a technical mapping procedure should be based on such data.

The main result of the baseline survey is that the geodata available for farmers in Germany does not meet the requirements in accuracy or completeness necessary to be useful for the purposes of the PAM-Project (Table 1). This means that in most cases a separate survey done by the farmer is necessary.

As described in Step 1 of Chapter 1, a technical procedure how to conduct such surveys is being developed using a GNSS-RTK based approach. This means some extra work for the farmer, but only has to be conducted once and will be combinable with a regular tractor ride.

CONCLUSION

Precision Agriculture using GIS-methods offers the possibility to automate and therefore optimize important processes in crop protection. Integrating data from different public and private sources allows to generate new information which can facilitate the whole process. Crop protection measures can become less error-prone and easier documentable. Additionally the use of pesticides can be reduced. The result is a reduction of costs for farmers as well as an improved pollution control.

Accurate geodata are necessary to allow automatic pesticide application, but not always available. In such cases methods to generate such data have to be developed.

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