TOWARDS GLOBAL E-AGRICULTURE: THE CHALLENGE OF WEB-BASED DECISION SUPPORT SYSTEMS FOR GROWERS

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Towards Global E-Agriculture: The Challenge of Web-Based Decision Support Systems for Growers

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Abstract

Globalization is influencing several agriculture aspects: market globalization has increased export from producing to consuming countries where different food safety or pesticide residue regulations apply, and has raised awareness of global problems linked to agriculture production (i.e., chemical pesticide pollution). Pests, diseases and weeds may cause significant damages to growers and the cost of pesticide increases. Environmental pollution and risk of unwanted residues on food forced researchers to find ways to optimize pesticide applications. However, extension services and research in pest management is often fragmented and efforts to develop support tools for pest management are often duplicated. Furthermore, sometimes the knowledge does not spread from research centers to growers due to difficulties in knowledge transfer. Decision support systems (DSS) are widely used for assisting with integrated pest management (IPM), crop nutrition, and other aspects of information transfer. Developing highly portable and especially web-based DSSs that can be easily adapted to new environments is therefore desirable in view of agriculture globalization. Web-based models and DSSs have the major advantage of reducing software development, maintenance, and distribution costs, while making the relevant knowledge easily accessible to growers world-wide.

This paper presents two examples of web-based agricultural DSSs and demonstrates the potential use of these systems in a wide application range in order to adapt to the needs of globalization. Allowing the choice of different values for the parameters renders these DSSs very flexible. Their development process integrated agricultural expertise from two distinct research centers with information systems know-how from a third center, over two countries, demonstrating the need for a global software development that crosses country borders. The results show that it is possible to satisfy the prerequisites: reducing software development cost by enlarging the number of users and reaching growers among whom specific knowledge on diseases is not yet established.

Keywords: Web-Based Agricultural Decision Support Systems.
1 INTRODUCTION

Globalization is influencing several agricultural aspects: market globalization has increased export from producing to consuming countries which have different regulations on food safety or pesticide residues, and has raised awareness of global problems linked to agriculture production (i.e., chemical pesticide and fertilizer pollution). Pests, diseases and weeds may cause significant damage necessitating the use of large amounts of chemicals to control them. High costs of plant protection, environmental pollution, and risk of unwanted chemical residues on food forced researchers to find a way to optimize pesticide applications. However, extension services and research in pest management is often fragmented, and the efforts to develop support tools for pest management are often duplicated. Furthermore, sometimes the knowledge does not spread from research centres to growers due to difficulties in knowledge transfer. Decision support systems (DSS) are widely used for assisting with integrated pest management (IPM), crop nutrition, and other aspects of information transfer in several countries (Bange et al., 2004; Rydahl et al., 2003). Developing highly portable and especially web-based DSSs that can be easily adapted to a new environment is therefore desirable in view of agriculture globalization. Web-based models and DSSs have the major advantage of reducing software management and distribution costs, because little or no client software is required (Bajwa et al., 2003).

There are major advantages in developing a global and strategic web-based approach to pest management: it improves quality, accessibility, and cost-effectiveness of pest management information by reducing the use of resources, harmonizing procedures, and making information available also in areas where local extension services or consultants are not present. The web enables the communication of up-to-date agricultural research results to the growers. It tremendously extends the capabilities of current extension services and allows them to act more efficiently. The population of growers is often spread over large areas, away from major cities; the web provides the opportunity for bringing novel knowledge to their doorstep. Moreover, with the web, the knowledge does not stop at regional or national borders, but can spread to wide geographical and/or climatologic regions.

To optimize pesticide use it is necessary to provide a disease risk assessment on which to base treatments. A disease is the result of the interaction of a susceptible plant, presence of the pathogen, and suitable conditions for the infections; knowledge of these conditions enables the setting up of a disease risk model. This model can be computerized and integrated in a DSS that can help growers decide upon treatments selection. To facilitate use by growers such a system should have an easy-to-use user interface, allowing the manual input of data related to the plant, the pathogen and the environment. Such data may include the characteristics of the orchard/vineyard/field, the plant variety, the presence of the pathogen’s visible symptoms. Some data may be automatically collected or calculated by the system. For example meteorological data can be automatically obtained from weather stations or from an in situ wi-fi datalogger; plant phenological stages can be calculated with a plant growth model. After predicting the risk of disease, the system has to recommend treatments, taking into consideration disease risk, existing regulations (i.e., limitation in the use of a specific fungicide, avoid treatments close to harvest), characteristics and availability of pesticides.

A major challenge in building a generic DSS is allowing it to be customized to specific situations and needs. Such systems should allow also domain experts to update the disease risk model, as new knowledge is obtained or when applied in a different area, with different characteristics, without re-developing a new system. Thus, the risk model should be highly parameterized and domain experts should have easy access for modification of system tables.

The development of web-based DSSs to manage treatments against plant diseases will be discussed using two case studies (web-based DSSs) that have been recently developed in Northern Italy (Trentino Region): optimization of treatments on strawberry (Pestcon) and managing copper treatments in organic viticulture (Coptimizer). The first system will be discussed in detail, while the second will be presented by discussing major principles and differences.
2 METHODS

Two specific web-based DSSs were developed for use in crop protection. Even though they are disease-specific, they can be adapted to a wide range of conditions. The systems focus on the major diseases of the two crops (powdery and downy mildew of strawberry and grapevine, respectively), where treatment optimization is needed. In developing the DSSs we follow the same approach, with certain differences. Both systems aim at reducing and optimizing the use of treatments against a disease, by avoiding useless treatments when disease risk is absent. The first is based on applying the most effective treatment with the lowest side effect for each disease risk level, from a set of different options, and the latter optimizes preventive treatment comprising a single active ingredient when disease risk exists.

The systems were developed based on research results and experience obtained in Italy and Israel. This knowledge was used for building the algorithms for risk analysis and for defining the decision process.

Both systems are model-based agricultural DSSs (Power, 2007), meaning that systems' recommendations are based on a model that predicts the risk for disease development, and suggest treatments based on treatments history, risk level, and current regulations. The major system requirement was easy access for inexperienced computer users (growers). They should be able to use the system easily and get the needed recommendations along the plant growing cycle; they should be able to use the system at farm/plot or vineyard level. In addition, the system should allow easy access for domain experts (also non computer experts) at two levels: Extension service (power user) that should be able to customize parameters at area/region level and Administrator, that should set general parameters, modify the DSS tables and the disease risk model. A multilingual interface was implemented so that the systems are usable in different countries.

Each system works with its own specific risk assessment model, a user interface on which to provide data (fill-in forms), and an online connection for receiving weather information.

Username and password protected interfaces allow simple and easy access for the users (according to use/administrator privileges). Growers can update the system daily and retrieve feedback from the system. Experts (extension service, consultants, etc.) can adjust system parameters and export system data for further offline analysis.

2.1 Pestcon

Pestcon aims at helping growers reduce pesticide application against a major strawberry disease (powdery mildew). The objective is to reduce the risk of unwanted pesticide residues in tunnel strawberry production while maintaining a good protection against the disease. This can be achieved by applying the most suitable fungicide for the specific combination of phenological stage (plant susceptibility) and risk of disease. Biological control is preferred instead of chemicals when the disease risk is low. Very effective and persistent chemicals must be applied when the risk is high. The risk level is based on the combination of potential risk index, calculated from the basic risk (related to environmental and plant characteristics) and daily risk index (considering the susceptibility at the different phenological stages and the disease presence in the crop), and the presence of suitable conditions for the disease (depending on the daily average temperature between 6 a.m. and 5 p.m.). For each combination of risk index and suitable conditions for the disease, the most appropriate fungicide (biological control agent or chemical) is defined. The decision procedure is fixed (the potential and daily risks plus suitable conditions for the disease will lead to a defined treatment), but the system is very flexible since all the values of parameters and fungicide choice can be changed.

The system is relatively simple and has three main functional requirements - risk model, general services and users management - as detailed below (only high level requirements are presented here). The first part defines the decision model (named SafeBerry):

- The system will produce a treatment recommendation, based on a specific decision model, which considers:
Basic risk index (BRI), calculated according to specific parameters
- Daily risk index (DRI), calculated according to specific parameters
- Potential risk index (PRI), weighted on the basis of the BRI and DRI and according to a specific decision table
- Suitability of the weather to powdery mildew index (DRI), calculated according to parameters (average temperature of the last \( n \) days and forecast average temperature in the next \( m \) days)
- Recommendation for action (treatment date and type) will be weighted on the basis of the PRI and the DRI and according to a decision table.

The second part defines the general system capabilities:
- The system will enable:
  - Treatments management (recording, updating etc.)
  - Data collection (based on human observations)
  - The display of growing cycle information (bloom, harvest time, etc.)
  - Managing pesticides (registered/allowed pesticides for the use on strawberry)
  - Dynamically updating the decision model
  - Managing farms information
  - Managing of weather stations
  - Correlating a specific weather station to the registered farm.
- The system will operate a meteorological data retrieval service on a daily basis from the meteorological database.

The third part defines the types of users and their access rights. The system can be used with three levels of access. Each level includes the permissions of the lower level. The functionality allowed for each level is as follows (from the lowest access level to the highest):
- Grower (basic user):
  - Getting recommendation
  - Viewing recommendations history.
- Technician/consultant (power user):
  - Managing treatments
  - Managing observations
  - Managing farms and plots
  - Managing pesticides
  - Managing weather stations
  - Getting data analysis.
- Administrator (Domain expert, currently SafeCrop Centre):
  - Managing the decision model (SafeBerry)
  - Managing users.

As can be seen from the high level requirements above, the system has a specific recommendation model, which is data driven (e.g., changing the tables used by the model will change its behavior). Besides treatment recommendation, the system provides a variety of management services, where different users may use different services.

The system was developed using ASP.NET, C# and JAVASCRIPT, SQLSERVER was the application database.

### 2.1.1 Pestcon growers’ user interface

In order to illustrate the usage of the system, the following figures show the user interface of the main functional screens of the system:
At the beginning of a season, a grower has to provide initial information about the crops and the fields, which will be used later on by the system for making recommendations, by filling a form (Figure 1). During the growing season, whenever the grower wishes to consult the system for treatments recommendation, he/she needs to provide some specific information, such as last treatment, presence of disease, plants characteristics etc., by filling a second form (Figure 2). A technician/consultant has to provide temperature forecast, which should be done on a daily, basis for the whole region (Figure 3). When the data are entered, a recommendation (whether to treat or not) and a recommended pesticide are issued (Figure 4).
Figure 3. Technician/consultant data entry: forecasted temperature input screen

Figure 4. Daily recommendation output – system recommendation after applying the recommendation model to the input data (general information and weather data)
2.1.2 Pestcon administrator’s user interface

Figure 5. Decision model parameters management

A domain expert can log into the system and access the model’s data table via a dedicated user interface (Figures 5 and 6). The domain expert may adjust the model’s data table, based on new data as they become available, and change the behaviour of the system accordingly. Like the growers’ user interface, for ease of use, the expert's user interface is based on simple forms that can be filled.

Figure 6. Decision model parameters management

Pestcon can be easily adapted to different regions/countries regulations by simply changing the specific pesticides and conditions of application (i.e., minimum number of day before harvest). Pestcon is particularly suited to situations where a specific objective is needed, for example to avoid the risk of chemical residues on strawberry by restricting the use of a specific pesticide in a defined growing period or to assist growers in applying a complex integrated pest management program. Pestcon could be an additional tool to complement other existing DSSs on strawberry (Miličević et al., 2006) that do not include powdery mildew in the decision making.
2.2 Coptimizer

Coptimizer was developed to help growers optimize the use of a specific pesticide (copper) against downy mildew on grapevine. In organic agriculture, the use of a maximum amount of copper per year per hectare (or an average in a number of years per hectare) is defined in Europe by law (Commission Regulation EC 473/2002). Copper is washed away by rain, while plant growth results in new leaves that are not protected by the previous treatment. Furthermore, plant susceptibility to the disease changes during the growing season, in line with the phenological stage. Conditions for the disease can be modeled by a simple model which assumes that the risk of rain in the following day is equal to risk for disease infection. In this case the decision is taken based on a combination of whether the plant is still protected by the previous treatment and risk of infection in the following day. The system monitors the copper quantity already used and gives a warning when the grower is close to the fixed threshold. Also with this approach the system assures a good portability, because of the precautious, but generalized, disease forecasting model, and the flexible parameter setting possibilities regarding copper dosages and treatment intervals. Coptimizer is the first web-based DSS specifically designed and dedicated to organic agriculture.

This system as well, is a relatively simple model-based DSS, planned for use by three different types of users (similarly to Pestcon) and has the same main functional parts: Risk model, General services and Users management, as detailed below (only high level requirements are presented). The first part defines the decision model:

- Treatment recommendation: The system will provide the grower with a daily treatment recommendation for each of his vineyards; thus the grower will be asked to provide specific details:
  - Rainfall risk assessment – If grower previously associated the specific vineyard with a specific Extension Service, this value will be automatically provided. Otherwise, the grower will have to provide assessment manually by choosing one out of four possible risk levels: High, Medium, Low, and None.
  - Historical weather data (temperature and rainfall) – If the grower previously associated the specific vineyard with a specific Weather Station, these values will be automatically provided, otherwise, the grower will have to provide the data manually.
  - Growing rate – number of new leaves since last treatment. Last value provided will appear as default.
  - Growing stage – grower will be able to choose between the following stages:
    - Before bloom
    - During bloom
    - After bloom
    - After veraison
    - Before harvest.

The final recommendation will rely on the above mentioned details and the set of rules. Recommendation will be either to treat with a specified dosage of copper or not to treat.

The second part defines the general system capabilities:
- The system will enable:
  - Vineyard management (Grower): the system allows growers to add\delete\modify vineyards to their profile in the system. When adding a vineyard, the vineyard is automatically assigned a serial number to identify it uniquely in the system.
  - Season management (Grower): the system allows the grower to define growing seasons.
  - Treatment recording (Grower): The system will allow the grower to record treatments for tracking and further analysis purposes. When coming to update a new treatment, the grower will be presented with last treatment details in the following form: Date (DD/MM/YYYY), dosage of copper. The grower must provide the amount of copper used in the current treatment of a specific vineyard. Calculation may be done manually or with the aid of the system calculator. If the calculator is used, the calculation result will be automatically imported for use by treatment
recording. The system will automatically produce treatment reports. It will not be possible for the grower to modify the previous treatment records.

- Status display and warnings: The system will provide the grower with information regarding his copper usage status on every given day. This will include the amount of copper used and the amount remaining.
- Calculation support: The system will provide the grower with a designated calculator to help him carry out the following calculations:
  - Amount of product to be used in order to follow recommendation/personal choice
  - Amount of copper actually used.
- Reports generating: The system will allow the grower to produce the following reports:
  - Vineyard treatments report - list of treatments per specific vineyard including total amount used so far and amount remaining till end of year/period.
  - Overview report (current status of all vineyards in terms of amount used so far and amount remaining till end of year/period).

The third part defines the types of users and their access rights. The system can be used with three levels of access. Each level includes the permissions of the lower level. The functionality allowed for each level is as follows (from the highest access level to the lowest):

- Grower registration (Growers): growers wishing to use the system are required to register
- Registering approval: Extension Service (ES) is able to accept/deny request

The user characteristics are:

- Administrators. They have high technical skills and significant experience in maintaining computer systems in general; preferably experienced in raw database handling.
- Power users (consultants/technicians). They must be familiar with computer systems in general and windows environment in particular.
- User (growers). They may not be familiar with computer systems and windows environment and may have low computer skills.

As with the previous system, the focus was on providing an easy to use web-based system. The system was developed as a multilingual system too, so that it could be used by users of different countries.

The technology used included: MS-SQL Server 2005, IIS 6.0 Web server and .NET Framework, for compatibility with technology already in use at Safecrop Centre.

3 CONCLUSIONS AND FUTURE WORK

The World Wide Web opens new opportunities for knowledge sharing. This is especially important in agriculture, since knowledge in this field is scattered around the world and concentrated in research centers while the population of growers is spread over large and remote rural areas. The two examples presented here show that it is possible to generate model-based DSSs for agriculture with a potentially very wide application range in order to adapt to the needs of globalization. Developing web-based DSSs, which incorporate professional and scientific experience and maintain a good flexibility enables satisfying the prerequisites of reducing software development and maintenance costs and reaching growers among whom specific knowledge on diseases is not yet established. Cost reduction is achieved by a high level of parameterization and allowing knowledgeable users to tune the systems for specific conditions. Enlarging the number of potential users is another way to achieve overall cost reduction.

The two case studies show that is possible to target the issue of optimizing the use of a pool of different substances according to a risk level or to manage a fixed threshold of a single active ingredient, in an almost fully automated decision system, where a few inputs are required from the grower at the beginning of the season.

The systems can be further improved by using a more portable device than a desktop computer, such as Personal Digital Assistants (PDAs) or even smart phones. Such portability will allow growers to bring up-to-date knowledge right to the field.
The next step should be an evaluation of the systems' flexibility by applying them in different regions, where the conditions are different than in Trentino in order to prove their generality.

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