Review of new technologies critical to effective implementation of Decision Support Systems (DSS's) and Farm Management Systems (FMS's)

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Contents

1 Introduction

Soon after the introduction in the 1950ies of organic compounds as pesticides, advisors have taken a major responsibility that pesticides were applied according to legal, biological and economic conditions on a farm level.

In the 1970ies consciousness increased also on side-effects of pesticides. Even though pesticides are subjected to relatively strict regulation, where compounds perceived as harmful in food, feed or in the environment will not be registered, pesticides are occasionally found in food, feed and in the environment in concentrations exceeding threshold limits. Such occurrences may arise from various reasons, e.g. human errors, unusual conditions etc.

So, concurrently with strict regulation on pesticides, increasing political pressure has also been observed to reduce dependency and/or use of pesticides, which is actually also a key focus points in the ENDURE network. An immediate rationale could be that pesticides should be applied, 'as little as possible, as much as required'. This rationale has many implications, however, as many factors have been identified, which have significant potentials to reduce the use of pesticides:

- different weeds, pests and diseases have different negative impact in different periods of different production lines
- weeds, pests and diseases are not homogeneously distributed in time and space
- different pesticides produce different levels of efficacy on different species of weeds, pests and diseases and additional conditions on a field level
- objective and quantitative information on the a.m. factors is relatively sparse

In order to follow the a.m. rationale, pesticides should be applied in a relative high spatial resolution, e.g. only in fields or sections in fields, where a need have been detected, and the intensity should be adjusted to actual conditions. From a practical point of view, pesticides should be applied in optimum combinations of: time, place, compound, dose rate and spray technique.

Advisors are too few in number to conduct inspections in all fields several times throughout a growing season, and in order to avoid situations where losses in the quantity or quality of yields are observed, advisors often recommend pesticide spraying programmes, which are expected to be robust for a relatively broad variety conditions on national/regional levels. In order to perform satisfactorily in most fields, such spray programmes must reflect scenarios, which are worse than average, why many spray programmes will be 'overkill' as compared to actual needs. Such recommendations are often referred to as 'best practices'.

Using existing 'best practises' as a point of reference, DSS's may be a way to achieve:

- more 'punctual care' in procedures relating to pest management on farm- and field levels
- more efficient integration of results from research with biological systems and conditions on farm and field levels
- significant reductions in the use pesticides, without jeopardizing production economy

DSS's supporting conventional farming systems that include also use of pesticides, could include a variety of features to support various types of decisions, for example:

- strategical decisions for planning growing of different cultures and cultivars
- tactical day-by-day decisions throughout a growing season, e.g.:
    - prediction of points in time, where infestations of pests exceed economic thresholds for pesticide applications
    - assistance to identify species of weeds, pests and diseases
    - guidance on how to conduct field inspections to identify infestations

- o guidance to evaluate whether previous applications have performed as expected
- o selection of pesticide products and dose rates, mixes of pesticides and use of adjuvants
- o suggestion on spraying technique (spray task, type and size of nozzles, water volume, driving speed, etc.)
- o safety of workers (handling, personal protection aids, disposal of containers, etc.)
- o information on dealers

Following these recommendations, a DSS could include a single decision in a single crop x pest system or multiple decisions in multiple crop x pest systems. From an end-user standpoint, however, it may be convenient to achieve certain levels of centralization and/or unification, e.g.:

- terminologies and layouts in user-interfaces
- points of entrances
- functionality
- complexity
- points of references

In the activity IA2.4 of the ENDURE network, a major objective is to identify 'best parts' of existing DSS's for crop protection and possibly construct and validate DSS that has been unified on a European level. 'Best parts' are searched for in the perspective of reducing dependency and/or use of pesticides, which is an overall objective in the ENDURE network. Such 'best parts' will also be evaluated in the light of requirements, which main groups of end-users may have.

This report provides a status on 'Progress and prospects with the implementation of DSS for crop Protection in Europe' per 30th January 2009, which is the result of a survey in 27 EU-countries and Switzerland, which was made jointly by the 11 institutions that are specified on the front page of this report.

Efforts have also been made to integrate results from ENDURE IA2.5, in which efforts are made to integrate FMS's and systems for precision agriculture. Until now, however, activities in IA2.5 have been focussing on specific, technical aspects which are not directly relevant to existing DSS and possible new prototypes of DSS arising from new combinations of 'best parts'.

a. Instructions to the reader

Some sections in this report has been written and consolidated jointly by the joint group of authors, which has been listed on the front page. Sections with analyses of DSS for specific crop x pest systems have been written and reviewed by sub-groups among the authors according to the specifications in Table 3.2-1.Tables and figures have been numbered consecutively in each main section. References have been attached separately also to main sections.

b. Abbreviations used in this report

The following abbreviations have been used in this report

Abbreviation	Explanation
DSS	Decision support system.
FMS	Farm management system.

GIS	Geographical Information Systems. GIS can be used to collect, accumulate and present various data that refer to specific geographical positions.
IPM	Integrated Pest Management. Many definitions have been proposed. A major difference from conventional use of pesticides is that some adjustments have been implemented as compared to routine pesticide applications.
OSR	Oilseed rape
Pest	When used alone, 'pest' is a rubric including insects, various diseases and weeds. When listed in connection to 'diseases' or 'weeds', 'pest' means: 'insect'
TFI	Treatment Frequency Index. Accumulation of the number of full doses applied. TFI can be accumulated for specific spray programmes or for a spray season, etc.

c. Country-codes and DSS acronyms

All DSS's covered by this survey has been allocated with acronym names, which also indicate the country of origin. Complete lists of acronym names are shown in Annex C1 – Annex C4. The following country codes have been used:

Code	**Country**
Bu_	Bulgaria
Cz_	Czech Republic
Da_	Denmark
Es_	Estonia
Fr_	Frances
Ge_	Germany
Hu_	Hungary
It_	Italy
Nl_	Netherlands
Pl_	Poland
Sk_	Slovakia
Sp_	Spain
Sw_	Sweden
Sz_	Switzerland
UK_	United Kingdom

2 Summary

Weeds, pests and diseases are global threats to crop production, and pesticides are widely used to reduce quantitative and qualitative losses due to damage caused by these organisms. As pesticides are relatively cheap and effective as compared to alternative measures, pesticides are often used more or less by routine, and dose rates are often higher than needed to meet requirements on a field level.

By nature, weeds, pests and diseases are not equally distributed in time and space. For example, some insect attacks may occur only in a relatively small area and only in short period of time, why only the pesticide treatments that are adjusted accordingly will actually be efficient. Some pests and diseases are not immediately observable, why special remedies may be required to detect attacks that may cause losses.

Also by nature, the efficacy of various pesticides varies with different conditions that may also vary substantially in time and space. For example, some weed species are efficiently controlled by just 5-10% of the labelled dose-rate of an herbicide, while other weed species are practically not affected by the labelled dose-rate.

In order to integrate such existing knowledge-bases and thereby strive for the idea of using pesticides ‘as little as possible, as much as required’, farmers need a relatively high level of insight, alternatively some decision support. Logically, there should be a substantial potential for reducing the overall use of pesticides, if applications can be shifted from routine-based ‘best practises’ that are expected to be robust for a relatively wide range of situations towards applications that have been adjusted more specifically to conditions on a field or sub-field level.

Decision Support Systems (DSS’s) have been developed to assist decision-making processes relating to crop protection on a farm and field level. Some DSS cover a large range of decisions that may include complete programmes for monitoring, treatments and follow-up throughout one or more growing seasons, while other DSS’s focus on isolated decisions, e.g. prediction of the time for attacks of a single pest that exceed the economic threshold in a single crop. Some DSS’s recommend ‘ready-to-go’ actions on farm- and field levels, other DSS’s recommend actions that require some interpretation by- or linkage with advisors, before actions should be implemented on a field level.

The main objective of this report is to provide an overview of the ‘Progress and prospects for the implementation DSS’s’ in the domain of crop protection, which were under development and in use in the EU member states and Switzerland in the year 2008.

A DSS for crop protection may be perceived as just a single component in a complex line of decisions and actions on a farm management level. The authors of this report who also planned and conducted the survey, therefore decided to include a rather wide range of characteristics in the survey. A joint form was developed for collection of data on DSS’s (Annex B). This form includes a number of detail questions within the following main areas of questions:

- Which decisions are supported?
- Which modelling approaches have been used?
- How is communication with users being done?
- Has some impact been demonstrated?
- Have opportunities for integration with naturally adjacent systems been identified?
- Are procedures for updating being followed?
- Have opportunities for unification been identified?
- Has feedback to research been identified?
- In a local perception: have some ‘best parts’ been identified?

A set of minimum requirements to constitute a DSS of relevance to this survey was defined by the work group. These requirements specify that a DSS of relevance to this survey must include the following 4 elements:

1. evaluation of economic thresholds and/or recommendation of options for treatment
2. integration of various sources of information. Some 'added value' as compared to label- and standard recommendation must be demonstrated
3. use of decision algorithms and/or calculation models
4. use of computers

In the perspective of possibly reducing dependency and/or use of pesticides, the data collected was analyzed to possibly identify some 'best parts'. Obliviously, the questions listed above cannot immediately be integrated in a common scale, why 'best parts' have been seached for different characteristics.

The search for DSS's was conducted in the 27 EU-member states and in Switzerland by allocation of 1-4 countries to each of the authors of this report. Consideration was observed to allocate countries in geographical neighbourhoods of the data collectors.

The work of data collection was separated in two periods: June – October 2007 and March – August 2008. The latter period was added as a result of conclusions made on a pan-European workshop in March 2008 on results from the first period. Obviously, important regions and DSS's had been overlooked in the initial period of the survey. In September 2008 the total count of received reports were 72 including 65 filled in data forms and 5 unofficial reports, which were immediately considered to be a relatively high rate of returns. 70 of these data-reports were included in the analyses presented in this report.

The analyses work was organized by dividing the 70 data-reports in 4 major crops, according to the crop x pest systems that were covered by the data-reports and the skills and interests in the work group. The following 4 groups were appointed:

- diseases in horticultural- and fruit crops
- diseases in arable crops
- pests
- weeds

The main results from the analyses of data-reports are presented in separate sections of these 4 groups.

a. DSS's for diseases in horticultural- and fruit crops

Tactical decisions are supported in terms of whether to spray, mainly driven by weather data and weather forecasts and models that refer to the life-cycles of specific diseases. It a spray is needed, mainly recommended dose rates will be suggested. Use of economic thresholds and use of dose-adjustments are rare. Strategically decision considerations are restricted to a single DSS, which include considerations regarding reducing risk of inducing pesticide resistance.

The main end-users are advisors and farmers, and the DSS's communicate by use of a wide variety of modern electronic communication tools. Only 3 out of 19 DSS provide some indication on demonstrated impacts, however, potentials of reducing input of fungicides are only reported as levels of variability, referring to spatial and seasonal differences. Potentials for reductions are mainly explained by reductions in the number of treatments as compared to routine spraying programmes on a seasonal level.

Several DSS's have been integrated with weather stations and with infrastructures of consultancy networks. A few DSS's have also been integrated with complex farm management systems. Most DSS are updated on a regular basis, utilizing experiences from the late growing season. Opportunities for unification were reported for several DSS, however only the model structure itself might be exported. Some DSS have already successfully been adapted to conditions in different countries

Although more and more information is available to support decision making of stakeholders, still system approach seems to be in an initial stage of development. On the contrary, the spread of GIS technologies support the landscape level thinking, keeping in mind that an area wide approach would never replace the field level decision making procedure. Based on this survey, it can be concluded that the mainstream of development is the accelerated integration of data sources and DSS modules both at national and supranational level.

b. DSS's for diseases in arable crops

Initial studies of received data forms indicated that separate analyses could be made in 4 different crop x pest groups: a) Potato Late Blight group, b) cereal group, c) non-blight/non-cereal group and d) multiple crop x disease group.

All DSS's on potato late blight support decisions relating to the timing of first fungicide application. 2 French DSS also recommend date of spraying, compound to spray and dose rate and future applications.

DSS's on diseases in cereals use weather data to predict infection periods and risk of epidemic progress. Some DSS's focus on epidemiology, other DSS's focus dose-response relations with fungicides and a 3rd group integrate both.

In the non-cereal/potato group, a diverse set of decisions algorithms and tools have been developed, e.g. use of spore-traps, petri dish plate-based bioassays in the field. In the multiple crop x disease group, DSS developed by private companies seem to have a substantial appeal to growers and advisors, although the decisions supported may not be differing much from DSS developed by public sector.

DSS's for potato late blight and for cereals share a basic concept of using weather data and weather fore as input for algorithms that predict risk of infection. Timing of first application of fungicide is recommended. More advanced systems also calculate subsequent risk timing of subsequent applications.

DSS's in the non-potato/cereal and multi-system groups are more diverse in the modelling approaches, including decisions thresholds, regression based epidemic progress models to predict economic and epidemic severity thresholds and 'knowledge-based' algorithms to predict when and what should be applied.

Considering communication with end-users, most DSS's for potato late blight are accessible from the internet. In cases where meteorological data is needed, such are often automatically 'pulled' from relevant access points, thus reducing efforts by end-users. Communication of DSS's for cereals are relatively simpler.

DSS's for potato late blight have proven capable of reducing the number of sprays in a growing season. Treatment failures leading to epidemics and crop failures and a comparative low cost of routine fungicide applications are, however, an important hindering for uptake of such DSS's. DSS's for cereals, where substantial seasonal variation in infestation levels exist, are often rather in-transparent with respect to algorithms and calculations. At the same time, effective fungicides are relatively cheap, why routine-based treatments are perceived as rational 'insurance policies'. Non-cereal/potato and multi-system DSS's have had a relatively low impact, however, a few systems have a relatively high number of end-users.

Many DSS's have been integrated with natural adjacent systems, e.g. farm management systems, suppliers of various meta-data, e.g. weather stations. As DSS's for potato late blight are all web-based, updating can be made easily from a central point. DSS's for cereals and other cultures include web-based and PC-based techniques, but all DSS's are regularly updated.

The major group of DSS's has not yet been unified for conditions in other countries. A few DSS have, however, a least on a conceptual and/or structural level, been implemented in different countries.

Most DSS's for potato late blight are in a continuous process of development and validation in order to improve the predictive power, the potentials and other objectives too. There seems to be a common consensus that there is a need to extend the blight DSS's to provide predictions for other potato diseases, for the production of a 'one stop shop' for potato diseases.

Many factors influence the connections between DSS's and research, e.g. introduction of new growing practices, identification of new biological connections, factors that have specific influence, etc. DSS's should dynamically over time be adapted to such changes, offering qualified support for decisions.

c. DSS's for pests

Most DSS's support decision in different crop/pest systems, however 4 different DSS cover codling moth on pome fruit. Most DSS's support short term (tactical) decisions, mainly decisions on sampling periods and decisions on choice of chemical compound, dosage and timing and spraying techniques. Some DSS's also recommend non-chemical treatment options, e.g. techniques for mating disruptions. A few DSS's also include long term (strategically) decisions, e.g. choice of crop variety or use of trap crops.

To basically different modelling approaches exist:

- predictions of pest occurrence
- actual presence of pests in time and place.

The presence of pest populations, are assessed in basically 2 ways:

- sampling by the user
- forecasting based on sampling by other users

Possible economic damages are assessed in two ways:

- by comparing observed/predicted attack levels to economic threshold levels
- by use of yield loss model.

Outbreaks are predicted mainly by pest population dynamics models, which are mainly driven weather data, in particular temperature data. Some DSS's also integrate agronomic factors on a field level. Spatial distributions of pest are also modelled from catches in pheromone traps. A few DSS's also integrate models that predict crop growth-stage, which is relevant in cases where a pest will attack only at specific growth stages.

The major target groups are farmers and advisors, but all DSS's needs an intermediate step in terms of e.g. 'warning services' or advisors, in order to connect to farmers. The theoretical potential of the analysed DSS's is to reduce the use of pesticides and/or to achieve a more efficient positioning of pesticides. Demonstrated impact in practice is sparse, however. Uptake by farmers is generally quite low, but more advertising, training and a more strict regulation on pesticide use could promote additional uptake. Cheapness of routine application of insecticides and reluctance to conduct field inspections constrain additional uptake.

Several DSS'S have been integrated with FMS's and with suppliers of meta-data, e.g. characteristics of crop cultivars, weather-data and label information on pesticides. Basic models the predict occurrence of pest are generally suitable for unification. Models that include interactions between specific crops and pests are probable suitable for unification on a regional scale. Several DSS'S have contributed to pin-point new research objectives that could also support specific DSS'S concepts.

d. DSS'S for weeds

Older DSS's support decisions on whether a treatment is required, and which of a list of suggested and more or less standardised treatments that is favourable, given a set of constraints. Newer DSS's are characterised by more holistic approaches, including also much more differentiation in the recommendation of treatments.

Developments have progressed since the early 1990'ies, from tactical 'spray'/'no spray' approaches towards optimisations including many biological and environmental aspects.
Some additional evolution trends have been observed: 1) from strict economic approaches towards approaches that also include various environmental aspects, 2) from short-term (tactical) approaches towards long-term (strategic) approaches that also include aspects of the crop rotation.

Some DSS's have implemented various supportive tools, e.g. tools to assist weed identification and tools to identify spraying techniques, which may be perceived as a set of matching recommendations relating to the spraying equipment, e.g. combinations of spray tasks, wind speed, water volume, driving speed, nozzle type and –size, etc.

The older DSS's are generally installed on separated computers, while the newer DSS's can be upgradable by internet or internet-based.

Transparency of recommendations from the DSS's back to underlying data and literature is relatively weak. Consequently, the recommendations from the DSS'S will often be perceived as a 'black-box' to the end-users, why the integrity and reliability of the DSS's should be documented in different ways, e.g. by results from tests in practice.

All DSS's were designed to support decisions made primarily by farmers, and some of them are also supporting decisions made by advisors. Two DSS's use a generic modelling approach, which have enabled them to work in a large number of crops, a large number of weeds and a wide range of 'conditions', enabling them to manage most situations of crop infestations.

Most DSS's have demonstrated a potential for reducing input of herbicides while maintaining requirements for weed management on a farm level. Three DSS's take into account differences in potential environmental impact for alternative herbicide treatments. Some of the DSS's are still under development, while other DSS'S have been released for years.

The uptake of the DSS's is relatively sparse: up to 3% of national farmers. Even though some DSS's have demonstrated potentials for reducing herbicide input up to 40-50% on a crop x national level, if herbicide treatments are adjusted on a field level, a number of reasons have are reported for a relatively low uptake of such DSS's. For example, low incentives due to relatively low cost of routine herbicides treatments and low interest to conduct scouting for weeds before decisions on herbicide applications are made.

DSS's which have been designed mainly for farmers, may conveniently be integrated with naturally adjacent IT-tools used on a farm level, as needs for entering input data can thereby be rationalized. Several DSS's has been integrated with FMS's and suppliers of meta-data, e.g. weather-data, databases on pesticides and systems for site-specific herbicide application.

Some DSS's are suitable for unification in terms of basic principles, basic system architecture or as it is. A general shortcoming is the availability of specific data needed to establish specific algorithms and/or to estimate specific parameters in calculation models. Some DSS's have been successfully adapted and implemented in different countries, typically in countries, which are geographically near to the country of origin. Several existing DSS's have interacted dynamically with research groups to identify new questions for research which also benefit the robustness and potentials of specific DSS's.

e. identification of 'best parts' of DSS's

On 17th-19th March 2008, a pan-European workshop was convened in Flakkebjerg, Denmark. The objectives of this work-shop were:

- to shortly present as many as possible of the 65 DSS's on which filled-in data-forms were received to conduct a process that inspired for involvement and discussion of 'best parts' of these DSS's in relation to perspectives of reducing use and/or dependency of pesticides
- to achieve consensus regarding identification of specific 'best parts' for various attributes of various DSS's in various crop x pest systems

By allocation of this task to a pan-European workshop, possible bias arising from subjectivity among the authors of this report, which may arise from personal involvements in national programmes for development of DSS's for crop protection, was eradicated.

After short presentations of 49 different DSS's, a representative from ENDURE SA4, which aims to build up a European Information /-Competence Centre (EIC), presented results from a survey, which was conducted in 2007 to identify needs from end user with respect to decision support relating to crop protection in a broad sense. It was concluded that DSS's were generally highly ranked among farmers and advisors as compared to alternative sources of decision support. However, some general requirements to DSS's were identified in order to form a basis for successful implementation in practical farming. Use of a DSS should:

- offer some advantages as compared to alternative sources of decision support, e.g. better control, lower cost, lower environmental impact, etc.
- be at least as robust as alternative sources of decision support. Obviously false recommendations may lead to a total rejection of DSS's
- strive for adaptation to existing operations on a farm level

Discussion on possible 'best parts' were conducted in 5 separate groups: 1) potato late blight, 2) diseases in cereal crops, 3) diseases in horticultural- and fruit crops, 4) pests and 5) weeds. Each group gave a brief presentation to the plenum of the workshop of result from the discussions in groups. 'Concluding remarks' were produced from the discussions in plenum (Annex D3).

e1. best parts of DSS's for diseases in horticultural- and fruit crops

Modeling approaches are often very specific to specific crop x pest systems, why only little opportunity exists for identification of 'best parts' for possible unification. Considering the decisions that are supported, the identification of 'high risk' periods seem to be a prosperous way to follow for additional research and development. Later on, also systems that can recommend treatment options may be feasible, but still much research and development are required to construct operational applications.

In a relatively short time span, DSS's may be developed to make recommendations on a regional level, thus underlining the importance of involving also regional advisers in order to make systems operational on a field level. To ensure productivity and progress among researcher and developers behind a DSS, procedures that provide feed-back from farmers and advisors should be established.

Some steps to possibly fertilize the ground for more operational applications, e.g. ensure basic compatibility of different data sources, first of all: weather data.

Other steps may be made operational and valuable within a relatively short span of time, e.g. monitoring schemes for selected crop x pest systems, development of tool to assist identification of pathogens and strategic management of prevention of resistance development and environmental side-effects.

Cost-benefit analyses from a point of the end-users may be fruitful tool to evaluate potentials in different stages of DSS-development: from conceptual ideas to implementation plans. Arbitrary assessments of impacts of DSS's should also be made in different stages of DSS development, so that efforts may be concentrated on potent ideas, concepts and applications.

e2. best parts of DSS's for diseases in arable crops

Identification of "best parts' has been made separately in different crop x pest groups. Among the DSS's for potato late blight, systems that are based on the 'Simphyt' or 'NegFry' models, i.e. Da_BlightMan, may be adaptable to different geographical regions/countries is with only minor modifications of core systems.

DSS's for diseases in arable crops are dominated by 'single disease' generic systems, which could probably be combined to provide information on more than one disease (utilising generic metadata i.e. weather data). The Danish system (Da_CPODiseases) is well defined and already used in other Baltic countries with good success, and could be amenable to further development throughout northern Europe.

Considering the non-cereal/potato group of DSS's, potentials may exist to capitalise in-field monitoring techniques to be used: 1) in new geographic areas and/or 2) as a measure to further 'fine-tuning' of DSS-algorithms and -models. Furthermore specific models for diseases on oilseed rape have reached a level of maturity that inspire for construction of a specific DSS's. Considering diseases in beets, additional work on core model is required.

Integrated multi-model DSS's in Poland shows the potential to integrate systems (developed under Danish conditions) for other countries. This approach could be taken more widely. Commercial systems such as NI_PlantPLus demonstrate proven track record on a global scale, but integration with and/or from such systems would probably be limited by IP/commercial concerns.

e3. best parts of DSS's for pests

The major challenges for development of future DSS's are to develop structures at the European level for:

- construction and updating of DSS's
- communication languages
- exchange of biological data
- exchange of weather data

'Best parts' have been identified in several existing DSS's, which have been developed in different countries / institutions, and which cover different crop x pest systems

e4. best parts of DSS's for weeds

'Best parts' were identified in terms of 'building blocks', which are characterized by some kind of demarcations, e.g. in terms of crop x pest systems, modelling approaches, IT-structures, etc. Building blocks may be perceived as components, which may have some value/potential in themselves or as possible components for construction of DSS's that integrate 'best parts' from different DSS's. Such building blocks were identified the following groups of decisions:

- Decisions on activities and timing on a farm level: different operational approaches have been implemented in Da_CPOWeeds, UK_WeedManager and Fr_DecidHerb
- Decisions whether control needed:
    - weed density equivalents is implemented in It_GestInf
    - weed dynamics in crop rotations have been implemented in UK_VM
    - aspects of crop yield, weed seed production and cosmetic considerations have been integrated in Da_CPOWeeds
- Decision on herbicide and dose selection:
    - cross-tables have been implemented in Nl_MLHD
    - dose/response functions and optimization of herbicide mixes for cost or for TFI have been implemented in Da_CPOWeeds
    - site-specific evaluations have been implemented in Nl_MLHD
- Decisions on environmental impact:
    - risk factors and multi criteria assessment have been implemented in Fr_DecidHerb
    - risk of leaching have been implemented in It_GestInf
    - Treatment Frequency Index (TFI) is implemented in Da_CPOWeeds
- Integration of climatic conditions:
    - long term conditions has been implemented in Fr_DecidHerb
    - short term conditions have been implemented in Da_CPOWeeds and Fr_OptHerbClim

3 Methodology

3.1 Collection of data

The objective of this survey is to provide a status in the year 2008 on 'Progress and prospects with the implementation of DSS's for crop Protection in Europe'. As most of the participants in the work-group behind this survey were also involved in national programmes for development of DSS's for crop protection, competence to act was supported by the adoption of open and joint working processes in the ENDURE IA2.4 work group.

Consequently, methodologies for collection of data and for analyses of data were jointly decided. In Annex A, the log of the working process that lead to decisions also regarding selection of methodologies is presented. On a workshop in Wageningen in June 2007, consensus was achieved on the main structure and main and detail questions to include in the survey:

- the survey should include the present 27 member states of EU and Switzerland, which is also participating in the ENDURE network
- criteria to identify DSS's of relevance to this survey and a form for data collection were jointly developed
- a joint form for collection of data was produced (Annex B).

Consensus was also achieved in the work-group that a DSS of relevance for this survey must include the following four features:

1. economic 'thresholds' and/or recommendations of specific options for treatment
2. integration of various sources of information
3. decision algorithms and/or calculation models. Some 'added value' must be found as compared to label- and standard recommendations
4. operational from a computer

These qualities regarding relevance have been documented by answers to initial questions of the data collection form. No specific requirements were defined in terms of level of development, and level of use. This means that simple prototypes as well as finalized applications have equal opportunity to be included in the survey.

Subsequently, questions were formulated in the following main groups:

- Which decisions are supported?
- Which modelling approaches have been used?
- How is communication with users being done?
- Has some impact been demonstrated?
- Have opportunities for integration with naturally adjacent systems been identified?
- Are procedures for updating being followed?
- Have opportunities for unification been identified?
- Has feedback to research been identified?
- In a local perception: have some 'best parts' been identified?

Identification of 'best parts' will be pursued on 2 levels:

- subjective statements provided by the constructor of a DSS, or by the data collector
- more objective, joint analyses of the collected data-forms on different DSS's.

The total count of countries to be included in the survey is 28, and these countries were split up among the participants in ENDURE IA2.4, so that each participant got the responsibility for implementation of the survey in 1-4 countries, which were typically located mainly relatively near to the native country of each participant. Table 3.1-1 presents an overview of participants and allocated countries to conduct the survey in.

Table 3.1-1
Allocation of 28 countries for 11 persons conducting the survey

Country, participant, and person responsible for data collection	**Allocated countries to conduct survey in**
France, ACTA, David Gouache	France Spain Portugal
France, INRA, Nicolas Munier-Jolain	Germany Austria
Germany, JKI, Volkmar Gutsche	
UK, RRES, Neal Evans	UK Ireland
Denmark, AU, Per Rydahl	Denmark Sweden Finland
Poland, IHAR, Josefa Kapsa	Poland Lithuania Latvia Estonia
Netherlands, WUR, Thomas Been	Netherlands Belgium Luxemburg
Italy, CNR, Antonio Berti	Italy Greece Malta Cyprus
Hungary, SZIE, Nora Levay	Hungary Bulgaria Romania
France, CIRAD, Samuel Nibouche	Slovakia Czech Republic Slovenia
Switzerland, FAL, Tomke Musa	Switzerland
	Count: 28 countries

The survey was implemented primarily by contacting governmental departments and institutions, universities, extension services, etc. which were expected to be capable of providing overviews of institutions and companies that are involved in DSS development on regional and national levels. Supplementary documentation was searched in scientific literature, conference proceedings, leaflets, web-pages etc.

The data collection form (Annex B) was including rather detailed instructions on how questions should be interpreted, and how reported features should be documented by use of references. Stated features or characteristics that could not be supported by official references have been referenced to as ‘Personal communication’ with the person, who performed the data collection.

According to the original time plan of the survey, the data collection should finish by the end of November 2007. On a workshop in March 2008 it was concluded, however that some countries seemed to be rather poorly represented in the survey. Consequently, the work on data collection was prolonged until 15th August 2008, and 10 additional reports were collected.

3.2 Analyses of data

In total, 72 ‘reports’ were received, including 65 filled in data-forms and 7 ‘unofficial’ reports. These reports were rather inhomogeneous distributed between countries:

- Belgium, 1 (data form not used)
- Bulgaria, 1 (data form not used)
- Czech Republic, 1
- Denmark, 3
- Estonia, 1 (data form not used)
- Finland, 1 (data form not used)
- France, 27
- Germany, 13
- Hungary, 4
- Ireland 1 (data form not used)
- Italy, 1
- Latvia, 1 (data form not used)
- Lithuania, 1 (data form not used)
- Netherlands, 4
- Poland, 2
- Switzerland, 3
- Slovakia,1
- Spain, 1
- Sweden, 1
- United Kingdom, 4

The received reports represent 20 of the 28 countries that were included in the survey. Reports were not received from: Austria, Portugal, Luxembourg, Greece, Malta, Cyprus, Romania and Slovenia, and 2 unofficial reports were excluded from the analyses, as they were found to contain only sparse information. Initial studies of the data-forms indicated that the 65 filled in data-forms were heterogeneous with respect to:

- the number of questions that are actually answered
- the number and quality of references
- use of linkages between specific answers and specific references

Initial studies also indicated that the received data-forms could be grouped in the following main groups, covering 82 different crop/pest systems:

- Diseases in horticultural crops, 18
- Diseases in arable crops, 37
- Pests, 18
- Weeds, 9

In order to identify specific DSS's, an acronym name was allocated to each DSS. Annex C1 – Annex C5 contain lists of acronym names and specific cultures covered within each of these 4 crop/pest main groups, and analyses have been conducted separately in these 4 crop/pest groups. Groups were also appointed to conduct review of analyses. These internal reviews in the work group should ensure that conclusions are properly supported by data and documentation. Tasks were allocated as presented in Table 3.2-1.

Table 3.2-1
Allocation of tasks in the analyses of collected data forms on DSS's for crop protection

DSS crop/pest group	Co-ordinator	Analyses group	Review group
Diseases in horticultural- and fruit crops	Nora Levay	David Gouache Marc Raynal Volkmar Gutsche Nora Levay	Samuel Nibouche Antonio Berti Josefa Kapsa
Diseases in arable crops	Neal Evans	Neal Evans Thomas Been	David Gouache Per Rydahl
Pests	Samuel Nibouche	Samuel Nibouche Josefa Kapsa	Nicolas Munier-Johain Nora Levay
Weeds	Per Rydahl	Antonio Berti Nicolas Munier-Jolain Per Rydahl	Volkmar Gutsche Thomas Been Neal Evans

Analyses of filled in data-forms (Annex B) were conducted mainly by use of cross-tables, where selected features have been compared across different DSS's. In cases where references are missing for specific answers, 'Personal communication' with the person who submitted the filled-in data-form has been used as reference. Early studies of the received and filled-in data forms indicated, however, that the number of questions that had actually been answered, and the quality of specific answers, in terms of references used, differed strongly between DSS's, between crop x pest systems covered and between countries. Consequently, a high level of autonomy was delegated to the sub-groups conducting analyses of the received data-reports.

3.3 Discussion

3.3.1 Working process

Like traditional reviews published in peer-reviewed journals, this survey is based on existing publicly accessible material. However, when comparing the report from this survey with a traditional peer-reviewed paper, the following differences can be emphasized:

- this survey try to answer a set of questions, which were pre-defined according to objectives in the ENDURE network. Consequently, the documentation available varies substantially

between DSS's and between crop x pest systems. The selected methodology is considered to be advantageous in terms of comparing different DSS's on criteria, which are pre-defined and independent of rationales behind, and professional integrity of DSS's
- this survey is restricted to cover only 28 countries in Europe, but numerous DSS's have also been constructed in countries outside Europe. This survey, however, focus on identification of 'best parts' of existing DSS's in Europe as a basis for constructing and validating unified DSS's on a European level
- the questions that were included in the data-form used for the survey were negotiated by the participants in the survey. Due to this involvement, it may be expected that conclusions regarding 'best parts' for unification on a European level are also consolidated among the participants
- the responsibility of identifying relevant DSS's in different was allocated to single persons in the ENDURE IA2.4 working group. Consequently, the survey may have been heterogeneously implemented in different regions and countries

In summary, the methodologies used for collection and analyses on data on existing DSS's may be characterized as a set of focussed and negotiated efforts to answer predefined questions rather than meeting reference standards of quality that characterize traditional reviews.

3.3.2 Motivation of questions included in the survey

Decisions on how to structure the survey and which main and detail questions to be included in the survey, was jointly motivated by the participants in workshop in Wageningen in 2007 (Annex A). It was concluded that the following main questions should be included in the survey:

a. Which decisions are supported?

A great variety of decisions relating to crop protection can easily be identified, e.g.:

- decisions in different crop/pest systems
- tactical and/or strategic decisions
- decisions relating to single or multiple aspects of a crop protection

A viewpoint form end-users relating to convenience could be that all relevant information in relation to crop protection should be integrated.

b. Which modelling approaches have been used?

In order to evaluate potentials for implementation of a DSS it may be useful to include evaluations of the nature of the modelling approaches, e.g.:

- the potentials of using certain components of a DSS as a generic structure for expansions to different crop/pest systems, for different geographical, climatic conditions
- the needs for research data, meta-data etc. to construct and/or maintain algorithms and calculations
- research-driven, e.g. mechanistic, biological models that do not necessarily refer to specific objectives within crop protection
- expert-driven algorithms and maybe calculation models

c. How is communication with users being done?

Potential users of DSS's may have immediate interest relating to communication procedures, e.g.:

- which language is used in user-interfaces?
- which terminology is used in user-interfaces?
- how transparent are recommendations from DSS's?
- which technical tools of communication are being used?

d. Has some impact been demonstrated?

As all potential user of DSS's for crop protection are probably presently using alternative sources of decision support, e.g. from advisors, dealers, label prescriptions, etc., a DSS should offer some advantages as compared to such existing 'best practices', e.g.:

- reduce the use of pesticides, which may improve farm economy or contribute to political reduction plans
- improve the control of specific pests, e.g. by use of more targeted pesticide sprays

While demonstrating some advantages, the robustness of recommendations from a DSS should also be accounted for. A DSS should probably at least be matching the robustness in different production lines of alternative sources of decision support. Several examples exist that just a few incidents of obviously unsatisfactory recommendations from a DSS, have lead to a total rejection of such DSS's by potential end-users. Errors made by humans are probably more acceptable to end-users than errors made by an upcoming DSS.

e. Have opportunities for integration been identified?

In cases where a DSS has proven some success in terms of demonstrating suitable robustness, some potential and some up-take, it may be convenient from a point of the end-users to integrate the DSS with naturally adjacent systems. A clear advantage of such approach could be that the need for input of data by end-users is minimized accordingly.

d. Are procedures for updating being followed?

The need for updating will of course depend on the nature of a DSS. DSS's that are based on basic biological relations, which are independent on parameters like actual supply of crops, cultivars, pesticides, growing practises, etc. will of course have less need for updating than DSS's that include such parameters. In cases where the integrity of a DSS depend on regular updating, procedures that ensure timely and proper updating are considered to be crucial.

e. Have opportunities for unification been identified?

A central objective of ENDURE, activity no. IA2.4 is to identify opportunities for unification of existing DSS's for crop protection on a European level. Previous experiences of export of existing DSS's may be useful for such evaluations.

f. Has feedback to research been identified?

In cases where a DSS has proven some success in terms of demonstrating some robustness, some potential and some up-take, it may be convenient to use the basic concepts of a DSS as a framework for pin-pointing new objectives in research. A major advantage of such working strategy will be that results from research may be predesigned for integration in algorithms and structures that have already been implemented in practice.

g. In a local perception: have some 'best parts' been identified?

Identification of 'best parts' of existing DSS's in relation to reducing use and/or dependency on pesticides is an overall objective of this activity (ENDURE, IA2.4). However, local developers and local users of existing DSS's may have special perceptions of qualities of a DSS, which are not included in the questions asked in this survey, so this question is an invitation to supply such information, if relevant.

4 Results

Results from analyses of collected and filled-in data forms are presented in 4 crop x pest groups:

- DSS's for diseases in horticultural- and fruit crops
- DSS's for diseases in arable crops
- DSS's for pests
- DSS's for weeds

4.1 DSS's for diseases in horticultural- and fruit crops

Analyses by Nora Levay, Volkmar Gutsche, David Gouache and Marc Raynal
Review by Samuel Nibouche, Antonio Berti and Josefa Kapsa

The analyses include 19 DSS's representing 6 countries as users (Czech Republic, Germany, France, Hungary, The Netherlands, Slovakia) and 8 countries as developers (a. m. plus Austria & USA). Out of these 19 DSS's, 18 are computerized systems, whereas one is a "paper-based' forecasting method (Cz_GrowerSys). In 13 cases, DSS's have been developed for single crops that focus on one or more diseases, as follows:

- grape, 7
- apple, 2
- melon, 1
- onion, 1
- celery, 1
- olive tree, 1

In contrast, 6 out of the studied DSS's are integrated into a multiple crop x pathogen(s) DSS. Typically, the more integrated a system was (the more plant-pathogen systems were addressed), the less detailed information we could gain about their modeling approach.

Authors have grouped all investigated DSS's under 'non-commercial' versus 'commercial' labels; however categorizing was - up to a certain level - a subjective decision. The basic aspect was whether the DSS is developed by a company or some type of governmental or not-for-profit organization.

From France, Germany and The Netherlands, the use of nationally developed models is reported, whereas in other cases (i.e. e. Czech Republic, Hungary) the presence of international suppliers seems to be dominant. Basic attributes of the studied 19 DSS's are presented in Table 4.1-1.

Table 4.1-1
Basic attributes of the studied 19 DSS's

Question		DSS																		
Commercial (c) vs. Non-commercial (n)		N	C	N	N	n	n	n	n	n	n	n	c	c	c	c	N	c	c	N
Crop	Pathogen	Cz_GrowerSys *	Ge_ProPlant **	Fr_Cocloconium	Fr_Epicure	Fr_MilMel	Fr_MilpvOignon	Fr_Milvit	Fr_Phytochoix ***	Fr_QualProtVege	Fr_SovBurgundy	Fr_Tavelure	Hu_AdcoAgroTele	Hu_LufftSmart	Hu_Metos	Hu_BoreasIntermet	Sk_Galativitis	Nl_Opticrop	Nl_PlantPlus	Ge_Zepp-
Grape	*G. bidwelli*				X															
	E. necator				X						X		X	X	X	X	X		X	
	P. viticola				X								X	X	X	X	X		X	
	B. cinerea												X	X	X	X	X		X	
Apple	*V. inaequalis*											X		X					X	X
	P. leucotricha													X						
	E. amylowora													X						X
Olive tree	*C. oleaginum*			X																
Celery	*S. apiicola*									X								X	X	
Onion	*P destructor*																	X	X	
	P. porri						X													
	B. squamosa																	X	X	
Melon	*P. cubensis*					X														
Lettuce	*B. lactucae*																	X	X	
Cole crops	*M. brassicicola*																	X	X	
	P. brassicae																	X	X	
Leek	*P. porri*																	X	X	
	A. porri																	X	X	
	P. alli																	X	X	
Carrot	*A. dauci*																	X	X	
	E. polygoni																	X	X	
	C. carotae																		X	
Strawberry	*B. cinerea*																	X	X	
	Sphareoteca sp.																		X	
Asparagus	*S. botryosum*																		X	

Notes:
* Cz_GrowerSys is not a computerized system, thus, it is excluded from further analysis, crop/pathogen systems are not clearly specified
** Crop/pathogen systems are not clearly specified for Ge_ProPlant Czech Republic
*** Fr_Phytochoix is an environmental risk assessment tool, pesticide applications (against pests, pathogens, weeds) are addressed in general

The investigated DSS's vary greatly from certain aspects, which are probably reflecting that they were developed under different socio-economic environment, reacting on the needs of local farmers. However, some characteristics of the studied DSS's are relatively frequent, revealing tendencies in the development of DSS's.

a. Decisions supported

Table 4.1-2 summarizes types of decisions that are supported. All DSS's (models) support tactical decisions on treatment optimization, whereas some also consider strategic decisions. Tactical decisions are typically 'Yes'/'No'-suggestions for the need of treatment, thus, all DSS's are based on the identification of 'high risk' periods. In most cases, the DSS's provide suggestions about what type of treatment is needed: either a 'contact or systemic fungicide' type of advice or a concrete suggestion for which chemical group(s) could be used.

One DSS (Nl_Opticrop) suggests also dosage for treatments, nevertheless it is unclear if this is the officially suggested rate that can be found on the label of products, or the recommendation is adjusted to the outcome of the risk analysis (practically lower dosage than the recommendation). Astonishingly, only one DSS considers implementation technique in its algorithm, e. g. adjustment of the spraying machine, mixing, spraying technique (Fr_Phytochoix).

Table 4.1-2
Types of decisions supported by the studied DSS's

Question \ DSS	Ge_ProPlant	Fr_Cyclonium	Fr_Epicure	Fr_MilMel	Fr_MilPvOignon	Fr_Milvit	Fr_Phytochoix	Fr_QualProtVege	Fr_SovBurgundy	Fr_Tavelure	Hu_AgroAdcoTele	Hu_LufftSmart	Hu_Metos	Hu_BoreasIntermet	Sk_GalatiVitis	Nl_Opticrop	Nl_PlantPlus	Ge_Zepp
Recommendation for treatment?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	?	?	Y	Y	Y	Y	Y
Economic threshold?	?	N	N	N	N	N	N	Y	N	N	?	N	N	N	?	Y	N	N
Integration of information?	Y	Y	?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Use of calculation models?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Operational from computer?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Tactical decisions supported?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Strategic decisions supported?	?	?	N	?	?	N	N	N	Y	?	N	N	N	N	N	N	N	N
Decision made by farmers?	Y	Y	N	Y	Y	N	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	Y
Decision made by advisors?	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Identification of pests?	?	N	N	N	N	N	N	?	N	N	N	N	N	N	N	Y	Y	N
Monitoring of pests?	?	Y	N	Y	Y	Y	N	N	Y	Y	N	N	N	N	N	N	Y	N
Instructions on implementation?	N	N	N	N	?	N	Y	?	?	?	?	N	N	N	?	N	N	N
Cost-benefit analysis?	N	?	N	?	N	N	N	N	?	?	N	N	N	N	N	Y	Y	N
Considering pesticide resistance?	N	?	N	?	?	Y	N	N	?	Y	N	?	?	?	N	Y	?	N
Considering envir. impact?	N	?	N	?	Y	?	Y	N	?	?	N	N	N	N	N	Y	?	N

Notes:
Y: Yes
N: No
?: No data/not specified

Only one of the investigated DSS's offers economic threshold evaluation (Nl_Opticrop). Some answers of the questionnaires even pointed out that the economic threshold should be flexibly adjusted to actual local conditions; therefore the interpretation of the model output by a skilled advisor is essential and includes the discuss of both economic context as well as strategic aspects.

Two of the DSS's (Nl_Opticrop, Nl_PlantPlus) offer tools to support identification of pathogens, such as pictures, and description of the pathogen's biology. Both of these DSS's belong to the 'commercial' category and are integrated into a complex farm management system. Also these are the only two DSS's, which offer cost-benefit analysis for the end-users.

More models consider pathogen monitoring (7 DSS's), which means suggestion for the end-user to carry out monitoring and giving advice on how to conduct this. Nevertheless, it is unclear how intensively the result of this monitoring is considered in the model algorithm.

Only one DSS (Fr_SovBurgundy) is clearly reported to take strategic aspects into consideration, however, some of the questionnaires inform us about the indirect support of certain long-term decisions. The most frequently reported strategic aspect is the diversification of pesticide use in order to keep selection pressure on the development of pesticide resistance as low as possible. Two of the models (Fr_MilpOignon, Nl_Opticrop) consider environmental aspects too, namely potential soil- and groundwater pollution. There is one exceptional DSS out of the19 investigated, since this is an environmental risk assessment model for vine grape production dealing with applied chemicals against pests, pathogens and weeds in general (Fr_Phytochoix). This model considers such specific environmental factors as impact on biological diversity as well.

b. Modeling approaches

With one exception (Fr_Phytochoix), all models quantify the risk of infestation (disease pressure) based on weather data and relevant sporulation, maturation, incubation and temperature curves. Additionally such aspects are considered as variety susceptibility and/or variety resistance rating, phenological stages of the crop, geographical position of the field (elevation, slope etc.) and in some cases farming practices (irrigation, earlier spraying events). Interestingly, crop rotation is not a factor in any of the investigated models. (However, this could be relevant only to those models which deal with annual crops, such as: onion, celery, melon, leek, lettuce, cabbage crops and carrot.) Knowledge for the build-up of model algorithms mostly comes from available international literature and partially from field trials conducted by the model developer. On the other hand, weather data input covers precipitation, humidity, temperature, wind direction, wind speed and in some cases solar radiation. Some of the models have incorporated a weather forecast function based on real-time weather data input, whereas in other cases it is unclear if the model calculates only based on actual weather data or has any predictive potential.

However, all of the disease models require weather data, which may come either from some kind of an internet based data supplier, or directly from field meteorological equipments. Nevertheless, the observed trend in the development of data flow is that the role of web suppliers providing real-time meteorological data transfer is becoming more and more significant. Therefore, newest developments of DSS's are pressured towards compatibility with different input data sources.

In some cases (8 DSS's), information was received on regular validation trials, however in other questionnaires it stayed unclear, how frequently these models are adjusted and validated according to new scientific knowledge.

The one exceptional DSS (Fr_Phytochoix) is the model for quantifying the risk of environmental side-effects. This DSS is operated with somewhat different modeling approach: it is based on the physical-chemical parameters of soil and of the potentially applied chemical substance. Besides these parameters, it relies on 'experts judgments' (fuzzy logic) in the decision algorithm; nevertheless its scientific background is well traceable and relatively transparent to interested end-users based on scientific publications.

c. Communication with end-users

All investigated DSS's focus on advisors as end-users, whereas 15 out of them can be used by farmers as well. In four cases it was pointed out that end-users are exclusively advisors. These DSS's operate with a region level approach and the results of the model output should be adjusted to local observation by the advisor and the farmer together. On the contrary, all other models (which can be used by both advisors and farmers) are focused at field level. Communication channels are exclusively personal only in 2 cases:

- by advisors of a chemical company (Ge_ProPlant),
- directly contacting the model developer (Cz_GrowerSys)

For the rest of the models, various forms of telecommunication is used, namely fax, SMS, email alerts (typically weekly); online access to web service or combination of these services. In case of an online service, models are running on a web server instead of the PC of the end-user. Additionally to these channels, CD-ROMs are offered in case of two DSS's as a free option, whereas in four cases, CD-ROM is the only opportunity of running the DSS. Many of the reports mentioned the increase of internet use as a potential for spreading knowledge and service faster and more efficiently. On the contrary, the often reported constraining factor is that farmers are sometimes reluctant to use computers either because of the lack of motivation to do so, or due to the lack of time to spend with 'desk job' in the growing season.

In cases where a DSS is integrated into the advisory service, the above mentioned communication channels are supported with regular visit of an advisor. Typically, these advisory services are not related to the for-profit sector, but to an institutional advisory infrastructure. Two major bottlenecks have been identified in terms of information flow towards farmers based on the analysis of 19 questionnaires and personal communication with data providers. Firstly, it is essential to have a clear picture of the role of advisory service in each country, and to understand the most common way of information flow towards practice. In some cases this seems to be related dominantly to the for-profit sector, in other cases information flow towards end-users is relatively balanced between institutional and commercial communication. Secondly, it stayed unclear, up to what extent commercial companies, selling chemical products, play a role in the decision making of farmers. Most of these companies have already realized the need for advisory service (apart from the product selling events) and some of them run their research in terms of developing DSS's too. Up to now, the so-called institutional sector has little insight into these processes, which would be necessary to understand the potentials of the not-for-profit sector in the market of advisory services.

d. Demonstrated impact

Evaluating the questionnaires, it became clear that relatively little attention is turned on accurate follow-up of DSS's. Only in three cases out of 19 we got precise information based on surveys that quantifies the reduction potential in pesticide use as a result of the implementation of DSS's. In case of two models, reduction in pesticide use varies between 0-50% (Nl_Opticrop, Nl_PlantPlus). A third DSS (Fr_MilVit) points out that the reduction of pesticide use depends on the strength of the infestation in a given year (disease pressure); in less risky years reduction can be quantified up to 75%, whereas in bad years with strong infestation, only the effective control of the disease is targeted. Another DSS (Fr_MilMel) reports on more diverse use of pesticides after the implementation of the DSS (suppressing selection pressure on the development of resistance against chemicals), and lower costs spent on pesticides, based on a survey among end-users. Two models report on an annual theoretical saving of 2-3 treatments (Fr_Epicure) or 20-40% reduction in pesticide use (Sk_GalatiVitis) on average.

e. Opportunities for integration

In three cases (Hu_Metos, Nl_Opticrop, Nl_PlantPlus), the DSS's are fully integrated with a complex farm management system, whereas in one case , Ge_Zepp (Paso), integration has been carried out within consultancy service. (Integration within consultancy service practically means that access to various DSS's is provided for advisors, so that they can build up a complex overview of models in different cropping systems.) In ten cases (Fr_Tavelure, Fr_SovBurgundy, Ge_Zepp (Paso), Fr_QualProtVege, Fr_MilVit, Fr_MilPvOignon, Fr_MilMel, Cyclonium, Adcon, Hu_LufftSmart) there is potential for integration, mainly with weather station network (model structure is compatible with input data from different sources). In two cases (Fr_Phytochoix, Fr_Epicure) it is clearly stated that it would not be possible to integrate the model within other systems, and in three cases we have no information.

Based on the survey it seems that integration of services is an active ongoing process among developers across Europe. According to the reports two mainstreams can be identified:

- Integration into various kinds of Farm Management Systems. Such services are typically web-based or running on CD-ROMs and include multiple crop/pest, crop/pathogen systems, and sometimes such additional modules as economic farm analysis too.
- Integration into the infrastructure of consultancy network. Thus, information is filtered through advisors while reaching farmers. This system is typically operated with an area wide approach and the personal interpretation of model output by an advisor is an essential point.

f. Procedures for updating

Procedure for updating is relatively similar for all investigated DSS's: in most cases models are annually updated extracting and utilizing the experiences of the given growing season and possibly the freshly published scientific knowledge. One of the models reports on an additional monthly update of chemical substance database (Nl_Opticrop). In three cases the updating is theoretically continuous due to the fact that these models are integrated into complex farm management systems providing web service for end-users (Hu_Metos, Nl_Opticrop, Nl_PlantPlus). Thus, end-users do not detect by all means the actual update of the model; on the other hand developers have the chance to update DSS's continuously. In case of CD-ROMs the new version is typically distributed annually. Nevertheless, for some models there is no information on the updating procedure, neither about the frequency, nor the content.

g. Opportunities for unification

Relatively many reports reacted positively on the question about possible unification of DSS's: five models (Zepp-paso, Fr_Phytochoix, Sk_GalatiVitis, Fr_MilMel, Nl_Opticrop) are reported to have the potential for unification with other systems. It was pointed out that only the model structure itself might be exported, the input database should be adjusted to local environmental and legal conditions. In five cases (Fr_SovBurgundy, Fr_Tavelure, Fr_QualProtVege, Fr_MilpvOignon, Fr_MilVit) model exchange has been done already among some European countries, namely UK, Belgium, France and The Netherlands. One DSS (Nl_PlantPlus) is already greatly unified with models of different crop/pest, crop/pathogen systems, since this works as a module of a complex world-wide service. In three cases it was reported that unification would not be possible (Fr_Epicure, Cyclonium, Hu_BoreasIntermet) and in five cases we have no information.

h. feedback to research

The most common ways of feedback are annual meetings and personal communication through advisors. Besides, internet is providing wide opportunities for building up regular communication between developers and users (e.g. helpdesk, forum). In 10 reports feedback to research was considered to be active. In seven cases out of them validation trials are being conducted based on regular cooperation between end-users and model-makers. In case of five DSS's feedback to research is not possible (Fr_Phytochoix, Hu_BoreasIntermet, Hu_LufftSmart, Hu_Metos) and for one model (Fr_SovBurgundy), due to its initial stage of development, communication between end-users and model-makers is planned to be built up in the future. In two cases we have no information about the opportunity for feedback.

4.2 DDS's for diseases in arable crops

Analyses by Neal Evans and Thomas Been
Review by David Gouache and Per Rydahl

Crops and DSS-acronyms covered by analyses in this section are presented in Annex C2. The analyses included 37 DSS's originating from 12 countries.

a. Decisions Supported

Of the 35 systems identified as DSS's for diseases of arable crops, there are a diverse combination of decisions supported both in terms of diseases and crops, the 'level' of decision support and the 'complexity' of the systems. For example, some of the systems form completely comprehensive systems that support decisions on complete farming systems (many crops/many pests) (Pl_IPMI-DSS, Nl_PlantPlus, Hu_MetosLink)[the multi crop sub-group]. One report (Ge_Zepp) details many different DSS's produced by one Institute and associates in Germany, and contains information on Ge_SimCerc3 [eyespot models], Fusarium models Puccinia models, Ge_Simphyt [Phytophthora] models, Ge_Simlep [Colorado beetle] models, Cercospora [of beet] models, 'SIMPEROTA' [tobacco blue mould] models plus others). Details of some of the specific Arable DSS's mentioned in Ge_Zepp are described in more detail in the following report and thus Ge_Zepp will not be described further, since it is not a single DSS.

Similarly, Cz_GrowerSys does not constitute a DSS, being a synthesis of knowledge and management tools that have the potential to improve the decisions growers make on farm. The information contained in Cz_GrowerSys indicates potential for future development of DSS's in the Czech Republic, but will not be discussed further in this report. In contrast, some systems, for example Ir_report, do not constitute a DSS at all (being a report of field experiments that test four blight models) and are thus not included further in this report. Of the remaining arable diseases DSS's identified, 10 are potato blight DSS's [Blight sub-group], 10 are wheat- or 'cereal-based' DSS's [Cereal sub-group], 5 are associated with diseases of oilseed rape and 2 are DSS's of beet diseases [non-cereal/potato sub-group].

The final remaining three reports, (Nl_PlantPlus, Pl_IPMIDSS and Hu_MetosLink) are multiple crop/multiple pest systems [multi-system]. To help focus the analysis across these diverse systems, analysis has been done in sub-groups considering systems that aim to provide DSS's for similar crop disease problems. Even within the sub-groups, the level of decision supported is diverse. However, as one might expect, the common theme running through all of the systems is the principal aim to control (a) disease and/or diseases whilst minimising fungicidal input.

a1. Blight sub-group

The majority of the 'blight systems' utilise meteorological data to calculate infection periods and subsequent risk of epidemic progress. The decisions that are supported from this are a recommendation for the timing of the first fungicide application and often subsequent need for further application. The Ge_Simphyt-based models make recommendations on the first fungicide treatment date (Ge_Simphyt1) and the subsequent risk from blight throughout the season (Ge_Simphyt3) whilst the related system Ge_Ökosimphyt does the same for organic potato crops. Ge_Simphyt-models are also described in Ge_Zepp. The new Ge_Simblight system, which is fully configured to interface with FMS's, is also based on the Ge_Simphyt1 model and recommends the date of first application [1]. Sz_Phytopre also supports the timing of the first application and the need for subsequent applications [2] and has also been used in organic systems [3]. NegFry-based models developed for use in Denmark (Da_BlightMan) support decisions such as timing of first and subsequent fungicide application(s), compound and dose [4, 5]. The Danish system has also been used to produce timing recommendations in the Baltic states, for example, in Poland (Pl_IPMIDSS), Estonia and Lithuania [6].

In France, two blight DSS's have been developed. Fr_MilpvPomTer uses Guntz Divoux and Milsol models to calculate spray date and recommends compound and rate [7, 8]. The DSS also forecasts future sprays. The contrasting system Fr_MildiLis also calculates spray date and recommends compound and rate [9].

a2. Cereal sub-group

The majority of the cereal disease DSS's utilise meteorological data to calculate infection periods and subsequent risk of epidemic progress. In the main, the decisions that are supported from this are a recommendation for the timing of the first fungicide application and often subsequent need for further application. As observed with the blight systems, the cereal disease systems do this to varying degrees depending on the complexity of each individual system. In contrast to the blight systems, which are based on the classical NegFry models, the cereal diseases systems can be grouped into dose response-based models (Da_CPODiseases, Fr_CryptoLis), analytical descriptive compartmental epidemiology models (Fr_PreSept, Fr_Spirouil and Fr_TreatOptPieton), disease progress/plant growth stage models (Fr_SeptoLis, Ge_Simcerc3 and Ge_Simonto, Sz_FusaProg) or a mixture of all three (using a genetic algorithm) as seen in UK_WheatDiseaseMan.

a3. Non-cereal/potato subgroup

As a group, the non-cereal/potato disease DSS's are more diverse in their approach to decision support, with the systems approaching minimisation of fungicide use in an 'ad hoc' manner. For example, the Fr_KitPetales and the Pl_SPEC systems are not actually computer based models (although some decision support angles are delivered via the web with respect to assessment of whether a test result has significance to the need for a fungicide application or not), with the first of these systems being a petri dish plate-based bioassay that is done in the field [10] and Pl_SPEC being a network of spore traps designed to forewarn growers of the presence of ascospores of the phoma pathogen *Leptosphaeria* spp. [11]. However, the significance and usefulness of these systems should not be diminished because of this since forecasts are robust (less than 5% false positives in the case of Fr_KitPetales) and both systems reportedly have a large ground-swell of support from the many growers and advisors that have used the system [12-14]. Of the other OSR DSS's of this sub-group, Ge_Skleropro, a crop loss-related forecasting model that provides decision support for fungicide application against Sclerotinia, is a widely used and respected model [15, 16] that has now been 'professionally' developed into a complete DSS by Ge_Zepp [17].

One of the many features, with respect to decisions supported is that the predictions include the use of economic thresholds so that a spray recommendation is only made if the infection index is equal or greater than the economic threshold [16]. From all of the analyses of arable diseases, it is plain that profit margin is the overriding factor for growers and their advisors when considering control programmes, which presumably accounts for the success of the system. However, although simpler in design, the systems to predict, in autumn, the onset of phoma leaf spot (UK_Fororps) and severity of light leaf spot the following spring (UK_Fororls) in the UK are also well respected within the industry [18]. These use simplistic regression-based models to predict, at the fungicide treatment threshold for Phoma leaf spot and during the most effective spray window in the case of light leaf spot, whether there is an imminent epidemic (for phoma; [19]) or whether a light leaf spot epidemic will develop 6 months later (when fungicidal applications are ineffective) [20]. Neither system makes a recommendation of product or dose, since these decisions are made by the growers and their advisors.

With respect to the Beet DSS's, these also seem to be based on a more simplistic approach with respect to forecast systems for both blight and the cereal diseases. The Ge_Cercbet1 and Ge_ Cercbet3 models forecast the appearance of *Cercospora beticola* in the crop at a regional scale and plot scale, respectively [21]. In addition to predicting onset of disease (and allowing optimisation of timing), Ge_Cerbet3 is linked to a product efficacy database and makes recommendations of product/dose depending on weather conditions [17, 22-25].

a4. Multi-system subgroup

Of the three multi-system DSS's, Nl_PlantPlus and Hu_MetosLink are both commercial products developed by private companies. In contrast to other arable DSS's analysed in this report, both are an order of magnitude higher in terms of the decision support information they provide to growers and their advisors, should growers and their advisors be willing to pay. For example, Nl_PlantPlus delivers a comprehensive, global DSS with claims of a farmer user base of 10,000 in various countries around the world [26]. Although the actual decisions supported (in terms of disease threat and/or appropriate product and dose rate, for example) may not be that more informative than those systems developed within the 'public sector', there is something about the 'commercially-developed' systems that appeals to growers and advisors. It could be suggested that the extra, professional development time and money applied to such systems ensures the eventual products are more intuitive and/or are easier to use. Certainly, a survey of growers and advisors indicated that perceived usefulness and ease of use of individual DSS's were acknowledged as one of the main barriers to the uptake of DSS's in the UK [27].

The other multi-system DSS, Pl_IPMIDSS, developed in Poland is an extension of the Danish blight and cereal based models and reflect many of the attributes of, for example Da_BlightMan and Da_CPODiseases, but, in terms of decisions supported, differences form these underlying models are highlighted under each section below.

b. Modelling approaches

b1. Blight sub-group

Details of the main attributes of the blight DSS's are given in Table 4.2-1a. Ostensibly, the 11 blight DSS'sare based on infection and risk algorithms that use actual and/or forecast meteorological data to predict likely blight infection periods and recommend a date for the first application of fungicide against this particular pathogen. Some of the more advanced systems also calculate subsequent risk and prompt the grower/advisor when subsequent applications are required.

b2. Cereal sub-group

Details of the main attributes of the cereal DSS's are given in Table 4.2-1b. The 10 DSS's are based on infection and risk algorithms that use actual and/or forecast meteorological data to predict likely infection periods for a number of cereal diseases. All systems recommend a date for the first application of fungicide against the target disease(s). Some of the more advanced systems also calculate subsequent risk and prompt the grower/advisor when subsequent applications are required. In addition, Sz_FusaProg predicts subsequent DON (deoxynivalenol) contamination, since this is a critical consideration for the grower/advisor with regard to infection by *Fusarium graminearum* [28].

b3. Non-cereal/potato sub-group

Details of the main attributes of the non-cereal/potato DSS's are given in Table 4.2-1c In contrast to other sub-groups the approaches for non-cereal/potato DSS's are remarkably diverse. Fr_KitPetales and Pl_SPEC are both field based monitoring systems based on gathering information on pest incidence in the field in real time. In both cases incidence is then compared to Decision thresholds (calculated using ROC curves) in the case of Fr_KitPetales [10] and economic thresholds for control for Pl_SPEC [12, 13]. Ge_SkleroPro is a crop loss-related forecast model that include economic thresholds to trigger the recommendation for a specific product/dose dependant on current weather conditions [15, 16]. By contrast, the two UK based oilseed rape DSS's (UK_Fororps; Phoma leaf spot) and (UK_Fororls; light leaf spot) use regression-based epidemic progress models to predict for economic and epidemic severity thresholds, respectively [19, 20]. Similar disease progress models, coupled with crop development algorithms (Ge_Cercbet1) and also fungicide efficacy data (Ge_ Cercbet3) to predict regional onset, and plot based prevalence of Cercospora leaf spot of sugar beet in Germany, respectively [22-24, 29].

Table 4.2-1a
Main characteristics of the DSS's for diseases of arable crops.

Question \ DSS	Ge_Simphyt1	Ge_Simphyt3	Ge_Ökosimphyt	Ge_Simblight1	Sz_Phytopre	Da_BlightMan	Es_Report	Li_Report	Fr_Milpv	Fr_Fr_MildiLis
Short term decisions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Operated by the farmer	Yes	Yes	No[a]	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Suggestion of treatments options	No	No	No	No	Yes	No	No	No	Yes	Yes[e]
Evaluation of envir. impact of different control options	No	No	No	No	No	No	No	No	Yes	No
Instructions relating to weather conditions	No	No	No	No	Yes[b]	Yes	Yes	Yes	Yes	Yes
Instructions on follow-up	No	Yes	Yes	No	Yes	No	No	No	Yes	Yes[b]
Long term decisions	No	No	No	No	No	No	No	No	Yes	No
Identification of pests	No	No	No	No	No	Yes	Yes	Yes	Yes	No
Use of economic thresholds	No	Yes	No	No	No	No	No	No	Yes	No
Instructions on treatment implementation	No	No	No	No	No	No	No	No	No	No
Implications for pesticide resistance	No	No	No	No	No	No	No	No	Yes[d]	No
Use of cost/benefit analyses	No	No	No	No	No	No	No	No	No	No
Monitoring of pests	No	No	No	No	Yes	Yes[c]	Yes[c]	Yes[c]	Yes	Yes

Notes:
[a] Advisors
[b] Rainfastness and effective control period given.
[c] Integrates with www.web-blight.net
[d] DSS designed to reduce number of sprays.
[e] Chemical treatments only.

Table 4.2-1b
Main characteristics of the cereal DSS's for diseases of arable crops identified in the survey.

Question \ DSS	Da_CPODiseases	Fr_CryptoLis	Fr_PreSept	Fr_SeptoLis	Fr_Spirouil	Fr_TraitOptPietin	Ge_SimCerc3	Ge_Simonto	Sz_FusaProg	UK_WheatDiseaseMan
Short term decisions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Operated by the farmer	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Suggestion of treatments options	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes
Evaluation of environmental impact of different control options	Yes	No	-	No	-	-	No	No	No	No
Instructions relating to weather conditions	Yes	No	Yes	Yes	Yes	Yes	No	No	Yes	No
Instructions on follow-up	Yes	No	Yes	Yes	Yes	Yes	No	No	No	Yes
Long term decisions	Yes	No	Yes[2]	No	Yes	Yes	No	No	Yes[3]	No
Identification of pests	Yes	Yes	Yes	No	Yes	No	No	No	No	Yes
Use of economic thresholds	Yes	Yes	No	Yes	No	No	No	No	Yes	No
Instructions on treatment implementation	No[1]	No	Yes	No	Yes	Yes	No	No	No	-
Implications for pesticide resistance	Yes	Yes	Yes	No	-	-	No	No	No	-[4]
Use of cost/benefit analyses	No	No	Yes	-	Yes	Yes	No	No	No	Yes
Monitoring of pests	Yes	No	Yes	Yes	Yes	Yes	No	No	No	Yes

Notes:
[1] Prototype that recommends spray techniques currently under development.
[2] Considers chemical options with regard to resistance issues.
[3] Used to develop cropping systems to reduce Fusarium infection and subsequent DON contamination risk.
[4] Model re-parameterised annually to take account of resistance. Includes specific restrictions on stobilurins, but no rules fro other compound groups.

b4. Multi-system subgroup

Details of the main attributes of the multi-system DSS's are given in Table 4.2-1c. For the PI_IPMIDSS system, decision algorithms are used to predict when and what should be applied with respect to the main cereal diseases with respect to field assessment of incidence levels coupled with weather data. The blight disease component is based on a NegFry algorithm to predict primary infection period and subsequent calculation of spraying intervals using weather data [30, 31]. Both the commercial systems NI_PlantPLus and Hu_MetosLink use a 'knowledge-based' integration of information approach and 'expert opinion' based approach to modelling, respectively.

Table 4.2-1c
Main characteristics of the non-cereal/potato and multi-system DSS for diseases of arable crops identified in the survey.*

Question \ DSS	Fr_KitPetales	Ge_SkleroPro	Pl_SPEC	UK_Fororps	UK_Forols	Ge_Cercbet1	Ge_Cercbet3	HU_MetosLink*	Nl_PlantPlus*	Pl_IPMIDSS*
Short term decisions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Operated by the farmer	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Suggestion of treatments options	Yes	No	Yes	No	No	No	No	No	Yes	Yes
Evaluation of environmental impact of different control options	Yes	No	No	No	No	No	No	No	N/K[2]	No
Instructions relating to weather conditions	No	No	No	No	No	No	No	Yes	Yes	No
Instructions on follow-up	No	No	No	No	Yes	No	Yes	No	Yes	Yes
Long term decisions	No	No	No	No	No	No	No	?[1]	No	No
Identification of pests	Yes	No	Yes	No	Yes	No	No	No	Yes	Yes
Use of economic thresholds	No	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes
Instructions on treatment implementation	No	No	No	No	No	No	No	No	No	No
Implications for pesticide resistance	Yes	No	No	No	No	No	No	No	N/K[2]	Yes/No
Use of cost/benefit analyses	No	Yes	No	No	No	No	No	No	Yes	No
Monitoring of pests	Yes	No	Yes	No	Yes	Yes	No	No	Yes	No

Notes:
[1] Capable of supporting long-term decisions, but only used for short-term (tactical) decisions,
[2] Not known

c. Communication with users

Table 4.2-2 (a, b and c) highlight communication levels between the DSS's and the end user and with the exception of UK_WheatDiseaseMan, all systems are internet based and are thus easily accessible to growers and advisors. The Internet provided a new impetus for the development and implementation of DSS's since early development in the early 1990's, but it is curious that the 'revolution' has never caught on to a great degree and uptake of some systems is still limited. Perhaps the reason for this was highlighted by a survey of UK growers and advisors [27] which indicated that the end user often felt that their needs and concerns had not been adequately heard, or that they had not even been consulted, during the development process, so that the finished product was too scientific, cumbersome to use on a daily basis. Much of this criticism from the UK growers/advisors was levelled at UK_WheatDiseaseMan and the ArableDS module 'shell' in particular. The importance of two-way communication should not be underestimated.

c1. Blight sub-group

For all of the blight models, the black box approach means there is no need for the user to understand or comprehend the complexity of the algorithms that underlie the system. All systems also are internet based. Simphyt-based (Ge_Simphyt1, Ge_Simphyt3 and Ge_Ökosimphyt) and the Ge_Simblight1 models require similar input of meteorological data and field observations before the simulation analysis can be run. Output takes a matter of seconds and is direct to the user. For some of the more complex/comprehensive systems, for example Da_BlightMan [32] and Phytopre (Sz_Phytopre), users are required to register and certain user-defined information (e.g. location) is used to pre-prime the DSS. For example meteorological data is 'pulled' from the nearest available meteorological station or relevant dataset without the need for further input from the user. Such systems are thus extremely user-friendly with minimal input time required before recommendations are made. Although all of the blight systems are designed to be used competently by farmers, mention is made that the majority of users generally take advice from, for example, advisors with field experience.

c2. Cereal sub-group

In general, communication with users seems to be a lot less comprehensive for the cereal disease DSS's in comparison with blight systems. This is probably a reflection of the less stringent need for timing of fungicide application of the majority of cereal diseases in comparison with the destructive power of blight epidemics where a missed spray 'window' could jeopardise a whole crop. The exception to this is the three French systems, Fr_PreSept, Fr_Spiroul and Fr_TraitOpt-Pieton where output requires detailed analysis by technicians/advisors and growers are actively dissuaded from making decisions from the models. Here the role of the technical advisor is critical with respect to the grower's actions.

c3. Non-cereal/potato sub-group

Obviously, for Fr_KitPetales and Pl_SPEC, communication and comprehension of the results is paramount to successful use of the DSS. In the case of Fr_KitPetales, often the grower and /or his advisor will actually be doing the petal test in the field, but this highlights the need for clear, simple interpretation of the results and a clear understanding of whether an application threshold has been reached [14]. In contrast, although growers/advisors are not directly involved in analysing spore trap tapes for apothecia or monitoring pseudothecial development on debris reservoirs, the results from this detailed and labour intensive process need to be communicated to end users effectively for predictions to be timely [12]. The same can be said for the other non-cereal/potato DSS's all of which are Internet based, allowing quick updating to a central point.

c4. Multi-system subgroup

All three systems are Internet based so that interaction with end users is quick and using the DSS's is easy. In the case of Nl_PlantPlus, communication by the Internet allows global use and widespread uptake, which would not have been possible some 10-15 years ago.

d. Demonstrated impact

d1. Blight sub-group

For analysis of impact, please see Table 4.2-2a. All of the blight DSS's reported have had significant impact on potato growers and their advisors, with proven records of reducing spray applications to those targeted at initial infection periods. Those that predicted subsequent infection periods also contribute to reduced environmental impact through reducing the number of sprays applied to the crop in comparison with traditional 'calendar' sprays. However, as detailed in the reports on Fr_Milpv ([8, 33]) and Fr_Mildilis, uptake by growers and their advisors is often hindered for a number of reasons, the great fear that farmers have of treatment failure resulting in a blight epidemic and the comparative low cost of fungicides compared with crop failure, both of which conspire to make growers extremely cautious. These factors, although not unique to DSS's for blight, probably affect take-up of the blight forecast systems more markedly than for DSS's for other crops and/or disease problems.

Table 4.2-2a
Synthesis of the blight DSS's features about the potential/demonstrated impacts

Question \ DSS	Ge_Simphyt1	Ge_Simphyt3	Ge_Ökosimphyt	Ge_Simblight1	Sz_Phytopre	Da_BlightMan	Es_Report	Li_Report	Fr_Milpv	Fr_MildiLis
Internet version	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Potentials for ↘ fungicide use	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
potentials for ↗ economic profit	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
potentials for ↘ environmental impacts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
↗ Risks (yield, economics)	No	No	No	No	No	No	No	No	Yes[6]	No
Number of end-users	n/k[1]	n/k[1]	n/k[1]	n/k[1]	~100	+++[5]	n/k[1]	n/k[1]	****[7]	~500[8]
Level of using	33%[2]	33%[2]	33%[2]	33%[2]	↘	+++[5]	n/k[1]	n/k[1]	na [7)]	++[8]
End-users	a, b	a, b	a, b	a, b	a, b	a, b	n/k[1]	n/k[1]	a, b	a, b
Confidence of end-users with recommendations	++	++	++	++	80%[3]	n/k[1]	n/k[1]	n/k[1]	**	++
Short term Validations	Yes	Yes	Yes	Yes	Yes	Yes	n/k[1]	n/k[1]	Yes	Yes
Long term validations	No	No	No	No	-[4]	n/k[1]	n/k[1]	n/k[1]	No	No
Limitations			A	A	AB	A	n/k[1]	n/k[1]	CD	C
References	[34, 35]	[35]	[35, 36]	[1, 35]	[3, 37]	[32, 38]			[8, 33]	[9]

Notes:
1) Not known
2) 33% of users consider model output in decisions
3) 80% of users confident in the predictions.
4) Validated since 1990.
5) 80% of advisors and 5-10% of growers actively use the system.
6) 2007, DSS recommended many sprays on all cultivars.
7) 250 growers+ 6 groups of technicians+ 30 advisors (3500 growers via warning system).
8) About 500 farmers, 1000 internet connections per day during June

a: farmers
b: advisors
c: teachers

A: Large distances between met stations and farms
B: Security/Firewall problems with access
C: Low incentive
D: lack of marketing

d2. Cereal sub-group

For analysis of impact, please see Table 4.2-2b. In comparison to the Blight DSS's which generally seem to have demonstrated a large impact with growers and their advisors, cereal disease based systems seem to have had less of an impact. Generally, the cereal disease based systems are much younger systems an indeed, some such as Fr_SeptoLis and Ge_Simonto are still under development and so have had little impact at all to date. Also, whereas blight is a constant and annual threat requiring multiple applications for control in most growing seasons (and control regimes are therefore 'set'), cereal diseases tend to be less predictable from season to season. This has consequences both for and against the current and future use of cereal disease

DSS's. For example, underlying algorithms and models an be complex to take account of many crop, disease ad environmental components which al has implications on take-up (for example, causing the demise of UK_WheatDiseaseMan or requiring specialist 'technical' interpretation in the case of Fr_PreSept, Fr_Spiroul and Fr_TraitOptPieton.

Table 4.2-2b
Synthesis of the cereal DSS's features about the potential/demonstrated impacts

DSS / Question	Da_CPODiseases	Fr_CryptoLis	Fr_PreSept	Fr_SeptoLis	Fr_Spirouil	Fr_TraitOptPietin	Ge_SimCerc3	Ge_Simonto	Sz_FusaProg	UK_WheatDiseaseMan
Internet version	Yes	Yes	No	Yes[4]	No	No	Yes	Yes	Yes	No[8]
Potentials for ↘ fungicide use	Yes	Yes	Yes	Yes[4]	Yes	Yes	Yes	Yes	Yes	Yes
Potentials for ↗ econ. Profit	Yes	N/K	Yes	-[4]	Yes	Yes	Yes	Yes	Yes	Yes
Potentials for ↘ envt. Impacts	Yes	Yes	Yes	Yes[4]	Yes	Yes	Yes	Yes	Yes	Yes
↗ Risks (yield, economics)	No	No	Yes	No	Yes	Yes	No	No	No	No
Number of end-users	++[1]	+[2]	N/K	-[4]	N/K	N/K	N/K	N/K	-[4]	~100[9]
Level of using	+++	N/K	N/K	-[4]	N/K	N/K	N/K	N/K	-[4]	-[9]
End-users	a, b	a, b	b	a, b	b	b	a, b	a, b	a, b	a, b, c
Confidence of end-users with recomm.	High	-	N/K	-[4]	N/K	N/K	++[6]	++[6]	-[4]	-[9]
Short term Validations	Yearly	-	-	-[4]	-	-	Yearly	Yearly	Yearly	No
Long term validations	Since 1990	1994-2004	Since 1976	-[4, 5]	Since 1976	Since 1976	Since 2001[7]	1992-2006	Since 2004	No
Limitations	A, B	B, C	D	-[4]	D	D	-	-	E	F
References	[39-42]	[43]	[44]	[45]	[46, 47]	[48]	[17, 25, 49-51]	[17, 21, 25, 52, 53]	[28]	[54-57]

Notes:
1) 1000 (3%) of growers, 300 advisors and 300 other subscribers.
2) 3 Cooperatives, about 200 users per month at peak times.
3) Weather data errors can affect forecasts. Also, requires specialist analysis, so growers are not encouraged to use the system.
4) System still under development
5) Developed on data from 100+ trials over 10 years in 2 regions.
6) 33% of farmers use recommendations in the decision making process
7) About 100 fields/weather stations per annum
8) CD–ROM based, with Internet met data updates
9) System no longer in use.

a: farmers
b: advisors
c: teachers

A: Reluctance to do field inspections
B: Prefer to trust advisors/own judgement
C: Not all Cooperatives have an intranet
D: Lack of incentive/pesticides so cheap
E: lack of interest in computers
F. Use needed (time consuming) training. Also, the DSS was perceived as a threat by advisors.

As mentioned for some blight systems, it would seem that one of the major restrictions on uptake of cereal disease DSS's is the lack of incentive to growers to use such systems with regard to the relatively cheap cost of fungicide. For many growers, it seems the policy is to treat as an 'insurance policy' even if the actual threat from a particular disease is negligible. This socio-economic conundrum is probably the largest obstacle to the uptake of DSS's, particularly for diseases.

d3. Non-cereal/potato sub-group

Even though the non-cereal/potato sub-group models are less comprehensive than those reported in the blight and cereal sub-groups, it is interesting to note that these systems seem to have had a big impact in terms of numbers of users and the way in which end-users value the systems (Table 4.2-2c). A possible explanation for this could be that general information regarding crop protection strategies on what could be regarded are less important crops within the arable rotation is less well defined in comparison to high risk crops such as potato or the more widely grown cereals and that as such, end users will accept and utilise any information available.

d4. Multi-system subgroup

Both Hu_MetosLink and Pl_IPMIDSS report low 'demonstrated impact' at the present time, but probably due to both systems being relatively newly developed and with poor uptake to date [58, 59] (Table 4.2-2c). In contrast the commercial product Ni_PlantPro reports 10,000 users on a global scale [26]. Often it is commercial systems, for example with dedicated helpdesks or technical advisors available to answer queries that do best in terms of two-way communication between the 'system' and the end-user.

e. Opportunities for integration

e1. Blight sub-group

Some blight DSS's integrate with Farm Management Systems, particularly the Simphyt-based models which are integrated within the ISIP (Integrated System for Integrated Plant Production) system used by the German advisory service [17] (Table 4.2-3a). Fr_Milpv also integrates with FMS systems. Although not integrated with a FMS, Da_BlightMan is well integrated within the Danish Advisory System since Plantinfo (which contains Da_BlightMan) has the ability to send SMS text messages/warnings direct to growers and advisors. Presumably, Es_Report and Li_Report systems, which are based on the Da_BlightMan system share the same level of integration (or the potential, at least).

Table 4.2-2c

Synthesis of the non-cereal/potato and multi-system DSS's features about the potential/demonstrated impacts*

Question \ DSS	Fr_KitPetales	Ge_SkleroPro	Pl_SPEC	UK_Fororps	UK_Forols	Ge_Cercbet1	Ge_ Cercbet3	Hu_MetosLink*	Nl_PlantPlus*	Pl_IPMIDSS*
Internet version	No[1]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
Potentials for ↘ fung. Use	Yes	Yes[3]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Potentials for ↗ econ. Profit	Yes	Yes[4]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Potentials for ↘ envt. Impacts	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
↗ Risks (yield, economics)	Yes	No	No	No	No	No	No	No	No	No
Number of end-users	2000?	N/K	6000	+[7]	~100 p.m.[8]	N/K	N/K	Low	10000	5-6
Level of using	N/K	N/K	V. High	+[7]	+[8]	N/K	N/K	Low	High	Low
End-users	a, b	A, b	a, b	a, b	a, b	a, b	a, b	a, b	a, b	a, b
Confidence of end-users with recommendations	Good	33%[5]	V. good	+[7]	Good	33%[5]	33%[5]	N /K	Good	Good
Short term Validations	Annual	N/K	N/K	Annual	Annual	N/K	N/K	N/K	Yes	Annual
Long term validations	2000-2007[2]	1994-2007[6]	2004 onwards	15 years	Since 1996	1998-2007[9]	1998-2007[9]	N/K	Since 1995	Wheat 2001-, Potato 2004-
Limitations	A	-	-		-	B	B	C	C	-
References	[10, 60]	[15, 16]	[11, 13]	[19, 61]	[18, 20, 62]	[17, 22, 23, 25]	[17, 23-25, 29]	[63]	[26]	[64]

Notes:

1) Petri dish-based bioassay
2) 700 individual fields
3) Fungicide application reduction between 39 and 81%
4) Potential net return 23-45€/ha
5) Survey in 2005, 33% of end-users use predictions directly in their decision making process
6) 172 Observations
7) Too new to tell
8) ~100 registered users, but website gets 50-200 hits per month, depending on time of year.
9) 200 weather stations and 800 monitoring fields

a: farmers
b: advisors
c: teachers

A: Time consuming/ergonomically challenging
B: Distance between available met sites and farms
C. Lack of motivation/Scepticism

↗: 'increased'
↘: 'reduced'

e2. Cereal sub-group

Although the German DSS's Ge_Simserc3 and Ge_Simonto do not integrate with other DSS's or with meta-databases, each system is fully integrated with the German Advisory service FMS ISIP (ISIP=Integrated System for Integrated Plant Production) [21]. In contrast, Da_CPODiseases integrates well both on a local scale with the Danish FMS, but also with meta-databases for information on pesticides currently available, cultivar resistance and weather data [65]. Although lacking links to a FMS, Fr_CryptoLis links well with other Arvalis DSS's providing an umbrella of systems for growers within France [45]. The same criterion applies the Septoria model currently under development for France form Arvalis (Fr_SeptoLis). It is interesting to note that the UK_WheatDiseaseMan system, judged to be too overly complicated by users, was integrated (and ran within) the UK Arable DS framework system, but that growers did not like this configuration, preferring to manage disease based on cultivar grown rather than current and past field situation [66]. Fr_PreSept, Fr_Spiroul and Fr_TraitOptPieton no integration with FMS, but share common access to the Meteorological databases of Mateo-France as does Sz_FusaProg [67].

Table 4.2-3a
Synthesis of the blight DSS's features about the links with other systems

Question / DSS	With farm management systems	With site specific management systems	With meta-data	Others	Comments
Ge_Simphyt1	Yes	No	No	No	Integrated with ISIP[1]
Ge_Simphyt3	Yes	No	No	No	Integrated with ISIP[1]
Ge_Ökosimphyt	Yes	No	No	no	Integrated with ISIP[1]
Ge_Simblight1	Yes	No	No	No	Integrated with ISIP[1]
Sz_Phytopre	No	No	Yes[2]	No	2) Integrated with weather stations of agricultural schools and plant protection offices
Da_BlightMan	N/K	Yes[3]	Yes	Yes	3) Plantinfo integrated into the Danish field database of DAAS
Es_Report	N/K	N/K	N/K	N/K	
Li_Report	N/K	N/K	N/K	N/K	
Fr_Milpv	Yes	?	Yes	Yes[4]	4) To be unified with Fr_MildiLis
Fr_MildiLis	No	No	Yes[5]	No	5) With regional weather forecasts and the Arvalis fungicide database

Notes:
[1] ISIP – Integrated System for Integrated Plant Production

e3. Non-cereal/potato sub-group

Table 4.2-3c indicates current and potential possibilities for integration. As with the other sub-groups, integration with FMS's depends on the complexity of the system with respect to programming and the compatibility of the DSS and the FMS. Where integration is possible, analysis of the reports suggests that integration has already happened (For example, the Ge_Zepp-based models Ge_SkleroPro, Ge_Cercbet1 and Ge_Cercbets3). It is interesting to note that both UK_Fororps and Uk_Fororls were conceived to be modules of the UK-based FMS/DSS ArableDS, but this has not been possible since the demise of UK_WheatDiseaseMan and the subsequent lack of funding for the further development of ArableDS ([66, 68].

Table 4.2-3b
Synthesis of the cereal DSS's features about the links with other systems

DSS \ Question	With farm management systems	With site specific management systems	With meta-data	Others	Comments
Da_CPODiseases	Yes	No	Yes[1]	No	1. pesticide information, cultivar resistance and weather data
Fr_CryptoLis	No	No	Yes[1]	Yes[2]	1. pesticide information, cultivar resistance and weather data 2. Linked to other Arvalis DSS's
Fr_PreSept	No	No	Yes[3]	No	3. Weather data
Fr_SeptoLis	No[4]	No[4]	Yes[2]	Yes[2]	2. Linked to other Arvalis DSS's 4. Under development
Fr_Spirouil	No	No	Yes[3]	No	3. Weather data
Fr_TraitOptPietin	No	No	Yes[3]	No	3. Weather data
Ge_SimCerc3	Yes[5]	No	No	No	5. Integrated with ISIP [1]
Ge_Simonto	Yes[5]	No	No	No	5. Integrated with ISIP [1]
Sz_FusaProg	No	No	Yes[3]	No	3. Weather data
UK_WheatDiseaseMan	Yes[6]	No	Yes1	No	1. pesticide information, cultivar resistance and weather data 6. Integrated with ArableDS, but growers didn't use the system

Notes:
[1] ISIP – Integrated System for Integrated Plant Production

Within the non-cereal/potato sub-group, there is little potential for integration between the different DSS's since the systems and approaches used appear far too diverse, particularly with regard to the field based system Fr_KitPetales. There is potential to integrate spore trapping systems with disease progress-based models (something being considered for the UK oilseed rape systems, for example) but the cost of setting up the necessary network of volumetric spore traps (and the subsequent processing of the spore trap tapes) could be considered to prohibit this for the foreseeable future [12]. Obviously, Ge_Cercbet1 and Ge_Cercbet3 are already integrated, with Ge_Cercbet3 being a refined version of the original model.

e4. Multi-system sub-group

For the multi-system DSS's, integrations potential does not appear great. PI_IPMIDSS is reported not to be compatible with any Polish FMS's although the underlying models produced in Denmark are fully integrated with the Danish Advisory Service FMS [69, 70]. Of all DSS's described, the Danish-produced systems lend themselves to further integration with respect to covering new geographical areas with relatively minor re-parameterization [40].

Table 4.2-3c
Synthesis of the non-cereal/potato and multi-system DSS's features about the links with other systems*

Question / DSS	With farm management systems	With site specific management systems	With meta-data	Others	Comments
Fr_KitPetales	No	No	No	No	
Ge_SkleroPro	Yes[1]	No	No	No	[1] Integrated with ISIP
PI_SPEC	No	Yes[2]	No	No	[2] Under development
UK_Fororps	Yes[3]	Yes[4]	Yes[4]	-	[3] Developed as a module for Arable DS [4] Could be used with on-farm met data for a localised prediction.
UK_Fororls	Yes[3]	Yes[4]	Yes[4]	-	[3] Developed as a module for Arable DS [4] Could be used with on-farm met data for a localised prediction.
Ge_Cercbet1	Yes[1]	No	No	Yes[5]	[1] Integrated with ISIP [5] Proposed to integrate with a comprehensive DSS for major sugar beet diseases
Ge_Cercbet3	Yes[1]	No	No	Yes[5]	[1] Integrated with ISIP [5] Proposed to integrate with a comprehensive DSS for major sugar beet diseases
Hu_MetosLink [1]	N/K	N/K	No	No	
NI_PlantPlus [1]	Yes[6]	No	Yes[7]	?	[6] Can integrate with any FMS [7] Regional weather forecasts
PI_IPMIDSS [1]	No	No	Yes[7]	No	[7] Regional weather forecasts

f. Procedures for updating

f1. Blight sub-group

Details of dissemination and update method are given in Table 4.2-4a. Interestingly, all blight systems are web-based and so can be easily and centrally updated. In this way, the latest version of models and subsequent forecasts are 'pushed' to end users.

f2. Cereal sub-group

Details of dissemination and update method are given in Table 4.2-4b. The cereal disease DSS's that are currently used, tend to be web delivered and so can be easily and centrally updated. In this way, the latest version of models and subsequent forecasts are 'pushed' to end users. The exceptions are Fr_PreSept, Fr_Spiroul and Fr_TraitOptPieton which require interpretation by specialist Technicians in any case, so personal contact between the growers and their technical advisors is paramount for all three systems. The other exception, UK_WheatDiseaseMan was developed during the early years of the Internet age and a tactical decision was made to disseminate the system via CD-ROM. It has been suggested that this was one of the reasons the DSS became defunct, since the system was therefore 'PC based' rather than portable. At that time, UK growers were not particularly keen on using computers on farm, preferring to make decisions in consultation with paid advisors, a point that is still true (to a lesser extent) today [27, 66].

Table 4.2-4a
Procedures for updating blight DSS's

	Distribution	Cost	Comments	References
Ge_Simphyt1	Web	0 – 70 €	Annually	[17, 25]
Ge_Simphyt3	Web	0 – 70 €	Annually	[17, 25]
Ge_Ökosimphyt	Web	0 – 70 €	Annually	[17, 25]
Ge_Simblight1	Web	0 – 70 €	Annually	[17, 25]
Sz_Phytopre	Web	18-30 €	daily	[67]
Da_BlightMan	Web/Fax[1]	Free[2] 2250 DK[3]	5-6 times per season	[69]
Es_Report	Web	N/K	N/K	
Li_Report	Web	N/K	N/K	
Fr_Milpv	Web	150 €[4]	daily	[71]
Fr_MildiLis	Web/SMS[5]	Individual: 75€ Group: 50-60€ per annum	Technical database: annually 2+ times daily with respect to weather data.	[72]

Notes:
[1] Indirect use of forecasts by tele-fax to advisors/farmers
[2] Free to farmers associated with DAAS
[3] All other users have to pay this amount for access to the metadata
[4] 150€ per farm (for use of DSS), or 60€ for warning information only.
[5] Blight warnings sent by SMS

f3. Non-cereal/potato sub-group

Details of dissemination and update method are given in Table 4.2-4c. After listing almost exclusively 'web-based' distribution methods for both the blight and cereal DSS's (with the exception of the sadly defunct UK_WheatDiseaseMan) it seems strangely quirky to list the main distribution point for and Arable disease DSS as 'Via Post Office'. However, the report indicates that growers and advisors show a lot of respect to Fr_KitPetales since it is relatively easy to use and answers straight decision support questions in a very visual manner [14]. As for blight and most cereal DSS's, all other systems in this sub-group are web-based with respect to distribution method.

Updates tend to be done annually, presumably on a seasonal basis at sowing or crop emergence depending on the system. The exceptions to this are Pluses and UK_Fororls. For Pl_SPEC, spore concentrations are monitored on a daily basis (in terms of the number of *Leptosphaeria* ascospores counted per daily area of spore trap tape) and forecasts are updated on the website on a weekly basis [13]. For UK_Fororls, a preliminary light leaf spot forecast is produced using previous summer pod incidence, deviation from 30 year mean summer (July-August) temperature and 30 year mean winter rainfall. The forecast is then refined during the early part for the following March to account for actual deviation in winter rainfall from the 30 year mean (polycyclic disease with rain splashed conidia, drier winter cause less severe epidemics, wetter winters cause more severe epidemics) [20].

Table 4.2-4b
Procedures for updating cereal DSS's

Question / DSS	Distribution	Cost	Comments	References
Da_CPODiseases	Web	100 € growers 150 € Advisors	Annually	[39, 65]
Fr_CryptoLis	Web	20 € HT/Year	Annually	[45]
Fr_PreSept	Via Ministère Agriculture	N/K	Weekly (Daily if required)	[44]
Fr_SeptoLis	Still under development (Web?)	Still under development	Still under development	
Fr_Spirouil	Via Ministère Agriculture	N/K	Weekly (Daily if required)	[47]
Fr_TraitOptPietin	Via Ministère Agriculture	N/K	Weekly (Daily if required)	[48]
Ge_SimCerc3	Web	0 – 70 €	Annually	[25]
Ge_Simonto	Web	0 – 70 €	Annually	[25]
Sz_FusaProg	Web	12 €	Daily	[67]
UK_WheatDiseaseMan	CD-ROM[1]	<100 € per copy	Weather daily, program parameters yearly	[66]

Notes:
[1] CD-ROM Installation, program and weather updates via Internet

Table 4.2-4c
Procedures for updating no-cereal/potato and multi-system[6] DSS's

Question / DSS	Distribution	Cost	Comments	References
Fr_KitPetales	Via Post Office	5€ each test	Annually updated	[10, 60]
Ge_SkleroPro	Web	0 -75 € p.a.	Annually updated	[16, 17, 25]
Pl_SPEC	Web[1]	Free[2]	Weekly	[73, 74]
UK_Fororps	Web	Free[3]	Annually (Sept/Oct)	[19]
UK_Fororls	Web	Free[4]	Twice annually (Sept/Oct and March)	[18]
Ge_Cercbet1	Web	0 -75 € p.a.	Annually updated	[17, 22, 23, 25]
Ge_Cercbet3	Web	0 -75 € p.a.	Annually updated	[17, 23-25, 29]
HU_MetosLink[6]	PC/web-based	1.2€ Ha	N/K	[63]
Nl_PlantPlus[6]	CD-ROM, Web	550 €[5]	Hourly	[26]
Pl_IPMIDSS[6]	Web	???	Annually	[64]

Notes:
[1] web-server, sms and email notification
[2] Funded by DuPont Poland
[3] Development of models funded by Defra LINK, subsequent updating funded by Defra.
[4] Development of models funded by HGCA, subsequent updating funded by Defra.
[5] Depends on country, but 550 € in the Nl.
[6] Multi-system DSS

f4. Multi-system sub-group

Details of dissemination and update method are given in table 4.2.4c. As for the majority of DSS's analysed in this report, the multi-system DSS's are web-delivered ensuring updates are instantaneous and are automatically fed through to the end-user. This is particularly relevant to the global, 'commercial' Nl_PlantPlus system, which is updated on an hourly basis.

g. Opportunities for unification

g1. Blight sub-group

Potentials, opportunities and restrictions regarding unification are presented in Table 4.2.5a. All of the blight DSS'shave investigated opportunities for unification to one extent or another, both across country border lines and different climatic regions. As some systems use similar underlying models (for example the Simphyt models [17, 25], and Da_BlightMan and Es_Report/Li_Report [58, 69]) and thus are already integrated/unified to a higher or lower degree. Similarly, These DSS's have been successfully used in different geographical regions/countries, for example throughout Scandinavia and the Baltic countries of the former Soviet block [75] with only minor re-parameterization and some cosmetic changes to webpage aesthetics.

In contrast, although based on different models, it is interesting to note that there is an expectation for Fr_Milpv and Fr_MildiLis to be unified to produce a single blight prediction system within France [71].

Table 4.2-5a
Potentials, opportunities and restrictions regarding unification of blight DSS's

Question / DSS	Unification			Restric-tions	Feedback to research	Origi-nality	Reference
	Oppor-tunity	Poten-tial	Short-comings	owner/ access			
Ge_Simphyt1	Yes	Yes	No	Yes	Yes	Yes	[35, 76]
Ge_Simphyt3	Yes	Yes	No	Yes	No	Yes	[17, 35, 76, 77]
Ge_Ökosimphyt	Yes	Yes	No	Yes	No	Yes	[76]
Ge_Simblight1	Yes	Yes	No	Yes	Yes	Yes	[1, 17, 25, 34, 76]
Sz_Phytopre	No	No	No	?	No	No	[67]
Da_BlightMan	Yes	Yes	?	?/No	Yes	Yes	[4, 32, 69]
Es_Report	?	?	?	?	?	?	[58]
Li_Report	?	?	?	?	?	?	[58]
Fr_Milpv	Yes	Yes	Yes	?	Yes	Yes	[7, 8, 33, 71]
Fr_MildiLis	No	Yes	Yes	Yes	Yes	Yes	[9, 72]

g2. Cereal sub-group

Potentials, opportunities and restrictions regarding unification are presented in Table4.2.5b. As observed for the blight Systems, the Danish Da_CPODiseases has already shown a high degree of potential since this DSS has also been implemented in Estonia (mentioned in the report Es_Report, but not highlighted further in this report), Latvia, Lithuania and Poland. Models appear to work well, following re-parameterization for different climatic conditions. In contrast, systems developed in other European countries appear to have a limited current and/or potential possibility for unification. For example, the Arvalis systems Fr_CryptoLis and the recently developed Fr_SeptoLis are well integrated within the Arvalis organisation, but are currently considered as 'in house' systems for the foreseeable future [45]. The systems Fr_PreSept, Fr_Spiroul and Fr_TraitOptPieton show some potential for use in other geographical locations, but would also require re-parameterization.

Systems developed in Germany also show potential, since the only requirement for model input is Meteorological data (Ge_Simserc3 and Ge_Simonto), although use would be carefully controlled via a licence agreement which may prove restrictive and/or costly [17, 25, 52, 78]. In contrast the UK_WheatDiseaseMan system does not show great potential for unification with other systems. Models were parameterised for the UK, use in other geographical locations might be possible, but only after re-parameterisation and validation.

Table4.2-5b
Potentials, opportunities and restrictions regarding unification of cereal DSS's

Question / DSS	Unification: Opor-tunity	Unification: Poten-tial	Unification: Short-comings	Restric-tions owner/ access	Feedback to research	Origi-nality	Reference
Da_CPODiseases	Yes[1]	Yes	Yes[2]	No	Yes	Yes	[39, 65, 79]
Fr_CryptoLis	Yes	-	-	Yes[3]	-	-	[45]
Fr_PreSept	Yes[4]	Yes[4]	Yes[2]	Yes[3]	Yes	Yes	[44]
Fr_SeptoLis	Yes	Yes[5]	No	Yes[3]	Yes	Yes	[45]
Fr_Spirouil	Yes[4]	Yes[4]	Yes[2]	Yes[3]	Yes	Yes	[47]
Fr_TraitOptPietin	Yes[4]	Yes[4]	Yes[2]	Yes[3]	Yes	Yes	[48]
Ge_SimCerc3	Yes	Yes	No	Yes[6]	No	Yes	[25, 80]
Ge_Simonto	Yes	Yes	No	Yes[6]	Yes	Yes	[17, 25, 52, 78]
Sz_FusaProg	No	No	No	N/K[3]	Yes	Yes	[28, 67]
UK_WheatDiseaseMan	No	No	No	Yes[7]	Yes	Yes	[66]

Notes:
[1] DSS also implemented in Estonia, Latvia, Lithuania and Poland
[2] Models need re-parameterization for use in other countries
[3] Negotiable
[4] Potentially, at least
[5] Could be used independently or as part of a larger system.
[6] Owned by the Crop Protection Services of the German Federal States. Use possible via a licence agreement.
[7] All use subject to agreement with the IP owner (HGCA). Normally granted for research purposes, but negotiable for commercial use.

g3. Non-cereal/potato sub-group

Potentials, opportunities and restrictions regarding unification are presented in Table 4.2-5c. In terms of potential for unification, both the field-based monitoring DSS's (Fr_KitPetales and Pl_SPEC) offer potential, both for extending geographical areas covered and also integration into model-based DSS's, with respect to disease onset variable integration [12, 14]. Of the two, Fr_KitPetales would be easier to implement with respect to both unification targets since, as discussed previously the cost of setting up a network of spore traps and the associated manpower required to regularly process spore tapes would probably be inhibitory [12]. However, the associated costs may depreciate in the near future since quantitative PCR systems (specific for *Leptosphaeria* spp. DNA) are now being developed, which would cut the cost of processing spore sample tapes [81].

Of the disease progress forecast systems of oilseed rape, it should be possible to unify the two British systems UK_Fororps and UK_Fororls since both are similar in terms of model construction, being primarily weather data driven and this is currently under consideration by the model developers [68]. Ge_SkleroPro has already shown potential under non-German field conditions, for example in the UK, where predictions of Sclerotinia stem rot risk were acceptable under heavy disease pressure years [82]. Growers and advisors in Northern Europe would certainly welcome a DSS that covered the main oilseed rape diseases (phoma stem canker, Sclerotinia stem rot and light leaf spot) if such a system could be developed. One potential problem with regard to unification of system could be IP/ownership issues since, in the cases of, for example, Ge_SkleroPro, both Ge_Cercbet models and the two UK_Fororls or UK_Fororps systems is that IP ownership belongs to Governmental funding bodies, and, for example, in the case of the UK, these are even different bodies.

g4. Multi-system sub-group

Potentials, opportunities and restrictions regarding unification are presented in Table 4.2-5c. In terms of unification, Pl_IPMIDSS already unifies many different arable DSS models into one system and it will be interesting to observe whether levels of uptake by the farming community increase as the system develops in Poland. Regarding the commercial systems Hu_MetosLink and Nl_PlantPLus, it is difficult to judge the real potential for unification with other system, but these opportunities are probably limited due to commercial concerns. The authors of this report suspect that any integration concerning the commercial DSS's would 'into' these systems rather than 'out of' which might exclude potential users should they not be willing to pay for a commercial service.

Table 4.2-5c
Potentials, opportunities and restrictions regarding unification of non-cereal/potato and multi-system DSS's*

Question / DSS	Unification: Oppor-tunity	Unification: Poten-tial	Unification: Short-comings	Restric-Tions owner/ access	Feedback to research	Origi-nality	Reference
Fr_KitPetales	Yes[1]	Yes[1]	No	No	Yes[2]	Yes	[10, 60]
Ge_SkleroPro	Yes	Yes	No	Yes[3]	No	Yes	[16, 17, 25]
Pl_SPEC	Yes	Yes	Yes	N/K	Yes[4]	Yes	[73, 74]
UK_Fororps	Yes[5]	N/K	Yes[6]	Yes[7]	Yes	Yes	[19]
UK_Fororls	Yes[5]	N/K	Yes[6, 8]	Yes[7]	Yes	Yes	[18]
Ge_Cercbet1	Yes	No	No	Yes[3]	N/K	Yes	[17, 22, 23, 25]
Ge_Cercbet3	Yes	No	No	Yes[3]	N/K	Yes	[17, 23-25, 29]
Hu_MetosLink*	N/K	N/K	N/K	No[9]	Yes	Yes	[63]
Nl_PlantPlus*	Yes[10]	Yes[10]	Yes[11]	Yes[12]	Yes	Yes	[26]
Pl_IPMIDSS*	Yes[13]	Yes[13]	Yes[14]	N/K	Yes[15]	No	[64]

Notes:
[1] DSS also implemented in Poland
[2] Switch to use quantitative PCR
[3] Owned by the Crop Protection Service of the German Federal States. Use may be possible under a licence agreement.
[4] Incorporating Pathogen information, and metadata such as weather data
[5] Could integrate with systems for other diseases
[6] Only predicts for one disease when others also drive fungicide decisions
[7] Complicated IP issues
[8] Requires input from the UK OSR Pest and Disease Survey, which relies on continued funding from Defra/HGCA
[9] Commercial product
[10] Worldwide systems have proven scientifically sound at the farm level.
[11] Highly dependant on input of correct weather data
[12] Licence agreement
[13] Core DSS has proven track record outside Denmark in various countries
[14] Model parameters need re-parameterization for use outside Denmark
[15] Pathogen constantly evolving requiring constant monitoring and testing

h. Feedback to research

h1. Blight sub-group

Feedback to research has been observed for different blight DSS's. Most DSS reports highlight the need for continual validation of the systems in order to improve predictions and the incorporation of new factors (such as soil moisture; Ge_Simphyt1 and Ge_Simblight1) to further improve the predictive power of the system [17]. In terms of extending original use to other agricultural systems, there are instances where original systems have (with minor modifications or re-parameterisation) been adapted to provide blight predictions for, for example, organic production systems (Ge_Ökosimphyt and Sw_Phtyopre). There seems to be a common consensus that there is a need to extend the blight DSS's to provide predictions for other potato diseases, for the production of a 'one stop shop' for potato diseases.

h2. Cereal sub-group

Feedback to research seems to be a key feature of the cereal DSS's. With the exception of Ge_SimCerc3, all reports suggest that continual new research is necessary to improve models or the power of predictions, often through the development and incorporation of sub-models (e.g. Plant architecture sub-model for Fr_SeptoLis, DON contamination sub-model for Sz_FusaProg). In contrast with blight systems, this probably highlights the complexity of the cereal disease model systems. Also in contrast with the blight systems, there seems to be no requirement for the development of cereal disease DSS's for use in organic systems.

h3. Non-cereal/potato sub-group

Feedback to research is an important feature of the DSS's of this subgroup. Both field-based monitoring systems (Fr_KitPetales and Pl_SPEC) are currently assessing the merits of recently developed quantitative PCR methods to cut time, speed up assays and reduce person hour input. As costs (time and work effort) are restrictive to the potential integration of both systems in the future, developing new technologies may help secure a future for monitoring systems in the coming years. For example, quantitative PCR techniques have recently revolutionised the whole area of aerobiology, where researchers are now able to use spore monitoring techniques to assess the population dynamics of, for example, fungicide insensitive isolates of many fungal species using mutation site specific primers [83].

h4. Multi-system sub-group

Continued research seems to be important, even for commercial systems since cropping systems do not remain constant, pathogens evolve (at varying speeds) and the weather is for ever changing. In addition, systems can usually be improved through research and validation to improve models and predictive power. For example, Hu_MetosLink utilises recent weather patterns to 'back cast' the future, rather than forecast the future and model refinement continues [63]. Even Nl_PlantPLus continues to require constant adjustments to the basic underlying models in order to use them for predictions of other diseases or pests [26].

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4.3 DSS's for pests

Analyses by Samuel Nibouche and Josefa Kapsa
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Crops and DSS-acronyms covered by analyses in this section are presented in Annex C3. The analyses included 15 DSS's originating from 6 countries.

a. Decisions supported

Table 4.3-1 details the crop-pest systems addressed by the 15 DSS's. Some DSS's include a single pest, while other DSS's are polyvalent and cover several pests simultaneously in one crop or a cropping system.

There is few overlapping between DSS, except a) in pome fruits where four pests are covered both by Sz_Sopra and Ge_Pomsum, and b) for the grain aphid *Sitobion avenae* (F.) covered by Fr_Colibri and Da_CPODiseases. The codling moth, *Cydia pomonella* (L.), is the most addressed pest, with four DSS's.

Table 4.3-1
Crop-pest systems addressed by the 15 DSS's

Crop	Pest (DSS)		Fr_Bruchilis	Sz_Sopra	Sp_GEP	Nl_NemaDecide	Ge_Proplant	Fr_Tordeuces	Fr_Tordeuces Plum	Fr_Cobold	Fr_Dacus	Fr_EVA	Fr_Colibri	Fr_ActivLimaces	Da_CPODiseases	Ge_Pomsum	Ge_Simlep3
pea, faba bean	bean betle	*Bruchus rufimanus*	X														
Pome fruits	rose Apple aphid	*Dysaphis plantaginea*		X													
	European apple sawfly	*Hoplocampa testudinea*		X												X	
	codling moth	*Cydia pomonella*		X	X			X								X	
	smaller fruit tortrix	*Grapholita lobarzewskii*		X													
	pear psylla	*Cacopsylla piri*		X													
	apple blossom weevil	*Anthonomus pomorum*		X												X	
	summer fruit tortrix moth	*Adoxophyes orana*		X												X	
	bud moth	*Spilonota ocella*														X	
	Green budworm	*Hedya nubiferana*														X	
	winter moth	*Operophtera brumata*														X	
	rose tortrix moth	*Archips rosana*														X	
	apple grass aphid	*Rhopalosiphum insertum*														X	
	green apple aphid	*Aphis pomi*														X	

Crop	Pest		Fr_Bruchilis	Sz_Sopra	Sp_GEP	Nl_NemaDecide	Ge_Proplant	Fr_Tordeuces	Fr_Tordeuces Plum	Fr_Cobold	Fr_Dacus	Fr_EVA	Fr_Colibri	Fr_ActivLimaces	Da_CPODiseases	Ge_Pomsum	Ge_Simlep3
	red spider mite	*Panonychus ulmi*														X	
	apple brown tortrix	*Pandemis heparana*			X												
stonefruits	European cherry fruit fly	*Rhagoletis cerasi*		X													
	Mediterranean fruit fly	*Ceratitis capitata*			X												
	Oriental peach moth	*Cydia molesta*			X												
	plum fruit moth	*Cydia funebrana*							X								
	olive fly	*Dacus oleae*									X						
potato	Nematodes					X											
	Colorado potato beetle	*Leptinotarsa decemlineata*															X
winter oilseed rape	flea beetle	*Psylliodes chrysocephala*					X										
	cabbage stem weevil	*Ceutorhynchus quadridens*					X										
	rape stem weevil	*Ceutorhynchus napi*					X										
	rape blossom beetle	*Meligethes aeneus*					X										
	cabbage seed weevil	*Ceutorhynchus assimilis*					X										
	brassica pod midge	*Dasineura brassicae*					X										
cotton	Cotton bollworm	*Helicoverpa armigera*								X							
vineyards	grape moth	*Lobesia botrana*										X					
cereals	grain aphid	*Sitobion avenae*											X		X		
	bird cherry oat aphid	*Rhopalosiphum padi*													X		
	Rose-grain aphid	*Metopolophium dirhodum*													X		
	cereal leaf beetle	*Oulema melanopa*													X		
cereals, sunflower OSR, sugar beet	slugs													X			

b. Which risks are modelled?

There are two categories of DSS's in terms of which risk that is modelled. One category of DSS's focuses on the phenology of pests. Such DSS's predict:

- the risk of occurrence of pest outbreaks, and/or
- the demographic structure of pest populations (presence of pests in time and place

DSS's belonging to the second category are Fr_ActivLimaces, Fr_EVA, Fr_Tordeuses, Fr_TordeusesPlum, Fr_Dacus, Ge_Proplant, Sz_Sopra, Sp_GEP, Ge_Simlep3 and Ge_Pomsum. This category of DSS estimates the risk of economic damages according to plant phenology and pest population size. With such DSS's, pest populations are assessed, basically in two ways:

- by recording the results of the pest sampling made by the user (Da_CPODiseases, Fr_Simbad),
- by forecasting the future pest population with a demographic model that uses user's sampling data as input (Fr_Colibri).

Economic damages are assessed in two ways:

- by comparing the pest population level (observed or predicted) to an empirical action threshold or an economic injury level (Da_CPODiseases),
- by using a yield loss model that estimates economic damage by coupling a pest model with a crop model (Fr_Colibri, Fr_Simbad, Nl_NemaDecide).

c. Decisions, which are supported

Most of decisions addressed by the DSS are short term (tactical) decisions:

- sampling periods
- chemical treatment options, e.g. choice of active ingredient / product, dosage and optimal date of treatment, according to pest instars present, impact on environment and cost,
- non chemical control measures (mating disruption)

Some long term (strategic) decisions are addressed by some DSS's: choice of variety, use of trap crops. Four DSS's provide help for identification of pests, see Table 4.3-2. Four DSS's also provide instructions on treatment implementation (spraying techniques, etc.).

c. Modelling approaches

c1. Modelling of pest outbreaks and phenology

Modelling of pest population dynamics is the most common approach among the DSS. Eleven DSS's use this approach: Sz_Sopra (Samietz et al. 2007), Fr_Tordeuses (Roubal and Rouzet, 2003), Fr_EVA (Jacquin et al. 2003), Ge_Proplant (Johnen and Meier, 2000), Fr_TordeusesPlum, Fr_Dacus (Régis and Jacquin, 2000), Ge_Simlep3 (Jörg et al. 2007), and Ge_Pomsum.

These DSS's use temperature-driven demographic models which calculate rates for development, mortality, reproduction. Input data are weather data and sometimes pest sampling (egg sampling, pheromone trapping, etc.).

In addition to weather data, Fr_ActivLimaces also take into account agronomic factors (crop, previous crop, soil, stubble management, etc.) to assess the risk of slug economic damages (Chabert et al. 2003).

c2. Modelling of pest spatial distribution

Sp_GEP models the spatial distribution of the codling moth *Cydia pomonella* at the regional scale. The model computes maps of 'iso-catch' curves from a pheromone trap network, using a geostatistical approach (Ribes et al. 1998).

c3. Modelling of crop phenology

The approach used in Fr_Bruchilis relies on crop ecophysiological modelling of faba bean crop. A plant model predicts the occurrence of the crop growth-stage that is susceptible to bruchid attacks. Input data are weather, crop cultivar and sowing date.

c4. Coupled crop-pest models

Coupled crop-pest models are the most complex DSS's. Only two DSS's belong to this category: Fr_Colibri for cereal aphid (Plantegenest et al. 1999) and Fr_Simbad for cotton bollworms (Nibouche et al. 2003), the later currently being an experimental tool.

These DSS's use several models that are interconnected:

- an insect population dynamics model, that models the number of insects according to weather, natural enemies and crop phenology,
- a crop model, modelling the crop phenology according to weather, soil, variety, agronomic practices,
- a yield loss model that predicts the economic damage according to the crop phenology, the pest population and the abiotic constraints.

d. Communication with end-users

The target groups of users of the DSS's are:

- farmers, 7 DSS's
- advisors, 9 DSS's
- technicians from warning services, 4 DSS's
- pesticide distributors, 2 DSS's

Figure 4.3-1 illustrates the two approaches in the decision process using pest DSS's.

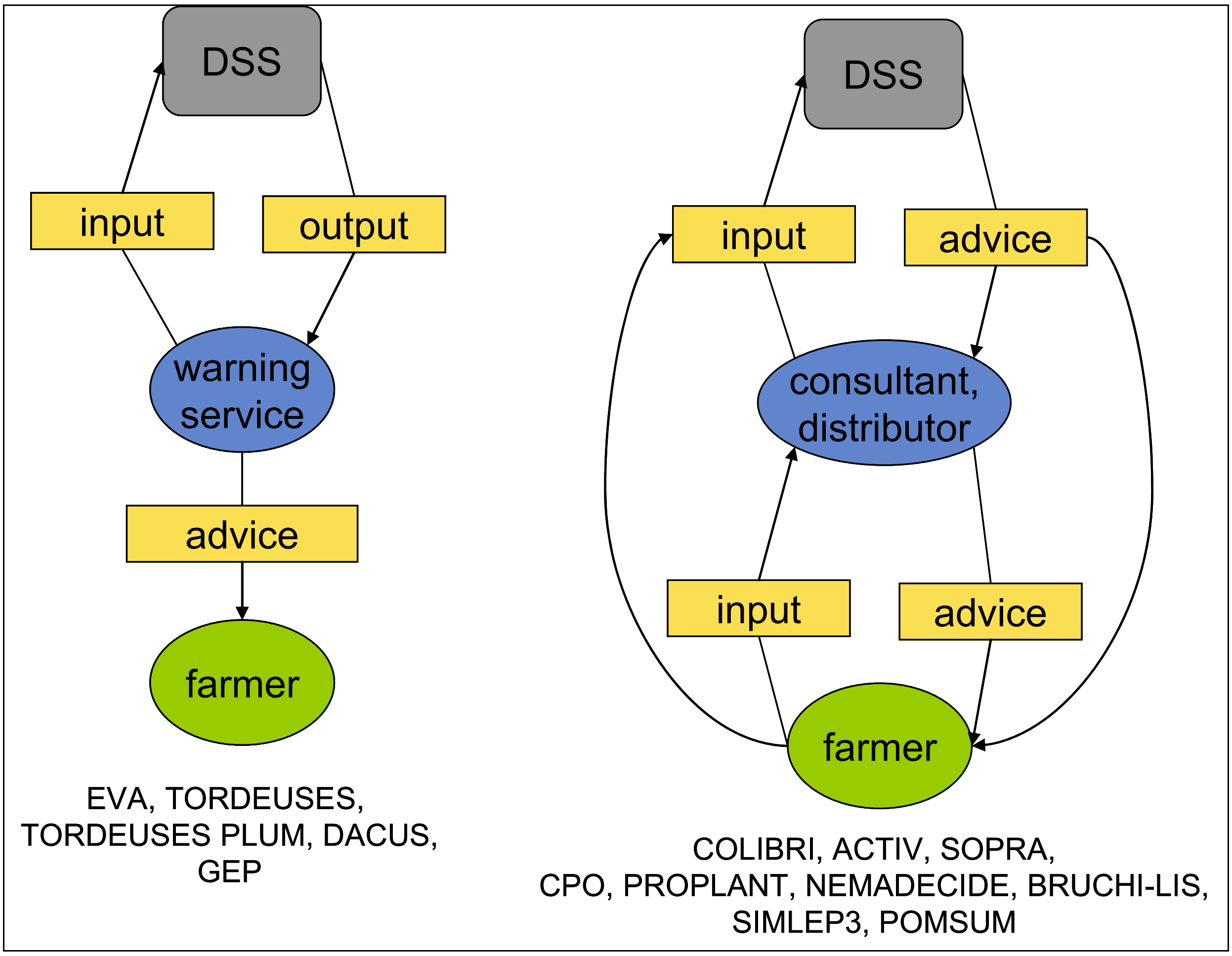

Figure 4.3-1
Illustration of the decision process in pest DSS's

In the first approach, the DSS produces predictions (population level across time or space) and these predictions are used by a warning service or advisors to deliver advices to the farmer. Predictions made by the model are only one element used in the process, and it has to be interpreted and modulated by the expert knowledge of advisors or technicians to produce the final advice (Jacquin et al. 2003).

In the second approach, the output of the model is directly an advice that may be delivered to the farmer, directly or via an intermediary (advisor or pesticide distributor). Most DSS's may be used indifferently by farmers or advisors. The use of some of them is restricted to pesticide distributors (Fr_Colibri, Fr_ActivLimaces).

Table 4.3-2
Main characteristics of the DSS's for pest control identified in the survey.

DSS / Question	Fr_Bruchilis	Sz_Sopra	Sp_GEP	Nl_NemaDecide	Ge_Proplant	Fr_Tordeuses	Fr_TordeusesPlum	Fr_Simbad	Fr_Dacus	Fr_EVA	Fr_Colibri	Fr_ActivLimaces	Da_CPODiseases	Ge_Pomsum	Ge_Simlep3
Short term decisions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Operated by the farmer	Yes	Yes	No	No	Yes	No	No	No	No	No	No	No	Yes	Yes	Yes
Suggestion of treatments options	Yes	Yes	No	No	Yes	No	No	No	No	No	No	Yes	Yes	No	No
Evaluation of environmental impact of different control options	No	Yes	No	No	No	No	No	No	No	No	No	No	Yes	No	No
Instructions relating to weather conditions	Yes	Yes	No	No	No	No	No	No	No	No	No	Yes	No	No	No
Instructions on follow-up	Yes	Yes	No	No	Yes	No	No	No	No	No	No	No	Yes	No	No
Long term decisions	No	No	No	Yes	No	No	No	No	No	No	No	No	No	No	No
Identification of pests	No	Yes	No	No	No	No	No	No	No	No	Yes	Yes	Yes	No	No
Use of economic thresholds	No	No	No	Yes	No	No	No	Yes	No	No	Yes	No	Yes	No	No
Instructions on treatment implementation	Yes	Yes	No	No	No	No	No	No	No	No	No	Yes	No	No	No
Implications for pesticide Resistance	No	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
Use of cost/benefit analyses	No	No	No	Yes	?	No	No	Yes	No	No	Yes	No	No	No	No
Monitoring of pests	No	Yes	Yes	Yes	No	No	No	Yes	No	No	Yes	Yes	Yes	Yes	Yes

e. Impact

e1. Potential

The main potential of all DSS's is the reduction of pesticide use and/or the better positioning of pesticides. This is achieved by supporting decisions on:

- to decide to spray or not
- to determine the adequate period for field sampling
- to choose a control measure adapted to the pest present (mating disruption, larvicide, ovicide, etc.).

Two DSS's (Sz_Sopra and Nl_NemaDecide) also promote the use of control methods alternative to pesticide use (mating disruption, varietal resistance and crop rotation). All DSS's that have been included in this survey aim for a reduction of the use of pesticides through avoiding of systematic scheduled control measures. This evolution is a key point of IPM, according the definition by IOBC, which contribute to an objective of reduction in the reliance on pesticides and reduction in associated environmental impacts. The second key point of IPM, i.e. the promotion of environmentally friendly control methods, is less addressed by existing pest DSS's.

Risks for crop safety have not been clearly identified for most of DSS's. However, some answers to the survey underlined the risks caused by the possible lack of representativeness of weather stations or by the existence of local environments with particular micro-climate conditions.

An overview of potentials and demonstrated impact is presented in Table 4.3-3.

e2. Validation / duration of use

Most of DSS's have already been validated, with multi-year and multi-local confrontation of predictions with observations. Some DSS's have been extended during more than ten years (Da_CPODiseases, Fr_ActivLimaces, Fr_Colibri, Fr_EVA, Fr_Tordeuses, Fr_TordeusesPlum, Fr_Dacus, and Sz_Sopra). Other ones are more recent, with less than five years of use (Fr_Bruchiis, Ge_Proplant French version, Nl_NemaDecide, Ge_Simlep3 and Sp_GEP). One is still a research tool which validation is under progress (Fr_Simbad).

Table 4.3-2
Synthesis of the pest DSS's features about the potential/demonstrated impact.

DSS / Question	Fr_Bruchiis	Sz_Sopra	Sp_GEP	Nl_NemaDecide	Ge_Proplant	Fr_Tordeuses	Fr_TordeusesPlum	Fr_Simbad	Fr_Dacus	Fr_EVA	Fr_Colibri	Fr_ActivLimaces	Da_CPODiseases	Ge_Pomsum	Ge_Simlep3
Potential for ↘ pesticide use and ↗ economic profit	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Promotion of environ. friendly control of pests	No	Yes	No	Yes	No	No	No	No	No	No	No	No	No	No	No
Risks identified (yield, economics)	No	No	No	No	?	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
Level of using by end-users	ND	++	++	ND	ND	?	?	ND	?	?	?	?	++	?	?

Notes:
?: no answer in the survey
ND: no available data or not relevant (experimental DSS)
++: large use (see details in text above)

e3. Take up

Some statistics are available regarding the number of end-users:

- Da_CPODiseases (and Da_CPOWeeds) is used by 3% of farmers and around 200 advisors
- Nl_NemaDecide (Netherlands) is used by seven large companies covering the majority of potato crops
- Sz_Sopra (Switzerland) is used by all advisors and around 2000 farmers
- Fr_EVA, Fr_Dacus, Fr_Tordeuses & Fr_TordeusesPlum (France) and Sp_GEP (Spain) have a large diffusion through warning services, although not quantified by the answers to the survey.

Some factors promoting take-up of DSS's and transfer to field have been identified:

- advertising in professional media

- training of advisors and farmers
- more stringent regulation about pesticide use

Some factors are also constraining take-up:

- the field inspections, when pest sampling is an input data of the DSS's,
- the cheapness of insecticides,
- the low number of weather stations in some regions.

f. Opportunities for integration

The integration with a farm management system is:

- already done for Da_CPODiseases, Ge_Pomsum and Ge_Simlep3
- underway for Nl_NemaDecide
- not made for the other DSS's, although considered as possible for some of them.

Integration with suppliers of 'meta-data' exists for:

- weather data,
- pesticide or cultivar databases from industry.

DSS links with other systems is presented in Table 4.3-3.

Table 4.3-3
Synthesis of the pest DSS's features about the links with other systems

Question / DSS	With farm management systems	With site specific management systems	With meta-data	Comments
Fr_Bruchilis	No	No	No	
Sz_Sopra	POSSIBLE	No	Yes (1)	(1) weather data, pesticide database
Sp_GEP	No	?	No	
Nl_NemaDecide	UNDERWAY	Yes (1)	Yes (2)	(1) geographic information on soil sampling (2) cultivar and pesticide databases
Ge_Proplant	?	?	?	
Fr_Tordeuses	No	No	Yes (1)	(1) weather data
Fr_TordeusesPlum	No	No	Yes (1)	(1) weather data
Fr_Simbad	No	No	No	
Fr_Dacus	No	No	Yes (1)	(1) weather data
Fr_EVA	No	No	Yes (1)	(1) weather data
Fr_Colibri	POSSIBLE	No	Yes (1)	(1) pesticide database
Fr_ActivLimaces	POSSIBLE	No	Yes (1)	(1) pesticide database
Da_CPODiseases	Yes	No	Yes (1)	(1) weather data, cultivar and pesticide databases
Ge_Pomsum	Yes	No	No	
Ge_Simlep3	Yes	No	No	

g. Procedures for updating

Some DSS's can be updated annually (Fr_Bruchiis, Nl_NemaDecide, Fr_Colibri, Fr_ActivLimaces, Da_CPODiseases, Ge_Pomsum, Ge_Simlep3). Lower number of the support systems must be updated weekly (Sp_GEP, Fr_Tordeuses, Fr_EVA, Fr_ActivLimaces). Few DSS's should be controlled daily (Ge_Proplant) or daily when needed (Da_CPODiseases). An overview is presented in Table 4.3-5.

Table 4.3-4
Synthesis of the pest DSS's about the procedures for updating

DSS / Question	Fr_Bruchiis	Sz_Sopra	Sp_GEP	Nl_NemaDecide	Ge_Proplant	Fr_Tordeuses	Fr_Simbad	Fr_EVA	Fr_Colibri	Fr_ActivLimaces	Da_CPODiseases	Ge_Pomsum	Ge_Simlep3	Fr_TordeusesPlum
Annually	Yes			Yes					Yes	Yes	Yes	Yes	Yes	
Weekly			Yes			Yes		Yes		Yes				
Daily					Yes						Yes			

h. Potentials, opportunities and restrictions for unification

Basic models of pests' development are suitable for a unified modelling platform in most of reviewed pest DSS's (Da_CPODiseases, Fr_EVA, Fr_Tordeuses, Nl_NemaDecide, Ge_Simlep3, and Ge_Pomsum). Local weather data is needed for all of them. A few systems offer potential for unification of different pests and crops into management of pests at a regional scale (Sz_Sopra, Sp_GEP and Fr_Simbad). There is no information on the potential impact for unification of Fr_ActivLimaces, Fr_Colibri, Ge_Proplant and Fr_Bruchiis systems. An overview is presented in Table 4.3-6.

Table 4.3-5
Synthesis of the pest DSS's features about the potential impact for unification

Question / DSS	Potential impact	Description
Da_CPODiseases	Yes	Based on initial models opportunity of unification crop and countries have been developed
Fr_ActivLimaces	No	
Fr_Colibri	No	
Fr_EVA	Yes	Only basic model is suitable for export; local climate data is needed
Fr_Simbad	Yes	Deals with some major pests of cotton crop in EU countries
Fr_Tordeuses	Yes	Only basic model is suitable for export; local weather data is needed
Ge_Proplant	No	
Nl_NemaDecide	Yes	Core models are independent, local climate data is needed
Sp_GEP	Yes	Potential for management of pests at region level
Sz_Sopra	Yes	Different pests and crops are unified in the system
Fr_Bruchiis	No	
Ge_Pomsum	Yes	Only basic model is suitable for export; local weather data is needed
Ge_Simlep3	Yes	Model is suitable for several EU countries, local weather data is needed

The survey of DSS's showed that Sp_GEP is presently the only system that could be integrated in a modelling platform without restriction. Availability of the others is conditioned:

- in relation to development of prototypes and implementation of the whole or parts in other countries: Da_CPODiseases
- in cooperation with the owner: Sz_Sopra,
- to discuss, depending on agreement with Agricultural Ministry: Fr_EVA, Fr_Tordeuses, Sp_GEP.

The status about the potential for unification is unknown so far for 7 DSS's: Fr_ActivLimaces, Fr_Colibri, Fr_Simbad, Ge_Proplant, Fr_Bruchiis, Ge_Pomsum, and Ge_Simlep3.

i. Feedback to research

In some of the DSS's, feedback to research has been demonstrated:

- Improvement of models and experimental methodology: Da_CPODiseases, Fr_ActivLimaces
- Modelling of population dynamics and pest distribution: Fr_ActivLimaces (slugs), Fr_Colibri (*Sitobion avenae*), Fr_EVA (Torticidae), Sp_GEP, Sz_Sopra, Fr_Bruchilis, Nl_NemaDecide (effect of few pathogens on yield losses)
- Modelling of new pests dynamics: Fr_Colibri (aphids in autumn), Sz_Sopra
- Modelling of crop phenology: Fr_Simbad, Fr_Bruchiis, Nl_NemaDecide
- Parameterization of existing models - testing new pesticide dose ranges: Fr_EVA, Fr_Tordeuses, Sz_Sopra, Nl_NemaDecide
- Validation of models, testing possibility for reducing pesticide input: Fr_EVA, Fr_Tordeuses, Ge_Pomsum, Ge_Simlep3
- Methods of validation: Fr_Simbad, Nl_NemaDecide.
- Development of an algorithm for the coupling of crop and insect models: Fr_Simbad

j. References

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4.4 DSS's for weeds

Analyses by Antonio Berti, Nicolas Munier-Jolain and Per Rydahl
Review by Volkmar Gutsche, Thomas Been and Neal Evans

Crops and DSS-acronyms covered by analyses in this section are presented in Annex C4. The analyses include 9 DSS's originating from 7 countries.

a. Decisions supported

The analysed DSS's have been released in a very long time span, ranging from 1992 (Sw_Dosekey) to 2007 (Fr_OptherbClim). During this period, the approach to the rationalisation of weed control has markedly changed. The older systems aim to optimise weed control evaluating whether a treatment is required or not and then which is the best treatment option, given a set of economic and cultural restraints (It_GesInf) and weather conditions (Sw_Dosekey).

Among the newer systems a first group appears to be characterised by a more holistic approach, aiming to optimise weed control considering aspects such as dosage (dose reduction, mainly), timing in relation to weather and soil conditions, optimisation of spraying machines. It is anyway worth noting that in these DSS's the need of a treatment is often defined on the base of expert knowledge/rules. A second group is designed to cope with a specific problem not considered by existing systems (ex. Fr_DecidHerb and herbicide resistance).

It seems that the focus has moved from the economics to environmental issues, even if an evaluation of potential pollution risks seems to be a common trait also for the older systems. All the systems use a short-term approach and 4 of them (Nl_MLHD, Da_CPOWeeds, Fr_Phytochoix, UK_WeedManager and Fr_DecidHerb) considers also long-term effects of weed control decisions on weed population dynamic.

While all the considered DSS's are able to identify the 'best' treatment option, differences arise in the type of factors considered: only UK_WeedManager and Nl_MLHD considers also sprayers, weather, follow-up of treatments, risk of resistances, potential environmental impact and an economic approach. Da_CPOWeeds is a complex system particularly devoted to dose/response evaluation and optimization of mixes (minimization of cost or TFI). Sw_Dosekey aims in particular to relate herbicide efficacy to weather conditions, Pl_IPMIDSS was built by several Polish Institutions in co-operation with the Danish Institute of Agricultural Science and is particularly devoted to wheat and potato protection, It_GesInf is a short-term bio economic model, Fr_Phytochoix is an expert system aiming to choose pesticides with an accurate information on the impact on the environment, Fr_OptherbClim considers mainly climatic conditions and Fr_DecidHerb is focused on weed resistance. All the DSS's can be run directly by final users and four of them allows a direct identification of weeds (Pl_IPMIDSS, Nl_MLHD, Da_CPOWeeds and UK_WeedManager), while the others requires a previous knowledge on weed recognition. Only 3 (Nl_MLHD, Da_CPOWeeds and UK_WeedManager) are also suited for weed monitoring.

b. Modelling approaches

Main characteristics of the DSS's for weed control identified in the survey are presented in Table 4.4.1.It_GesInf differs from most of the other considered DSS's, being basically a procedural system for bio-economic evaluation of the opportunity of weed control. This DSS then applies directly the economic threshold approach to weed control selection, while the other DSS's seems to be based on decision algorithms for the selection of the treatment. In most cases calculation models are used for subsequent decisions related to herbicide application (dosage, timing, efficacy in relation to weather conditions etc.). This again seems to indicate an evolution of DSS's from a 'spray or not to spray' approach to an optimisation of weed control depending on biological and environmental aspects.

Table 4.4.1
Main characteristics of the DSS's for weed control identified in the survey

Question \ DSS	Sw_DoseKey	It_GesInf	Pl_IPMIDSS	Nl_MLHD	Da_CPOWeeds	Fr_Phytochoix	UK_WeedManager	Fr_DecidHerb	Fr_OptherbClim
Short term decisions	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Operated by the farmer	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Suggestion of treatments options	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Evaluation of environmental impact of different control options	No	Yes 1)	No	Yes 2)	Yes 3)	Yes	Yes	Yes	No
Instructions relating to weather conditions	Yes	No	No	Yes	Yes	No	Yes	No	Yes
Instructions on follow-up	No	No	Yes	Yes	Yes	No	Yes	No	Yes
Long term decisions	No	No	No	Yes	Yes	No	Yes	Yes	No
Identification of pests	No	No	Yes	Yes	Yes	No	Yes	No	No
Use of economic thresholds	No	Yes	Yes	Yes	Yes	No	No 3)	No 4)	No 5)
Instructions on treatment implementation	No	No	No	Yes	No	Yes	Yes	Yes	No
Implications for pesticide resistance	No	No	Yes/No 6)	Yes	No	No	Yes 7)	Yes	No
Use of cost/benefit analyses	No	Yes	No	Yes	No (8)	No	Yes	No	No
Monitoring of pests	No	No	No	Yes	Yes	No	Yes	No	No
First publication	1992	1997	2002	2002	2003	2003	2003	2005	2007
References	Ref. 1, 2, 3	Ref. 4	Ref. 5	Ref. 6	Ref. 7, 8	Ref. 9	Ref. 10	Ref. 11	Ref. 5

Notes and references:

Notes
1) based on Ground Water Danger Index (GWDI), taking into account i.e. mobility and WMO guidelines for drinking waters
based on 'environmental points' (Dutch rating)
2) based on Treatment Frequency Index (TFI)
3) UK_WeedManager includes optimisation algorithms for the whole cropping system
4) threshold are considered not very effective for dealing with long term population management and herbicide resistance
5) Decision rules defined by experts and based on experimental data
6) Models are based on numerous field experiments taking account pesticide resistance
7) A resistance module generates a warning if a weed management strategy is likely to promote herbicide resistance
8) Only the cost of suggested treatments is presented

References
1) www.sjv.se/amnesomraden/vaxtmiljovatten/vaxtskydd/ograsjordbruk/ograsdatabasen.4.111089b102c4e186cc80003707.html
2) www.sjv.se/amnesomraden/vaxtmiljovatten/vaxtskydd/ograsjordbruk/dosnyckelhostsad.4.111089b102c4e186cc80003765.html
3) www.sjv.se/amnesomraden/vaxtmiljovatten/vaxtskydd/ograsjordbruk/dosnyckelvarsad.4.111089b102c4e186cc80003772.html
4) Berti & Zanin, 1997
5) Kapsa , 2008
6) Kempenaar & van den Boogaard, 2004
7) Rydahl, 2004
8) Rydahl, 2003
9) www.ensaia.inpl-nancy.fr/lae/Equipe/AgrDur/Francais/Recherche/Phytochoix/Texte integral.pdf
10) Collings et al., 2003
11) Munier-Jolain et al., 2005

It is worth noting that most of the newer DSS's consider many different factors for treatment selection. The final decision is then made through a multi-criteria approach, which can be more easily expressed through some decision rules instead of some mathematical function.

All the systems give a recommendation for the treatment, but only 4 of the 9 DSS's analysed use explicitly an economic threshold approach. Even if an economic evaluation is almost always present (at least in the formulation of selection criteria), the economic threshold concept seems to be declining, leaving space to a more complicated evaluation of economic risk, considering also the carry-over effects of the present year treatment decisions.

Considering main originality as perceived by data collectors, different features can be highlighted. Originality in Fr_DecidHerb is achieved by decisions based on multi-criteria analysis including risks for propagation of weeds in subsequent crops, efficacy and cost of treatments, environmental impact, risk of development of resistant weed biotypes and labour organisation on a farm scale (Mace et al., 2007). It_GesInf is the only DSS offering bio-economic evaluation of treatment options (Berti, 2008). Nl_MLHD is the only DSS offering an evaluation of the expected efficacy shortly after an herbicide application. This is valuable to support decisions on supplementary control measures (Kempenaar, 2008). Originality in Da_CPOWeeds are the integration of different criteria to quantify the need for weed control, the use o dose-response functions to quantify herbicide efficacy in different conditions, the optimization of compositions of 2-4 herbicides and the strategy to manage multiple herbicide treatments (Rydahl, 2004).

Fr_Phytochoix display information on the impact of pesticides on ground- and surface water, air and biodiversity (Bockstaller, 2008). Fr_OptherbClim support decisions for delay of herbicide treatments depending on climatic conditions (Bonin and Citron, 2008).

c. Communication with users

The DSS's differ for their programming structure and ways of distribution. The older systems are generally stand-alone programs, designed to run on single computers, while most of the newer DSS's are internet-based or, at least, easily upgradable through internet. The use of rapid and diffuse web connections seems to be a common trait of the more recent system, permitting an effective solution of the problem of maintaining up-to-date the DSS's, particularly for the databases on herbicide use and efficacy.

For all the DSS's considered, the developers refer to published results and/or on a description of the decision process, eventually with the explanation of the models used. This potentially permits to trace back the decisions to the original data, even if this should require a deep knowledge of the models used in the DSS.

Despite of this, for the final user most of the DSS acts as a 'black-box'. The user generally cannot interact with the algorithms used and with databases and he is not allowed to insert its own rules modifying the DSS behaviour depending on its own experience.

This behaviour can be considered a safe attitude for the consistency of the system, leaving to the user only the responsibility for its own field information, while decision rules and efficacy databases are controlled by the developers, aiming to guarantee up-to-date information on weed control options. It is worth noting that in some case, especially for herbicide performances, there should be also patent issues, thus requiring a particular care in the diffusion of information on herbicide characteristics and efficacy.

d. Demonstrated impact

A synthesis of the weed DSS's features about the potential/demonstrated impacts is presented in Table 4.4.2. All the nine DSS's surveyed consider the farmers are possible end-users, although most of them also consider a possible use by the advisors. Only one report (UK_WeedManager) cited the potential for the use of the DSS as a teaching tool for demonstrating the complexity of the management of weeds, the diversity of time scales to be considered and the interactions between the possible management options. However it is likely that this kind of use for education purpose might be an unexpected output of most DSS's primarily designed for field applications, even though the designers might not have this kind of use in mind when filling the survey questionnaires.

The number of actual users varies from one system to one another, with a strong relationship with the date of release: the youngest DSS's are still under test Fr_DecidHerb; Fr_OptHerbClim), while Da_CPOWeeds (first version released in 1991) counts approximately 1600 end-users in Denmark. Apparently, there is a large uncertainty regarding the actual level of use of DSS's in the decision making of end-users. Only the Danish system is able to quantify a number of more than 30.000 web logins over a 6-month period in year 2007. Six DSS have web-based interfaces, but there is no obvious relationship between the technology used for dissemination (either internet or CD-ROM) and the number of end-users or the frequency of use.

One distinctive feature of Da_CPOWeeds and Fr_DecidHerb is their generic nature, as they cover a large range of crops (respectively 30 and 12) while the other DSS's regard a more limited number of crops. Most systems cover a large number of weed species, making it possible to deal with most situations of crop infestations. UK_WeedManager includes a complex long-term demography model for weed populations, that needs to be parameterized, which can be the reason why the number of weed species considered remains lower than in the other systems.

Most DSS's surveyed pretend to have the potential for reducing the use of herbicide (thus being in line with the scope of the ENDURE Network of Excellence), and consequently of reducing the cost of herbicide applications. Two DSS's are not related with the reduction of herbicide use/cost : the first one, Fr_OptHerbClim, is designed to choose the best timing of application, while the other one, Fr_PhytoChoix, makes it possible to substitute one herbicide by one another according to their potential environmental impact. Only three DSS's explicitly take into account the differences in potential environmental impact among the different herbicides available for the farmer. Fr_Phytochoix and Fr_DecidHerb use the same complex indicator for environmental impact, while It_GesInf uses a simple risk indicator associated with the half-life and the mobility of the molecules in the soil, three other DSS's use the TFI for this purpose, but TFI provides an indication of the level of reliance on herbicides rather than the risk regarding transfers of residues in the different compartment of the environment and their impacts on non-target organisms.

The level of use of a DSS might be depending on the confidence of end-users regarding the recommendations that are provided. When assessed, the confidence of end-users seemed to be good. This might be a bias due to the fact that the designers of the DSS's were often involved in the filling of the survey reports. A questionnaire survey made with about 300 farmers subscribing Da_CPOWeeds, showed that farmers had great confidence in the robustness of recommendations coming from the DSS's, but that the DSS was not well adapted to farmers 'decision behaviours', as farmers have little interest in making field assessments and are generally confident by 'own experiences' or recommendations from advisors (Jorgensen et al., 2007).

Best practices for weed control are normally identified from rather comprehensive field tests. Consequently, farmers may expect similar validation of recommendations produced by DSS's. Most DSS's have been evaluated by analysing field consequences of recommended management options on short term bases (quality of weed control, economical return). Fr_DecidHerb is the noticeable exception that was not validated so far by comparisons of recommendations with standard practises. However, most DSS's have only sparsely been validated for long-term aspects.

Table 4.4.2
Synthesis of the weed DSS's features about the potential/demonstrated impacts

Question \ DSS	Sw_DoseKey	It_GestInf	Pl_IPMIDSS	Nl_MLHD	Da_CPOWeeds	Fr_Phytochoix	UK_WeedManager	Fr_DecidHerb	Fr_OptHerbClim
Date of release	1990	1997	2002	2002	1986-1995	2003	2003	2005	2007
Internet version	yes	no [1)]	yes	Yes	yes	no [1)]	no [1)]	yes	Yes
Number of crops	2	3	1	4	30	1 [2)]	1-11	12	3 [3)]
Number of weed species	≈ 100	≈ 20	20	- [4)]	105	all	12	250	All
Potentials for ↘ herb. Use	no	yes	yes	Yes	yes	no	yes	yes	No
Potentials for ↗ econ. Profit	no	yes	- [4)]	Yes	yes	no	yes	yes	No
Potentials for ↘ envt. Impacts	no	yes	- [4)]	↘ TFI	↘ TFI	yes	↘ TFI	yes	No
↗ Risks (yield, economics)	- [4)]	- [4)]	no	no	no	- [4)]	no	- [4)]	No
Number of end-users	110	≈ 10	- [4)]	250	1.600	> 200	- [4)]	** [5)]	** [5)]
Level of using	- [4)]	+/- [8)]	- [4)]	- [4)]	++/ ≈	- [4)]	- [4)]	na [7)]	na [7)]
End-users	a	A, b	a	a, b	a, b	a, b	a, b, c	a, b	a, b
Confidence of end-users with recommendations	++	- [4)]	- [4)]	- [4)]	+++	- [4)]	*** [6]	- [4)]	++
Short term Validations	- [4)]	yes	- [4)]	yes	yes	yes	ek [9)]	no	Yes
Long term validations	- [4)]	no	no	no	- [4)]	na [7)]	ek [9)]	no	na [7)]
Limitations	- [4)]	A			A, C	E	B, D	A, B	F
References	2), 3), 4)	5), 6)	7), 8), 9)	1a), 10)	1b), 11), 12), 13)	1c), 14), 15)	1d), 16)	1e), 17)	1f)

Notes and references

Notes	*References*
1) CDROM 2) Vineyards 3) Cereal crops 4) Unknown 5)The number of end-users is unknown so far because the system is currently under test 6) The system is not prescriptive, does not provide directly recommendations 7) not applicable 8) extensive use of advisors, little use of farmers 9) validation by expert knowledge a: farmers b: advisors c: teachers A: scouting weeds, identifying weeds B: lack of funding for maintenance C: Low incentive D: lack of marketing	1a) Been, 2008 1b) Rydahl, 2008 1c) Bockstaller, 2008 1d) Storkey, 2008. 1e) Munier-Jolain, 2008. 1f) Citron & Bonin, 2008 2) www.sjv.se/amnesomraden/vaxtmiljovatten/vaxtskydd/ograsjordbruk/ograsdatabasen.4.111089b102c4e186cc80003707.html 3) www.sjv.se/amnesomraden/vaxtmiljovatten/vaxtskydd/ograsjordbruk/dosnyckelhostsad.4.111089b102c4e186cc80003765.html 4) www.sjv.se/amnesomraden/vaxtmiljovatten/vaxtskydd/ograsjordbruk/dosnyckelvarsad.4.111089b102c4e186cc80003772.html 5) Berti & Zanin, 1997 6) Berti et al., 2003 7) www.ipm.pulawy.pl 8) www.ior.poznan.pl; www.dss.iung.pulawy.pl 9) Hansen et al., 2000. 10) Riethmuller, 2006. 11) Rydahl, 2004 12) Jørgensen et al., 2007a 13) Jørgensen et al, 2007b 14) Van der Werf & Zimmer, 1998 16) Collings et al., 2003 17) Munier-Jolain et al, 2005

For Da_CPOWeeds, however, level of residual weeds have been registered by routine in >1,500 field tests of different DSS-prototypes (Rydahl, 2004). For the presently distributed version, the Input of herbicides were reduced >40% in cereals. Prototypes that gave >10-15% total weed cover at harvest were discarded from the line of prototypes tested (Rydahl, 2008). The production of weed seeds from dosages of herbicides reduced to 1/8N was found to be insignificant in a weed seed bank perspective (Rasmussen, 1993a; Rasmussen, 1993b).

Until now, models that can predict future infestations of weeds are have not operational on a farm level. Consequently, farmers may be inclined to aim at a relatively high level of weed control every year, as this may be seen as a relatively cheap preparation for growing future crops where weed control is more costly or more difficult.

Among the number of reasons cited explaining a relatively low use of DSS's for weed management, two reasons are widely shared and often cited:

- the time necessary to scout for weeds, sometimes related with some problems for identifying weed species
- the lack of incentive for using the DSS's available

Apparently, the potential for saving the costs of some herbicide remains too low to drive the farmers to increase the use of these tools. Therefore farmers often prefer to go on relying on the advices of their advisor and/or on their own experience.

e. Opportunities for integration

A synthesis of the weed DSS's features about the links with other systems is presented in Table 4.4.3. The questionnaires of the DSS's survey included questions about the potential for integrating the systems into FMS's, Site Specific Management Systems (SSMS) or a system managing Meta-data.

The designers of the most recent systems generally express some interests for linking their system with a FMS. Only two systems are actually linked with a FMS, namely Da_CPOWeeds and UK_WeedManager. One important aspect of such integration is the facilitation of the data input related with the data storage of information about the field properties and its cropping history. All the DSS's that intend to make decision regarding the choice of herbicides must be related with databases including data on herbicide efficiency, costs, eventually environmental impact. Such database has to be regularly updated to allow sound recommendations.

In the same way, the systems that consider the climatic conditions for making recommendations have to be related with weather data and weather forecast. So far only two DSS's are formally linked with weather data management systems, namely UK_WeedManager and Fr_OptHerbClim, the latter being specifically dedicated to the optimization of the timing of herbicide application as a function of the weather.

Table 4.4.3
Synthesis of the weed DSS's features about the links with other systems

Question / DSS	With farm management systems	With site specific management systems	With meta-data	Others	Comments
Sw_DoseKey	No	No	no	no	
It_GestInf	No	No	no	no	No further development, lack of funding
Pl_IPMIDSS	No	No	yes, possible 1)	no	1) weather data, crop cultivars, pesticide
Nl_MLHD	yes, possible 1)	yes, possible 2)	yes, possible 3)	yes, possible 1)	1) CROP management system 2) maybe on-line sensing 3) weather data
Da_CPOWeeds	yes 1)	No	yes 2)	no	1) Danish farm management system 2) Database on herbicide label information
Fr_Phytochoix	No	No	no	no	already integrated in Fr_DecidHerb ?
UK_WeedManager	yes 1)	yes ?)	yes	no	1) Arable DSS
Fr_DecidHerb	yes, possible 1)	No	yes, possible 2)	no	1) farm management systems 2) GIS: risks for run-off and leaching
Fr_OptHerbClim	yes, possible	yes, possible	yes 1)	?	1) weather data

f. Procedures for updating

A synthesis on procedures for updating weed DSS's is presented in Table 4.4.4. One reason for choosing the web-based technology for the dissemination of DSS's is the easier updating of databases and models. Not surprisingly, the systems that are actually used by a number of end-users are those followed up with regular updating: Da_CPOWeeds, Nl_MLHD and Fr_PhytoChoix. The cost of maintenance of the system and the databases are cited as limits for further development and use.

Table 4.4.4
Procedures for updating weed DSS's

Question / DSS	Distribution	Cost	Comments	References
Sw_DoseKey	Web	free	No updating	2), 3)
It_GestInf	CD-rom	free	No updating (no funding)	1)
Pl_IPMIDSS	Web	?	Annual updating	b), 4)
Nl_MLHD	Web	10 - 100 €	Annual updating (program) Monthly updating (database) Nl_MLHD sensor : 1500 – 3000 €	1c)
Da_CPOWeeds	Web	100 - 150 €	2-4 annual updating	1d), 5)
Fr_Phytochoix	CD-rom	140 €	Annual updating	1e)
UK_WeedManager	CD-rom	?	Daily weather data	1f)
Fr_DecidHerb	Web	Not defined yet	Currently no updating	1g)
Fr_OptHerbClim	Web	Not defined yet	Annual updating of herbicide database	1h)

References:
1a) Berti (2008)
1b) Kapsa (2008)
1c) Been (2008)
1d) Rydahl (2008)
1f) Storkey (2008)
1g) Munier-Jolain (2008)
1h) Citron & Bonin (2008)

2) http://www.sjv.se/amnesomraden/vaxtmiljovatten/vaxtskydd/ograsjordbruk/ograsdatabasen.4.111089b102c4e186cc80003707.html
3) http://www.sjv.se/amnesomraden/vaxtmiljovatten/vaxtskydd/ograsjordbruk/dosnyckelhostsad.4.111089b102c4e186cc80003765.html
4) www.ipm.pulawy.pl
5) Rydahl P (2004). A Danish decision support system for integrated management of weeds. Aspects of Applied Biology 72, 2004, 43-53

g. Potentials, opportunities and restrictions for unification

Potentials, opportunities and restrictions regarding unification are presented in Table 4.4.5. Five of the nine DSS's on weeds have investigated opportunities for unification across country border lines and different climatic regions.

Nl_MLHD is expected to work well in different geographical regions, e.g. China and Canada.(Kempenaar 2008). The multi-criteria decision process in Fr_DecidHerb is expected to be adaptable also in other countries, but a major shortcoming is local availability of data, which must be inserted for use in different countries (Mace et al., 2007).This DSS is owned by INRA and the French Extension Service (Munier-Jolain 2008). Fr_Phytochoix is expected to be suitable for adaptation in additional crops (Bockstaller 2008). It has been estimated that Fr_OptHerbClim could be relevant to all regions of EU (Bonin and Citron 2008). The bio-economic model that drives It_GestInf will require local calibration in order to adapt to conditions elsewhere (Berti, 2008).

Actually, the Polish Pl_IPMIDSS is functionally and structurally identical with Da_CPOWeeds and Da_CPODiseases, but parameterisation and user-interfaces have been customized for differing conditions in the two countries (Domaradzki et al., 2003). This approach has also been used for implementation of Da_CPOWeeds in Estonia (Talgre et al., 2008), in Latvia (Kopmanis, 2005), in Lithuania (Auskalnis, 2003) and in Norway (Netland et al., 2005). In all these countries validation tests demonstrated that robust recommendations for weed management were produced, but potentials for reducing herbicide input varied between countries. A common and major shortcoming was availability of local data on herbicide efficacy. Da_CPOWeeds is owned by Aarhus University and Danish Agricultural Advisory Service.

A common shortcoming for unification of different DSS's on weeds is the availability of data that quantify the efficacy of herbicides in different dose rates on different weed species and different, supplementing conditions.

Table 4.4.5
Potentials, opportunities and restrictions regarding unification

Question / DSS	Unification			Restric-tions	Feedback to research	Origi-nality	Reference
	Oppor-tunity	Poten-Tial	Short-comings	owner/ access			
Da_CPOWeeds	Yes	Yes	Yes	Yes	Yes	Yes	(Czembor et al. 2003; Auskalnis 2003; Domaradzki et al. 2003; Rydahl 2004; Kopmanis 2005; Netland et al. 2005; Talgre et al. 2008; Rydahl 2008)
Fr_DecidHerb	No	Yes	Yes	Yes	Yes	No	(Mace et al. 2007; Munier-Jolain 2008)
Fr_OptherbClim	Yes	Yes	?	?	Yes	Yes	(Bonin and Citron 2008)
Fr_Phytochoix	Yes	?	?	No	No	Yes	(Bockstaller 2008)
It_GesInf	?	No	?	Yes	Yes	Yes	(Berti 2008)
Nl_MLHD	Yes	Yes	?	No	Yes	Yes	(Kempenaar 2008)
Pl_IPMIDSS	Yes	Yes	Yes	?	Yes	?	(Kapsa 2008)
Sw_DoseKey	No	No	?	No	Yes	?	(Jahr 2008)
UK_WeedManager	?	?	?	?	Yes	No	(Storkey 2008)

h. Feedback to research

Feedback to research has been observed for different DSS's. Da_CPOWeeds require data that support estimation of parameters for dose-response functions on single herbicide products for single herbicide applications against single weed species. Consequently, data from traditional field tests of 'best practices' (spraying programmes) of herbicides, are mainly useless. Da_CPOWeeds has also identified weak parts in decision algorithms and calculation models that may benefit from additional research. Specific requirements for methodology have been identified for efficacy tests of new herbicides (Rydahl, 2008).

In future, Nl_MLHD is expected to be able to include also herbicides, which are not photosynthesis inhibitors (Kempenaar, 2008).Fr_DecidHerb has inspired for development of new models which can predict weed infestations based on weed observations in previous crop and crop management options (Munier-Jolain 2008). Fr_OptHerbClim has demonstrated that specific pesticide products need specific parameters and specific models, too (Bonin and Citron, 2008). It_GestInf could be integrated with a module for the time evolution of weed competition in order to identify optimum treatment periods (Berti, 2008). UK_WeedManager has identified potentials to develop also biodiversity model and –applications. Much experimental work is required to integrate more weeds and more crops (Storkey, 2008).

i. Discussion

Nine reports on DSS's dealing with weed management, coming from 7 countries, were analyzed. Those systems were released from 1986 to 2007 and were therefore very heterogeneous in term of complexity, maturity and dissemination to end-users. Crops and DSS-acronyms covered by these analyses are presented in Annex C4.

The DSS's analysed reflects the development that take place in the last decades in the way weed control is approached. The older systems aim to identify a specific 'best' solution depending on the observed weed flora. Differences arise in the way the weed control option is indentified. Sw_Dosekey is based on expert rules, while It_GestInf is based on a direct application of competitive relationships between crop and weeds.

Newer DSS's, on the other hand, aims to tailor the 'best' solution to the specific agro-ecological conditions of the considered field. The identification of the weed control solution to be optimised is in most cases performed through a set of expert rules. A possible limit of this approach is that the DSS is forced to reflect the expert's ideas, limiting the possible solutions to those already previewed by the developers. However, in a world which seem imperfect in terms of objectively based knowledge and where ambitions exist to construct DSS's, which are widely applicable on a farm level (including many combinations of crop, weed species, herbicides and other 'conditions') this may be an approach, which may prove productive in a short term to meet certain objectives. Also more objective approaches will contain some elements of subjectivity, e.g. selected confidence levels for a specific context, methods of model parameterizations.

A system based on some kind of calculations driven by observations on weed presence in the specific field should present the theoretical advantage to consider always all the possible solutions (and, possibly, combination of treatments), identifying a solution that has not to be previewed in advance. A substantial practical advantage should also exist, because control measures which are differentiated on a field level should offer potentials to reduce herbicide input as compared to routine applications. For example, weed infestations (species and densities) vary much between fields, and some herbicides control some weeds by just 5-10% of the herbicide dose-rate that is printed on the label.

Nevertheless, this kind of systems had a very limited application, at least in Europe, because of their main drawback: the need of a precise and time-consuming assessment of weed presence. Even if this can be in some instances economically feasible, application of decision-support software for post-emergence weed control is viewed by farmers as difficult and too time-requiring (Berti et al., 2003).

The newer DSS's overcome this problem focusing their attention on the optimisation of weed control application, trying to reduce the use of herbicides through the optimisation of the dose applied and/or through a patch spraying approach. This approach has proven to be far more acceptable for farmers, reducing at a minimum the time required for a proper selection of weed control.

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5 Identification of 'best parts'

In the process of collecting answers to the questions specified in the data collection form (section 3.1), often persons, who had been personally involved in construction of various DSS's was contacted. By nature, such persons may be biased in terms of evaluating various criteria relating to identify best parts for possible unification on a European level.

A pan-European workshop was therefore convened 17th – 19th March 2007 in Denmark to identify 'best parts'. Representatives of all the DSS's, on which data-forms had been received, were invited to give a short presentation of their respective DSS's, intending to identify 'best parts' with respect to possible potentials of reducing dependency and/or use of pesticides.

5.1 Programme, participants and presentations in pan-European workshop

The data forms used to collect information on specific DSS's also provided information on persons, who were capable and willing to present the agronomic and scientific content of the DSS's. About 50 different DSS's were identified to possibly be presented on a pan-European workshop, which were venued by Aarhus University, Faculty of Agricultural Sciences, Dept. of Integrated Pest Management, which is located in a village named Flakkebjerg, about 100 km south-west of Copenhagen in Denmark.

INRA Transfert delivered a web-service, which was successfully used to administer registrations for the workshop. The final programme including links to presentations on the ENDURE Workspace and the list of participants have been included in Annex D.

5.2 Perspectives of needs from end-users

In ENDURE activity no. SA4, which aim for constitution of a European Information/-Competence Centre (EIC), a survey was made in the spring of 2007 to identify possible needs from end user with respect to decision support relating to crop protection in a broad sense. This survey was conducted in France, The Netherlands, Germany, United Kingdom and Denmark, obviously with a possible western European bias. The following groups of main end-users/stake-holders for DSS's on crop protection were identified:

- scientists
- advisors
- farmers
- input suppliers
- interest groups
- traders/producers

Interviews of 45-60 minutes of duration were conducted with 66 respondents. The respondents were asked to rank most important aspects of 'sustainable crop protection' on a 0-5 scale, where 'early warning systems' and DSS's were ranked around 4, and DSS's were in particular highly ranked as 'most valuable tactical knowledge' and 'most valuable strategic information'. In specific crops, however, different aspects were generally higher ranked, e.g. 'pesticides resistance prevention' in wheat.

Important challenges exist, however, if development and implementation of DSS's shall be successful. First of all, in order to inspire for implementation of a DSS, the DSS must include and offer some advantages (potential) as compared to existing best practises, e.g. better control, lower cost, lower environmental impact, etc. At the same time, recommendations from a DSS must be reliable (robust), probably even more reliable than human advisors. Several examples show, that obviously false recommendations from a DSS lead to a total rejection of further recommendations of such DSS.

Furthermore, the implementation of a DSS may require adjustment of certain farm practices, which require also integration with different operations on farm- and field levels, e.g. consultation of computer, use of specific field inspections, etc. So far, potentials of DSS's have been relatively sparse in term of economic revenues, why 'business as usual' is still perceived by many farmers as optimal strategies. Consequently, needs and perceptions by main groups of end-users should be taken into account in all phases of development and implementation of DSS's. In such considerations and procedures, however, it should be considered that DSS's may support some stakeholders and compete with services from other stakeholders.

5.3 Group work to identify 'best parts'

After the presentations of different DSS's, group work was made to identify 'best parts' of the presented DSS's in the context of reducing dependency and/or use of pesticides, which is among the listed objectives within the ENDURE network. Group work was conducted in 5 separate DSS groups:

- potato late blight
- diseases in arable crops
- diseases in horticultural- and fruit crops
- pests
- weeds

A brief report was made to the plenum by a representative from each group, and the following discussions was accumulated in a list of 'concluding remarks', which were subsequently consolidated by the ENDURE IA2.4 work group, and which have been included in Annex D3.

5.3.1 General considerations

Criteria to constitute a 'best part' for unification on a European level have not been specified. According to the overall objectives of the ENDURE Network, 'best parts' should contribute to developments that can possibly 'reduce dependency and/or use of pesticides' in Europe within the time-span of the ENDURE network, i.e. within additionally 2 years.

A more idealistic working process to construct and implement DSS's for crop protection has however been suggested (Levay, 2008):

- Identify the problems / objectives. The following objectives could be relevant:
    - reduce dependency / use of pesticides
    - justify use of pesticides xxx
    - improve productivity for farmers:
        - increase quantity / quality of yield
        - save costs
        - reduce 'environmental load'

- Identify requirements for a DSS. A developed DSS should ensure that:

  - management of weeds, pests and diseases:
    - are performed in a way, where the level of robustness (reliability) reflects the risk of reducing the value of the crop. Robustness should be demonstrated in validation trials for complete models and / or sub-models
    - holds some potential for reducing dependency / use of pesticides (impact) as compared to 'benchmark' practices
  - pesticides are applied in the best possible time, place and dose rates
  - system integrity is maintained by:
    - current updating
    - clear allocation of responsibilities
  - farmers and advisors are involved to consider:
    - objectives, complexity, terminology, etc. in the construction phase
    - possible integration with existing working procedures and tools on a farm level
    - training programmes

- Construction of DSS prototypes:
  - as many decisions as possible should be integrated for a selected crop / pest system
  - test for robustness and potential
  - when some robust and potent models / structures / systems have been identified, integration with adjacent systems could be considered, e.g. farm management systems, systems for precision agriculture, etc.

The major target groups will be farmers and advisors. Tools that support tactical decisions on a field level will have farmers as a major target group. Tools that support decisions on general / regional levels should include advisors as a major target group. DSS's could also play a role in formal justification and/or documentation of pesticide applications.

5.3.2 Best parts of DSS's for diseases in horticultural crops

As it has been mentioned in the beginning of this chapter, the studied decision support systems vary greatly from certain aspects, whereas they all show some common tendencies in terms of their evolution. According to this logic first those characteristics are pointed out, which are far the most common, thus well-tested by practice.

Aspects that is common in most of the evaluated DSS's:

- *Modelling approaches*
  In terms of disease models there is little space for big changes in modelling approaches. Science has gathered much knowledge on the development of crop diseases; scientifically robust data is available in international journals. However, it should be remembered that DSS's are operated in a dynamic socio-economic and biological context. Thus, it is essential to adjust models continuously; model parameters must be dynamically modified, fine-tuned and validated due to always changing environmental conditions.

- *Supported tactical decisions*
  Identifying 'high risk' periods and providing information on the need for treatment is proved to be a good way to follow in future research and development. At a European scale this might be the maximum objective, in fact. Conditions are so diverse in different countries across Europe, which makes questionable to manage going more deeply into details within

one complex pan-European DSS platform (i.e. no recommendation on treatment options). This type of potential common modelling platform is called the 'core engine' by the participants of this expert group.

- *Enhanced role of advisors as end-users*
  it became clear that advisors play a key role in communication with farmers. Thus, special attention should be turned on the information needs of advisors. It must be also considered whether the DSS's should focus at region or field level, which is in accordance to the identification of end-user (i.e. advisors/farmers/both?)

- *Information loop among stakeholders*
  Once a DSS is used in practice, most cases active feedback from farmers through advisors towards research is going on. This is a good practice, which should be raised at the European level. Nevertheless, the way of communication is a challenge, since the smaller a community is, the bigger role personal contacts play in the information loop.

- Aspects that is specific in some DSS's and has the potential as 'best part':

- *Compatibility with different data sources*
  Models should be developed considering the newest achievements in information technology, such as weather data exchange languages, meteorological data servers, European chemical databases, and possibly biodiversity databases for environmental impact assessment modules
  .
  - In terms of weather data input, there exists an interesting phenomenon which may concern model developers - the increasing number of meteorological data provider virtual communities. These are private people with own weather equipment, who are organized into a virtual community, providing meteorological data on a volunteer basis. Since the question of weather data ownership is a challenge, this source of information might be considered as a fragment of a complex European data flow.

- *Considering problems of implementation*
  This is certainly an issue in future developments; however it is linked to detailed recommendations on treatment options. As it was above mentioned, at a European scale it makes not too much sense to create a 'common European tool', which aims to give detailed recommendation for the end-user on treatment options, thus, implementation problems might be rather guidelines in our 'core engine' modelling platform. Nevertheless, implementation techniques could be addressed in future DSS developments.

- *Monitoring schemes*
  Providing support for monitoring in the form of guidelines linked to the model output, e.g. when, where and how to conduct monitoring and what do results tell us.

- *Pathogen/disease identification*
  Providing support for pathogen identification by description life cycle of the pathogen and showing pictures on the symptoms.

- *Considering strategic aspects*
  Resistance management in the sense of more diverse use of pesticides, considering environmental side-effects and presenting this information to the end-user in the decision making process (many cases this information is stuck at researchers, never reaching stakeholders in their everyday decision making procedures, neither farmers, nor

policy-makers)

- *Cost-benefit analysis*
  This is a tool mostly linked to commercial DSS suppliers, who integrate this service into a complex farm management system. It is unlikely that a potential European modelling platform could set the goal to offer such a module. Putting the DSS output into an economic context should stay the responsibility of personal interpretation, most often by a skilled advisor.

- *DSS Impact assessment*
  Accurate survey about the impact of DSS's on pesticide applications should be more intensively conducted. Such data collection could inform us whether we follow a good direction in reducing pesticide use or not, in fact, this could be a kind of feedback on how effectively our money was spent on research. On the contrary, we always have to manage certain level of uncertainty in terms of interpretation of such impact assessments.

5.3.3 Best parts of DSS's for diseases in arable crops

Identification of "best parts' has been made separately in different crop x pest groups.

a. Blight sub-group

- Commonality among Simphyt- and "NegFry'-based models (i.e. Da_BlightMan) mean that adaptations to different geographical regions and countries are often possible with only minor modification of systems.

b. Cereal sub-group

- Lots of "single disease' generic systems, which could probably be combined to provide information on more than one disease (utilising generic metadata i.e. weather data).
- Danish system (Da_CPODiseases) well defined and already used in other Baltic countries with good success. Could be amenable to further development throughout northern Europe.

c. Non-cereal/potato sub-group

- Potential to capitalise on in-field monitoring techniques, either to new geographic areas and/or to incorporate monitoring output as input parameters to "fine tune' computer model-based DSS's, particularly if utilisation of recently developed molecular genetic tools reduces costs.
- Potential to integrate proven specific oilseed rape disease models into a combined OSR disease DSS, again utilising generic metadata (i.e. weather data)
- Integrated beet disease systems being further refined.

d. Multi-system sub-group

- An integrated multi-model DSS in Poland shows the potential to integrate systems (developed under Danish conditions) for other countries. This approach could be taken more widely.
- Commercial systems such as NI_PlantPLus demonstrate proven track record on a global scale, but integration with and/or from such systems would probably be limited by IP/commercial concerns.

5.3.4 Best parts of DSS's for pests

The major challenges for development of future DSS's are to develop structures at the European level for:

- construction and updating of DSS's
- communication languages
- exchange of biological data
- exchange of weather data

Several existing DSS's have been identified, which have been developed in different countries / institutions, and which cover different crop / pest systems.

5.3.5 Best parts of DSS's for weeds

'Best parts' were identified in terms of 'building blocks', which are characterized by some kind of demarcations, e.g. in terms of crop x pest systems, modelling approaches, IT-structures, etc. Building blocks may be perceived as components, which may have some value/potential in themselves or as possible components for construction of DSS's that integrate 'best parts' from different DSS's.

The following 'best parts'/''building blocks' were identified:

- Decisions on activities and timing on a farm level: Da_CPOWeeds: UK_WeedManager: Fr_DecidHerb
- Decisions whether control needed:
    - Weed density equivalents: It_GestInf
    - Weed dynamics in crop rotations: UK_VM
    - Integration of crop yield, weed seed production and cosmetic considerations: Da_CPOWeeds
- Decision on herbicide and dose selection:
    - Cross tables: Nl_MLHD
    - Dose/response functions and optimization of herbicide mixes for cost or for TFI: Da_CPOWeeds
    - Site-specific evaluations: Nl_MLHD
- Environmental impact:
    - Risk factors, multi criteria assessment: Fr_DecidHerb
    - Leaching risk: It_GestInf
    - Treatment Frequency Index (TFI): Da_CPOWeeds
- Climatic conditions:
    - Long term conditions: Fr_DecidHerb
    - Short term conditions: Da_CPOWeeds, Fr_OptHerbClim

6 Conclusions

All authors of this report are also involved in national programmes for DSS development. In order to avoid subjective bias in the analyses of 'best parts' for unification on a European level, decisions on how to conduct the survey and how to analyse collected data, the practical work of analyses and quality audits of analyses were made jointly and transparently by the work group, which are also authors of this report.

Analyses of 65 data-forms on DSS's for crop protection, which were collected from 20 of the 28 countries that were included in the survey in the autumn of 2007 and in the spring of 2008, show a great variety of crop x pest systems covered, decisions that are supported, modelling approaches, stages of developments, means of distribution, level of uptake, potentials for reducing use and/or dependency of pesticides, etc.

Considering the resources available in the remaining period of ENDURE framework for construction and validation of operational DSS's that are expected to have some potential for contributing to reductions in the use and/or dependency on pesticides, only a few DSS x crop x pest systems can be selected for initial unification on a European level, including construction of operational DSS prototypes and validation of the recommendations produced by these. Construction and validation of DSS's that cover dominating weeds, pests and diseases in all important crops in Europe will take at least decades, why activities in this domain within the ENDURE network may be perceived mainly as inspiration for future and more comprehensive activities.

For the remaining time span of the ENDURE network, the following crop x pest systems and main activities are suggested for construction and/or validation of operational DSS prototypes:

- *diseases in potato*
  A concept for a unified and operational DSS prototype should be developed, and different DSS concepts should be analysed and tested for identification of high and low risk situations of disease attack, critical weather periods, fungicide degradation etc. and for recommendations of first spray, intervals to subsequent applications, doses, etc. Relevant sub-models should be validated with connected datasets on weather, levels of diseases attack and yield

- *diseases in wheat*
  Existing DSS's will be compared and validated. The 'best parts' will be compared and where possible combined or integrated to provide a level of integration

- *diseases in vine*
  2-4 existing DSS's should be selected and validated by use of weather data. By comparing the DSS's using a test dataset, the optimal level of unification of existing DSS's should be defined with careful consideration of legal, biological and technical limitations

- *codling moth in pome fruit*
  Several models should be compared and best parts should be identified in order to produce a common model, which should be validated against field data from different geographical regions using data on egg laying, larval hatching and adult flight

- *weeds in maize*
  Activities should concentrate on construction and test of a variety of DSS prototypes that possibly integrate: yield loss functions, dose-response functions, dose-optimization functions and multi-criteria assessments of alternative herbicide applications

Representatives of farmers and advisors should be invited to evaluate all stages of the processes of construction and validation of DSS's. In case some initial success in terms of demonstrating suitable balances between agronomic robustness, economic- and/or environmental potentials, various constraints and requirements from end-users, such DSS's should be subjected to further developments. A step-wise and iterative approach in the processes of construction and validation of DSS's, which use the above listed requirements, as feed-back to various steps in the process of construction, is recommended.

Promising DSS's may contribute also to pinpoint new research activities on interactions between crops, pests, pesticides and conditions. A major benefit in terms of operationalizing such new results is that they may also fill in gaps and weak points of a DSS. In this way results from research may effectively be disseminated to farmers and advisors, and implemented in practice on farm and field levels.

At the same time, promising DSS's may contribute points of reference for the crop x pest systems, which are covered by the DSS's. Points of reference may be established for decisions relating to separate parts of the decisions that needs to be considered in a crop x pest system or to more holistic decisions. The official version of a DSS may constitute present point of reference that may integrate relevant results from research supplemented by 'best guesses' from experts to fill in gaps within the conceptual framework of a DSS. Simultaneously, ideas for additional improvements and refinements of various DSS's could be prototyped.

An interesting question is how the interpretation of 'uncertainty' relating to various components of a DSS, e.g. variability in various data, known imperfections in calculation models, known weaknesses in expert-algorithms, etc. should be distributed between the constructors of the DSS's and the users of the DSS's. As the domain of crop protection is presently dominated by relatively cheap and relatively robust and more or less standardised programmes for pesticide applications, which in addition are also well incorporated in existing practices on a farm level, sustainable development and implementation of DSS's imply that the recommendations from a DSS must first of all be as robust as existing alternatives. If farmers expect (justified or not) an increased risk in connection to the implementation of a DSS, implementation may be very difficult. Consequently, recommendations from DSS's should be carefully and soundly validated. Secondly, implementation of a DSS must be easily adaptable to existing farm practices. Claimed potentials of DSS's, e.g. in terms of 'reducing use and/or dependency of pesticides', which is a general objective of the ENDURE network, should not compromise on these requirements.

As weeds, pests and diseases are rarely evenly distributed in a field potentials for reducing use of pesticides are expected to increase with an increased spatial resolution in the identification of details relating to attacks and in application of pesticides. To illustrate potentials for herbicide applications, efficient weed control of 100 weed seedlings per square meter have been obtained by placing single droplets of glyphosate on single weed plants in dose-rates around 1 g/ha. As the registered dose rate for this task in Denmark is 720 g/ha, this approach result in just 1/720*100%=0,1% of the registered dose for broad-spraying of glyphosate for this task in Denmark (Graglia, 2004 [in section 4.4]). Such approach may be perceived as ultimate resolution of site-specific application of herbicides, but significant potentials for reducing herbicide input also exist in spatial resolutions with larger grid-sizes. DSS's may be valuable to support decision algorithms also in various site-specific approaches to robust management of weeds, pests and diseases.

All in all, DSS's offer great potentials for contributing to 'reductions of the use and/or dependency of pesticides' in many European crop x pest systems. These potentials come about by following an overall principle of applying pesticides only when needed and just as much as required according to existing knowledge and local 'conditions' in a practicable spatial resolution. Due to the relatively immature stage of developments in this domain, however, only relatively small steps of progress may be demonstrated within the remaining resources of the ENDURE Network.

7 Annex

Annex A
Log on working process

The following activities have been conducted in ENDURE, activity no. IA24 on DSS's for crop protection:

Date	Activities and major outputs
Feb 07	Kick-off meeting in Antibes Minutes by Per Rydahl, AU - persons who shall work in IA24, were searched and identified.
Apr 07	Meeting in Paris in IA2 (The Virtual Lab) as a whole. Minutes by Ian Denholm, RRES - steering committee was constituted - tasks for the survey on DSS's for crop protection were identified.
Jun 07	Meeting in Wageningen Minutes by Per Rydahl, AU - questions to be included in the survey were identified. - tasks were allocated to participants
17th Sep 07	Official deadline for submission of filled in Part B and Part C data forms.
8th Oct 07	1st version of this status document was uploaded to Workspace Reports from Bulgaria, Czech Republic, Denmark, France, Netherlands, Hungary, Italy, Spain, Slovakia, Sweden, Switzerland were uploaded to Workspace. Some data collectors were permitted to submit reports until the further processing of the reports should be initiated.
15th Oct 07	2nd version of this document was uploaded to Workspace. Additional reports from Spain and France were uploaded to Workspace.
15th Nov 07	Meeting in Versailles Minutes by Per Rydahl, AU: - status of survey was provided - methodology to process data from survey was identified - agenda, dates and facilitation of pan-European workshop were identified - activities to suggest for JPA in M13-30 were identified
19h Dec 07	3rd version of this document was uploaded to Workspace. Additional reports from Ireland, UK, Germany, Estonia, Latvia, Lithuania and Poland were uploaded to ENDURE Workspace.
17-19 Mar 08	Pan-European workshop - 49 DSS's were presented - best parts identified within major crop/pest groups - Overlooked DSS's were identified, period for collection of data prolonged until 1st August 2008. Delivery of report with analyses of DSS postponed from M18 until M23

1 Aug 08	Additional 11 reports received from Germany.

16 Oct 08	Workshop in La Grande Motte:
	
	- draft for writing of analyses section for joint report was presented
	- agreement were made on:
	  - structuring of writing
	  - use of references
	  - use of annexes

29th Nov 08	After several reminders and several delays it was realized that writing of report could not be finished in 2008 due to lack of working capacity for some partners.
9th Feb 09	Draft for full report delivered for final review by the participants of ENDURE IA2.4.
6th Mar 09	Final report sent to ENDURE review group

Annex B
Form for collection of data on a DSS

Part B:
Form for collection of data on DSS's for crop protection in EU-countries and Switzerland

Identification of a DSS and the a data collector

Characteristics for identification of a DSS (Separate forms must be used for separate DSS's. Separate forms can also be used for different modules of a DSS)	(Write)
Name (If no official name exist of the DSS, please define an acronym for this survey)	
Country of origin	
Status on ownership (Institution names, address, contact persons)	
Key persons involved (Contact persons and key roles)	
Who can present this DSS on a pan-European workshop in Denmark in February/March 2008? (State name and address on person who can do that. However, this is not a final agreement to do so. Please note that costs for travel and accommodation will be covered only for ENDURE-members)	
Identification of data collector (Title, full name, employer and e-mail address of person conducting the collection of data in this form)	

Documentation

Sources of documentation for this survey (Research papers, conference papers, popular articles, personal communication, etc.)	**Ref. no.**

Existence of basic attributes required, to constitute a DSS that is relevant for this survey

Attributes (For each question at least one 'yes' must be stated. Otherwise the DSS is not relevant for the survey)	**Yes** (Write)	**Comments** (Write)	**Ref. no.**
1. Evaluation of economic thresholds and/or recommendations of options for treatment	_____ Yes, use of economic thresholds _____ Yes, recommendation of options for treatment		
2. Integration of various sources of information (Some 'added value' as compared to label- and standard recommendation must be demonstrated, please comment)	_____ Yes		
3. Use of decision algorithms and/or calculation models. (Some 'added value' as compared to label- and standard recommendation must be demonstrated, please comment)	_____ Yes, decision algorithms _____ Yes, calculation models		
4. Is operational from a computer	_____ Yes		

Features

Which decisions are supported?	**Yes/No**	**Comments** (Write)	**Ref. no.**
1. Which crop/pest systems? *(Combinations of crops and pests or groups of pests, e.g. '30 species of seeded weeds')*			
2. Short term (tactical) decisions? *(Decisions for a growing crop)*	___ Yes ___ No ___ Don't know		
3. Long term (strategic) decisions? (Decisions taking into account aspects of crop rotation)	___ Yes ___ No ___ Don't know		
4. Decisions made by farmers? *(If 'yes', please explain)*	___ Yes ___ No ___ Don't know		
5. Decision made by advisors? (If 'yes', please explain)	___ Yes ___ No ___ Don't know		

6. Identification of pests? (If 'yes', please explain)	___ Yes ___ No ___ Don't know
7. Monitoring of pests? (If 'yes', please explain)	___ Yes ___ No ___ Don't know
8. Evaluation of economic thresholds? (If 'yes', please explain)	___ Yes ___ No ___ Don't know
9. Suggestion of treatments options? (Explain type of treatment: chemical, biological, mechanical, thermic, integration of different techniques, etc. Explain also differentiation on treatment, e.g. intensity of machinery, reduction of pesticide dose rates, mixes, adjuvants, etc.)	___ Yes ___ No ___ Don't know
10. Instructions on treatment implementation? *(E.g. instructions on adjustment of machinery, mixing of spray volume, spraying technique, etc.)*	___ Yes ___ No ___ Don't know
11. Instructions relating to weather conditions? *(E.g. influence of weather on pest sampling, pest development or performance of pesticides)*	___ Yes ___ No ___ Don't know
12. Instructions on follow-up? *(Evaluation of effect of treatments, strategy and timing of additional treatments, next move, etc.)*	___ Yes ___ No ___ Don't know
13. Use of cost/benefit analyses? *(If 'yes', please explain)*	___ Yes ___ No ___ Don't know
14. Are there any considerations of implications for pesticide resistance? *(If 'yes', please explain)*	___ Yes ___ No ___ Don't know
15. Is any information/support provided on the potential environmental impact of different control options? (If 'yes' please explain)	___ Yes ___ No ___ Don't know
16. In a local perception: is there some main 'added value' as compared to other DSS's dealing with the same pests? (If 'yes' please explain)	___ Yes ___ No ___ Don't know

Modelling approaches

Which approaches have been used to construct the DSS?	**Yes/no**	**Comments** (Write)	**Ref. no.**
1. Use of decision algorithms? *(If 'yes' please explain main principles)*	___ Yes ___ No ___ Don't know		
2. Use of calculation models? (If 'yes' please explain type of calculation or write mathematical expressions)	___ Yes ___ No ___ Don't know		
3. Optimisation for certain criteria? (If 'yes', please stated criteria used for optimisation)	___ Yes ___ No ___ Don't know		
4. Methods for estimating parameters for calculation models? *(Describe methods. Use of central estimates, biased estimates, estimates guessed by experts, inter- and extrapolations, copy of estimates from different 'conditions', etc.)*	/		
5. Are there critical requirements for development and maintenance? (Supply of data, theoretical assumptions, etc.)	___ Yes ___ No ___ Don't know		
6. In a local perception: Is there some main originality as compared to DSS's dealing with the same pests? *(If 'yes' please explain)*	___ Yes ___ No ___ Don't know		

Communication of results

How are recommendations communicated to end-users?	**Yes/no**	**Comments** (Write)	**Ref. no.**
1. Give a short description of the process of using the DSS by the end user (What kind of data to input, what kind of output, which steps of running the DSS, how long time to get recommendations)	/		
2. Is original research data presented to the end-user? (If 'yes', please explain how)	___ Yes ___ No ___ Don't know		
3. Can recommendations from the DSS be traced back to original research data, other kinds of data and/or original expert statements? *(If 'yes', please explain how)*	___ Yes ___ No ___ Don't know		

4. Are algorithms and calculations used in the DSS, transparent to end-users
(If 'yes', please explain how)

___ Yes
___ No
___ Don't know

Impact

How successful is the DSS?	**Yes/no**	**Comments** (Write)	**Ref. no.**
1. What is the extent of model validation? *(Number of years, crops, trials, etc.)*			
2. Have potentials been identified? (If 'yes', please quantify. E.g. potentials for reducing use of pesticides, potentials for larger economic profits, potential for more environmentally friendly control of pests etc.)	___ Yes ___ No ___ Don't know		
3. Have increased risks to crop safety and/or farm economy been identified? *(If 'yes', please explain the nature of the risk, and the magnitude of the risk)*	___ Yes ___ No ___ Don't know		
4. How many end-users? (Preferably in some groups of main target end-uses and perspectives)			
5. How actively are end-users using the DSS? *(E.g. surveys or end-user performance, statistics on number of consults, etc.)*			
6. Has end-users been responding? *(Questionnaires, reports from help-desk, correspondence wit 'web-master', etc.)*	___ Yes ___ No ___ Don't know		
7. How efficient is the transfer from DSS to field? *(End user confidence with recommendations from system, call for second opinions, use of 'practical' adjustments, etc)*			
8. Have factors promoting take-up been identified? *(E.g. training, campaigns, advertising, discounts, etc.)*	___ Yes ___ No ___ Don't know		
9. Have factors constraining take-up been identified? (Lack of motivation, lack of economic incentives, competition, lack of interest in computers, etc.)	___ Yes ___ No ___ Don't know		

10. Have specific interests in different groups of stake-holders been identified regarding take-up? *(Competition/conflicts with other suppliers of decision support)*	___ Yes ___ No ___ Don't know		
11. In a local perspective: what are the main drawbacks/limitations of the DSS in its current state of development?			

Opportunities and potentials for integration

Have opportunities for integration been identified?	**Yes/no**	**Comments** (Write)	**Ref. no.**
1. With farm management systems (FMS)? *(If 'yes', please comment)*	___ Yes ___ No ___ Don't know		
2. With site-specific pest management systems? *(If 'yes', please comment)*	___ Yes ___ No ___ Don't know		
3. With suppliers of 'meta-data'? *(E.g. suppliers of weather data, characteristics on crops, on crop cultivars, pesticides, machinery, etc.)*	___ Yes ___ No ___ Don't know		
4. With other 'systems'? *(If 'yes', please explain)*	___ Yes ___ No ___ Don't know		

Distribution and updating

How is distribution and updating being done?	**Yes/no**	**Comments** (Write)	**Ref. no.**
1. Means of distribution? (E.g. CDs download of files from internet, files sent by emails, online access via Internet, etc.)			
2. Frequency of updating? (E.g. annually, monthly, weekly, daily, etc.)			
3. Cost of the system to end-users? (Major groups of end-users, annual basis)			

Unification

Have opportunities and potentials for unification been identified?	**Yes/no**	**Comments** (Write)	**Ref. no.**
1. Opportunities? (If 'yes' please comment. E.g. between pest, between crops, between geographical regions)	___ Yes ___ No ___ Don't know		
2. Potentials? (If 'yes' please comment. E.g. from previous experiences)	___ Yes ___ No ___ Don't know		
3. Shortcomings? (If 'yes' please comment. E.g. from previous experiences)	___ Yes ___ No ___ Don't know		
4. Critical assumptions? (If 'yes' please comment. E.g. from previous experiences)	___ Yes ___ No ___ Don't know		
5. Critical requirements? (If 'yes' please comment. E.g. from previous experiences)	___ Yes ___ No ___ Don't know		
6. Restrictions relating to ownership? (On what terms can the DSS or parts of it, be used by other institutions/countries)	___ Yes ___ No ___ Don't know		
7. Restrictions relating to access to the system? (Can the DSS, or parts of it, technically be used in other institutions/countries)	___ Yes ___ No ___ Don't know		
8. Costs of the system, or parts of it when used for further development in other institutions/countries? (Principles of cost calculation or price list)			

Feedback to research

In the context of the DSS, have new questions been raised to research?	**Yes/no**	**Comments** (Write)	**Ref. no.**
1. To develop new models or sub-models? (If 'yes' please comment)	___ Yes ___ No ___ Don't know		
2. To parameterise existing models? (If 'yes' please comment)	___ Yes ___ No ___ Don't know		
3. To validate DSS's? (If 'yes' please comment)	___ Yes ___ No ___ Don't know		
4. To other issues? (If 'yes' please comment)	___ Yes ___ No ___ Don't know		

Annex C1
Total list of DSS country codes and acronym names, which are included in the survey

Bu_GreenhouseOrnamentals
Cz_GrowerSys
Da_BlightMan
Da_CPODiseases
Da_CPOWeeds
Es_Report
Fr_ActivLimaces
Fr_Bruchilis
Fr_Cocloconium
Fr_Colibri
Fr_CryptoLis
Fr_Dacus
Fr_DecidHerb
Fr_Epicure
Fr_EVA
Fr_KitPetales
Fr_MildiLis
Fr_MilMel
Fr_MilpvOignon
Fr_MilpvPomTer
Fr_MilVit
Fr_OptHerbClim
Fr_Phytochoix 3
Fr_Presept
Fr_QualProtVege
Fr_SeptoLis
Fr_Simbad
Fr_SovBurgundy
Fr_Spirouil
Fr_TavelurePomme
Fr_Tordeuses
Fr_TordeusesPlum
Fr_TraitOptPietin
Ge_Cercbet1
Ge_Cercbet3
Ge_Pomsum
Ge_Proplant
Ge_Simblight1
Ge_Simcerc3
Ge_Simlep3
Ge_Simonto
Ge_Simphyt1
Ge_Simphyt3
Ge_SkleroPro
Ge_ZEPP
Ge_Ökosimphyt
Hu_AgroAdcoTele
Hu_BoreasIntermet
Hu_LufftSmart
Hu_MetosLink
Ir_Report
It_GestInf
La_Report
Li_Report
Nl_MLHD
Nl_NemaDecide
Nl_Opticrop
Nl_PlantPlus
Po_IPMIDSS
Pl_SPEC
Sk_GalatiViti 3
Sp_Gep
Sw_DoseKey
Sw_Fusaprog
Sz_Phytopre
Sz_Sopra
UK_Fororls
UK_Fororps
UK_WheatDiseaseMan
UK_WeedManager

Total count: 70

Annex C2

DSS's for diseases in horticultural crops. Acronyms and crops included

DSS acronym	Crops included
Cz_GrowerSys	Apple, apricot, cherry, cucumber, hop, onion, peach, tomato, vine
Fr_Cocloconium	Olive
Fr_Epicure	Vine
Fr_Fr_MilMel	Melon
Fr_MilpvOignon	Onion
Fr_MilVit	Vine
Fr_Phytochoix 3	Vine
Fr_QualProtVege	Celery
Fr_SovBurgundy	Vine
Fr_TavelurePomme	Apple
Ge_Zepp	Horticultures and fruits (not specified)
Hu_AgroAdcoTele	Vine
Hu_BoreasIntermet	Vine
Hu_LufftSmart	Vine
Hu_MetosLink	Apple, cucumber, lettuce, onion, pear, pepper, stone fruit, strawberry, tomato, vine
Nl_Opticrop	Carrot, celery, flower bulbs, leek, onion, strawberry
Nl_PlantPlus	Apple, asparagus, cabbages, carrots, celery, citrus fruit, leek, lettuce, onion, strawberry, tomato, tulip, vine
Sk_GalatiViti 3	Vine

Count: 18

Annex C3

DSS's for diseases in arable crops. Acronyms and crops included

DSS acronym	Crops included
Cz_GrowerSys	Barley, oilseed rape, potato, sugar beet, sunflower, wheat
Da_BlightMan	Potato
Da_CPODiseases	Cereals
Es_Report	Cereals
Es_Report	Potato
Fr_Bruchilis	Faba bean
Fr_CryptoLis	Wheat
Fr_KitPetales	Oilseed rape
Fr_MildiLis	Potato
Fr_MilpvPomTer	Potato
Fr_Presept	Wheat
Fr_SeptoLis	Wheat
Fr_Spirouil	Wheat
Fr_TraitOptPietin	Wheat
Ge_Cercbet1	Sugar beet
Ge_ Cercbet3	Sugar beet
Ge_Simblight1	Potato
Ge_Simserc3	Cereals
Ge_Simonto	Cereals, oilseed rape
Ge_Simphyt1	Potato
Ge_Simphyt3	Potato
Ge_Skleropro	Oilseed rape
Ge_Zepp	Cereals, oilseed rape, potato, sugar beet
Ge_Ökosimphyt	Potato
Hu_MetosLink	Oilseed rape, potato, soybean, sugar beet, sunflower, turf, wheat
Ir_Report	Potato
Li_Report	Potato
Nl_PlantPlus	Potato, sugar beet
Pl_IPMIDSS	Potato
Pl_IPMIDSS	Wheat
Pl_SPEC	Oilseed rape
Sz_Fusaprog	Wheat
Sz_Phytopre	Potato
UK_Fororps	Oilseed rape
UK_WheatDiseaseMan	Wheat
UK_Fororls	Oilseed rape

Count: 37

Annex C4

DSS's on pests. Acronyms and crops included

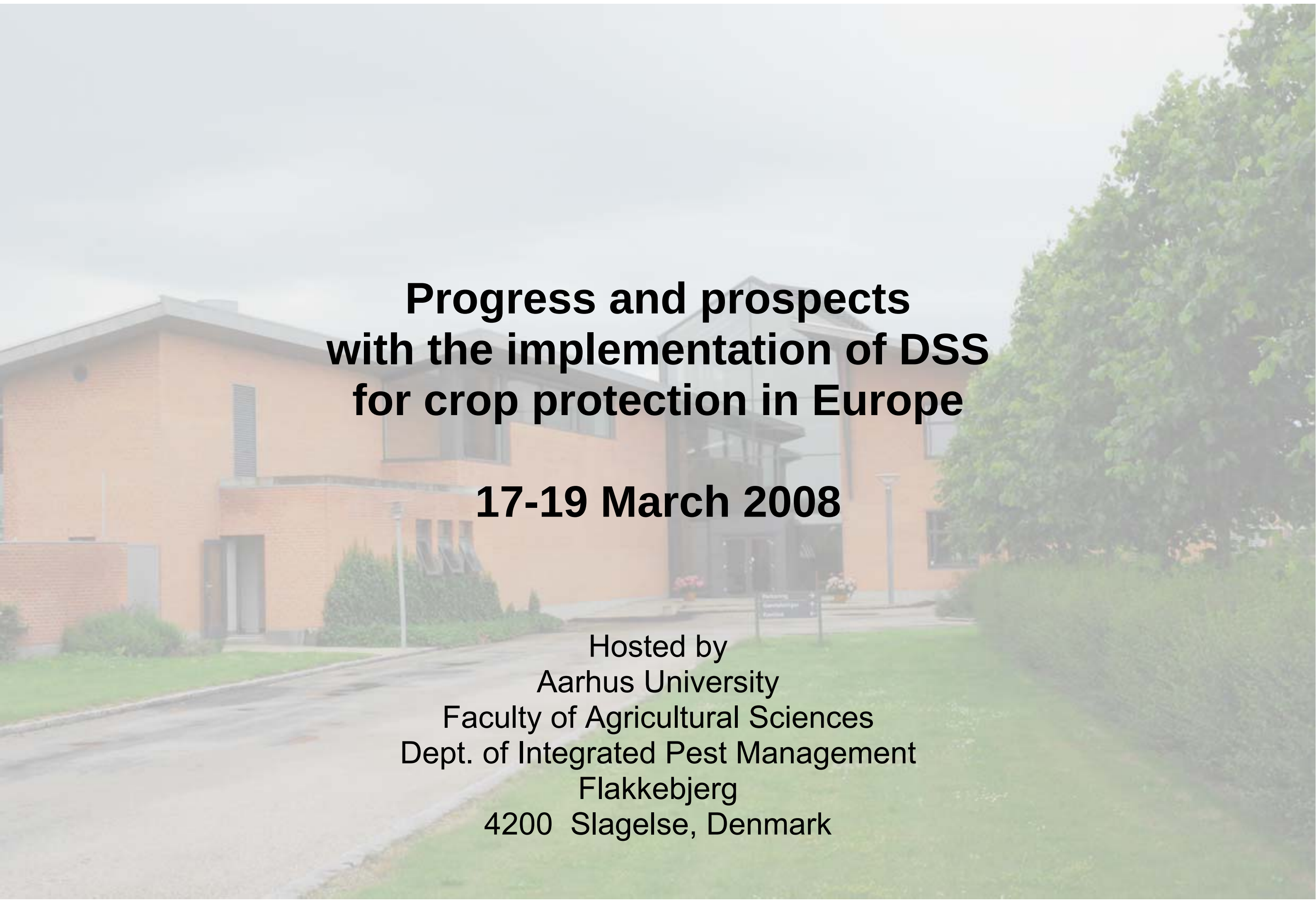
DSS acronym	Crops included
Da_CPODiseases	Cereals
Es_Report	Cereals
Fr_ActivLimaces	Corn, oilseed rape, sugar beet, sunflower, wheat, winter barley
Fr_Colibri	Wheat
Fr_Dacus	Olive
Fr_EVA	Vine
Fr_MilpvPomTer	Potatoes
Fr_Phytochoix 3	Vine
Fr_Simbad	Cotton
Fr_Tordeuses	Apple
Fr_TordeusesPlum	Plum
Ge_Possum	Apple
Ge_Proplant	Oilseed rape
Ge_Simlep3	Potato
Nl_NemaDecide	Potato
Pl_IPMIDSS	Wheat
Sp_Gep	Pome fruits, stone fruits
Sz_Sopra	Pome fruits, stone fruits
Count: 18	

Annex C5

DSS's for weeds. Acronyms and crops included

DSS acronym	Crops included
Da_CPOWeeds	Cereals, clovers, field pea, grass seeds, grassland, maize, oilseed rape, sugar beet
Fr_DecidHerb	Barley, field pea, flax, maize, oilseed rape, soya bean, sugasr beet, sun flower, wheat
Fr_OptHerbClim	Cereals
Fr_Phytochoix 3	Vine
It_GestInf	Maize, wheat, soybean
Nl_MLHD	Maize, onion, potato, sugar beet
Pl_IPMIDSS	Cereals
Sw_DoseKey	Cereals
UK_WeedManager	Beans, cereals, field pea, grassland, oilseed rape, sugar beet
Count: 9	

Annex D1
Pan-European workshop, 17-19 March 2007, programme



Progress and prospects with the implementation of DSS for crop protection in Europe

17-19 March 2008

Hosted by
Aarhus University
Faculty of Agricultural Sciences
Dept. of Integrated Pest Management
Flakkebjerg
4200 Slagelse, Denmark

Final Programme with links to presentations

17th April 2008

Introduction

ENDURE is a EU-supported 'Network of Excellence' aiming for development of durable strategies in crop protection and for ways to reduce the use and dependency on pesticides. In year 2007, a survey was made on DSS's available for crop protection across Europe.

To identify a DSS's of relevance for this study, some criteria were set up. Also a series of features to be investigated for each DSS was identified. Reports holding detailed descriptions on 54 DSS's were collected, and in the workshop entitled 'Progress and prospects with the implementation of DSS for crop protection in Europe', which will be convened in Flakkebjerg in Denmark on 17th - 19th March 2008, efforts will be made to identify some 'best parts' for unification on a European level. I am looking forward to a fruitful workshop on DSS's for crop protection in Flakkebjerg.

The workshop is intended for persons, who can offer experience, or who represent stakeholders within crop protection and decision support.

In the programme that was sent out on 21th December 2007, it was foreseen that some changes to the programme might be needed, when the registration period had finished. After termination of registrations, 3 presentations have been deleted. Furthermore, several names of speakers have been changed, and some relatively minor adjustments have been made, too. I thank everybody, who contributed to finalize the programme.

I am looking forward to welcome everyone in Flakkebjerg.

Flakkebjerg, 13th March 2008
Per Rydahl
Aarhus University
Faculty of Agricultural Sciences
Co-ordinator of ENDURE IA24

Programme

Start	Min		E-mail
		Monday, 17th March 2008	
1100	90	Registration desk opens *Room: Entrance Hall* Sonja Graugaard University of Aarhus Faculty of Agricultural Sciences Dept. of Integrated Pest Management Forsøgsvej 1, Flakkebjerg DK-4200 Slagelse, Denmark	sonja.graugaard@agrsci.dk
1230	45	Lunch *Room: Canteen*	
1315	10	**Opening of workshop** Welcome to Research Centre Flakkebjerg Per Kudsk Head of research unit: Pesticide Research and Environmental Chemistry University of Aarhus Faculty of Agricultural Sciences Dept. of Integrated Pest Management, Forsøgsvej 1, Flakkebjerg, DK-4200 Slagelse, Denmark	per.kudsk@agrsci.dk
1325	10	Comments to the programme of the workshop Per Rydahl Co-ordinator of ENDURE IA24 University of Aarhus Faculty of Agricultural Sciences Dept. of Integrated Pest Management Forsøgsvej 1, Flakkebjerg DK-4200 Slagelse, Denmark	per.rydahl@agrsci.dk

Start	Min		E-mail
		Late blight in potato *Moderator: Jozefa Kapsa, IHAR, Poland* *Room: Auditorium*	jkapsa@wp.pl
1335	10	Report from Estonia Late blight i potato Mati Koppel Jögeva Plant Beeding Institute 48309 Jögeva, Estonia	mati.koppel@jpbi.ee
1345	10	Report from Lithuania Late blight in potato Kestutis Tamošiunas Lithianian Institute of Agriculture Dotnuva-Akademija LT-5051 Kedainiai, Lithuania	lziaa@lzi.lt
1355	10	BlightManagement, Denmark Late blight in potato Jens G Hansen University of Aarhus Faculty of Agricultural Sciences Dept. of Agroecology Blichers Allé 20, P.O. BOX 50 DK-8830 Tjele, Denmark Bent J Nielsen University of Aarhus Faculty of Agricultural Sciences Dept. of Integrated Pest Management Forsøgsvej 1, Flakkebjerg DK-4200 Slagelse, Denmark	JensG.Hansen@agrsci.dk Bent.Nielsen@agrsci.dk
1405	10	MildiLis Late blight in potato David Gouache ARVALIS-Institut du vegetal 91720 Boigneville, France	d.gouache@arvalisinstitutduvegetal.fr
1415	10	Phytopre, Switzerland Late blight in potato Tomke Musa Agroscope Reckenholz-Tänikon ART Reckenholzstrasse 191 8046 Zürich, Switzerland	Tomke.musa@art.admin.ch

Start	Min		E-mail
1425	10	SIMPHYT/SIMBLIGHT, Germany Late Blight in potato Benno Kleinhenz ZEPP (Central Institution for Decision Support Systems in Crop Protection) Rüdesheimer Str. 68 55545 Bad Kreuznach, Germany	benno.kleinhenz@dlr.rlp.de
1435	15	Discussion	
1450	15	Coffee/tea break *Room: Entrance Hall*	
		Diseases in wheat *Moderator: Neal Evans, RRES, UK* *Room: Auditorium*	neal.evans@bbsrc.ac.uk
1505	15	CryptoLis, France Diseases in wheat SeptoLis, France Septoria in wheat David Gouache ARVALIS-Institut du vegetal Station de La Minière 78280 Guyancourt, France	d.gouache@arvalisinstitutduvegetal.fr
1520	15	Presept, France Septoria in wheat Spirouil, France Rust in wheat TraitOptPietin, France Eye spot in wheat Dominique Jacquin / Sylvie Jacquin DRAF-SRPV 8 rue Jacques Germain BP 177 21205 BEAUNE Cedex FRANCE	dominique.jacquin@agriculture.gouv.fr famille-jacquin@orange.fr
1535	10	Fusaprog, Switzerland Fusarium in wheat Tomke Musa Agroscope Reckenholz-Tänikon ART Reckenholzstrasse 191 8046 Zürich, Switzerland	Tomke.musa@art.admin.ch

Start	Min		E-mail
1545	10	SIMCERC, Germany Eye spot in wheat Benno Kleinhenz ZEPP (Central Institution for Decision Support Systems in Crop Protection) Rüdesheimer Str. 68 55545 Bad Kreuznach, Germany	benno.kleinhenz@dlr.rlp.de
1555	15	Discussion	
		Diseases in arable crops *Moderator: Volkmar Gutsche, BBA, Germany* *Room: Auditorium*	V.Gutsche@bba.de
1610	10	Report from Estonia Diseases and aphids in cereals Veiko Kastanje Estonian Research Institute of Agriculture Teaduse 4 Harju County EE-75501 Saku, Estonia	vogon@hot.ee
1620	10	WDM, UK Diseases in winter wheat David Parsons Cranfield University Bedfordshire MK 43 0AL, UK	d.parsons@cranfield.ac.uk
1630	15	CPOPestsDiseases, Denmark Pests and diseases in arable crops Karen E Henriksen / Lise N Jørgensen University of Aarhus Faculty of Agricultural Sciences Inst. of Integrated Pest Management Flakkebjerg DK-4200 Slagelse, Denmark	LiseN.Jorgensen@agrsci.dk KarenE.Henriksen@agrsci.dk
1645	10	GrowerSys, Czech Republic Diseases in arable crops Frantisek Muska State Phytosanitary Administration Zemedelska 1a 613 00 Brno, Czech Republic	muska34@rolny.cz
1655	15	Fororps, UK Phoma leaf spot in oilseed rape Fororls, UK	neal.evans@bbsrc.ac.uk

Start	Min		E-mail
		Light leaf spot in oilseed rape Neal Evans Rothamsted Research Harpenden Hertfordshire AL5 2JQ, UK	
1710	15	PlantPlus, The Netherlands Diseases in arable crops Corne Kempenaar PlantPlus, Waanderweg 68 7812 HZ Emmen, The Netherlands	corne.kempenaar@wor.nl
1725	15	proPlant expert, Germany Diseases in arable crops Thomas Volk pro_Plant GmbH Albrecht-Thaer-Straße 34 48147 Münster, Germany	th.volk@proPlant.de
1740	15	ISIP, Germany Pests and diseases in arable crops Manfred Röhrig ISIP e.V. Rüdesheimer Str. 60-68 55545 Bad Kreuznach, Germany	roehrig@isip.de
1755	10	SkleroPro, Germany Scerotina in rape Benno Kleinhenz ZEPP (Central Institution for Decision Support Systems in Crop Protection) Rüdesheimer Str. 68 55545 Bad Kreuznach, Germany	benno.kleinhenz@dlr.rlp.de
1805	10	SPEC, Poland Diseases in oilseed rape Malgorzata (Gosia) Jedryczka Institute of Plant Genetics Polish Academy of Science Strzeszynska 34 60-479 Poznan, Poland	mjed@igr.poznan.pl
1815	15	Results from analyses of reports on DSS's for diseases in arable crops Neal Evans, RRES, UK	neal.evans@bbsrc.ac.uk
1830	15	Discussion	

Start	Min		E-mail
1845		Shuttle bus departs from Research Centre Flakkebjerg for Hotel Antvorskov and Hotel Frederik d. II in Slagelse	
1945		Workshop dinner at Hotel Frederik d. II in Slagelse	

Tuesday, 18th March 2008

Start	Min		E-mail
0800		Shuttle bus departs from Hotel Antvorskov and Hotel Frederik d. II in Slagelse to Research Centre Flakkebjerg	

Diseases in vine

d.gouache@arvalisinstitutduvegetal.fr

Moderator: David Gouache, ACTA, France
Room: Auditorium

Start	Min		E-mail
0830	20	AgroAdcoTele, Hungary Diseases in vine BoreasIntermet, Hungary Diseases in Vine LufftSmart, Hungary Diseases in apple and vine Nora Levay Szent Istvan University Department of Plant Protection Pater K. u. 1 H-2103 Gödöllö, Hungary	Nora.Levay@mkk.szie.hu
0850	10	Epicure, France Diseases in vine Marc Raynal Entav ITV France 39 rue Montaigne 33290 Blanquefort, France	marc.raynal@itvfrance.com
0900	15	MilVit, France Plasmopara viticola in vine Fr_SOVBurgundy, France Uncinula necator in vine Dominique Jacquin / Sylvie Jacquin DRAF - SRPV Quartier Cantarel - BP 95 84 143 Montfavet CEDEX, France	dominique.jacquin@agriculture.gouv.fr famille-jacquin@orange.fr

Start	Min		E-mail
0915	15	GalatiViti 3, Slovakia and Hungary Diseases in vine Szőke Lajos Erdő tanya 4 H-6080 Szabadszállás, Hungary	szoke.lajos@kfk.kefo.hu
0930	15	Discussion	
0945	15	Coffee/tea break *Room: Entrance Hall*	
		Diseases in single horticultural crops *Moderator: Samuel Nibouche, CIRAD, France* *Room: Auditorium*	samuel.nibouche@cirad.fr
1000	15	Cycloconium, France Cycloconium oleaginum in olive tree MilMel, France Peronospora cubensis in Melon Christophe Roubal 1 - Christophe Roubal 2 DRAF - SRPV Quartier Cantarel - BP 95 84 143 Montfavet CEDEX, France	christophe.roubal@agriculture.gouv.fr
1015	15	MilpvOignon, France Peronospora porri in oignons QualProtVege, France Septoria in celeri Sophie Szilvasi (not attending, no presentation) Ministre de l'Agriculture Service régional de la Protection des Végétaux Nord Pas de Calais 81, rue Bernard Palissy BP 47 62750 Loos en Gohelle, France	sophie.szilvasi@agriculture.gouv.fr
1030	10	SIMPEROTA, Germany Peronospora tabacina in tobacco Benno Kleinhenz ZEPP (Central Institution for Decision Support Systems in Crop Protection) Rüdesheimer Str. 68 55545 Bad Kreuznach, Germany	benno.kleinhenz@dlr.rlp.de
1040	15	Discussion	

Start	Min		E-mail
		Diseases in multiple horticultural crops *Moderator: Antonio Berti, CNR, Italy* *Room: Auditorium*	antonio.berti@unipd.it
1055	10	GrowerSys, Czech Republic Diseases in horticultural crops Frantisek Muska State Phytosanitary Administration Zemedelska 1a 613 00 Brno, Czech Republic	muska34@rolny.cz
1105	10	MetosLink, Hungary Diseases in horticultural crops Nora Levay Szent Istvan University Department of Plant Protection Pater K. u. 1, H-2103 Gödöllö, Hungary	Nora.Levay@mkk.szie.hu
1115	15	Opticrop, The Netherlands Diseases in horticultural crops Henco Bouma Wageningen University and Research Centre Plant Research International B.V. P.O.Box 16 NL-6700 AA Wageningen, The Netherlands	info@opticrop.nl
1130	15	Results from analyses of reports on DSS's for diseases in horticultural crops David Gouache, ACTA, France	d.gouache@arvalisinstitutduvegetal.fr
1145	15	Discussion	
1200	15	Break	
1215	45	Lunch *Room: Canteen*	
		Pests *Moderator: Thomas Been, WUR, The Netherlands*	thomas.been@wur.nl

Start	Min		E-mail
		Room: Auditorium	
1300	10	NemaDecide, The Netherlands Nematodes in potato Thomas Been Wageningen University and Research Centre Plant Research International B.V. P.O.Box 16, NL-6700 AA Wageningen, The Netherlands	thomas.been@wur.nl
1310	10	Bruchilis, France Pea bruchids in faba bean Delphine Bouttet ARVALIS – Institut du végétal Station expérimentale 91720 BOIGNEVILLE, France	d.bouttet@arvalisinstitutduvegetal.fr
1320	10	Simbad (Cobold), France Bollworm in cotton Pierre Martin Cirad, Persyst Avenue Agropolis, TA B-DIR / 09 34398 Montpellier Cedex 5, France	pierre.martin@cirad.fr
1330	10	SIMLEP, Germany Colorado beetle in potato Benno Kleinhenz ZEPP (Central Institution for Decision Support Systems in Crop Protection) Rüdesheimer Str. 68 55545 Bad Kreuznach, Germany	benno.kleinhenz@dlr.rlp.de
1340	15	Gep, Spain Pests in pome- and stonefruit Jesus Avilla University of Lleida Centre UdL-IRTA Rovira Roure 191 E-25198 Lleida, Spain	jesus.avilla@irta.es
1355	15	Sopra, Switzerland Pests in pome- and stone fruits Joerg Samietz Agroscope Changins-Wädenswil ACW Schloss, P.O. Box 185 CH-8820 Wädenswil, Switzerland	joerg.samietz@acw.admin.ch
1410	15	EVA, France Lobesia botrana in Vine Fr_Tordeuses, France	christophe.roubal@agriculture.gouv.fr

Start	Min		E-mail
		Cydia pomonella in Apple tree Christophe Roubal DRAF – SRPV Quartier Cantarel - BP 95 84 143 Montfavet CEDEX, France	
1425	15	Results from analyses of reports on DSS's for pests Samuel Nibouche, CIRAD, France	neal.evans@bbsrc.ac.uk
1440	15	Discussion	
1455	15	Coffee/tea break	
		Weeds *Moderator: Nicolas Munier-Jolain, INRA, France* *Room: Auditorium*	munierj@dijon.inra.fr
1510	10	MLHD, The Netherlands Weeds in arable and horticultural crops Corne Kempenaar University and Research Centre Plant Research International B.V. P.O.Box 16, NL-6700 AA Wageningen, The Netherlands	corne.kempenaar@wor.nl
1520	10	OptHerbClim, France Weeds in cereals David Gouache / Delphine Bouttet ARVALIS-Institut du vegetal 91720 Boigneville, France	d.gouache@arvalisinstitutduvegetal.fr d.bouttet@arvalisinstitutduvegetal.fr
1530	15	CPOWeeds, Denmark Weeds in arable crops Per Rydahl University of Aarhus Faculty of Agricultural Sciences Inst. of Integrated Pest Management Flakkebjerg DK-4200 Slagelse, Denmark	per.rydahl@agrsci.dk
1545	15	DecidHerb, France Weeds in arable crops Nicolas Munier-Jolain INRA, UMR Biologie et Gestion des Adventices, 17, rue Sully, BP 86510, F-21065 Dijon Cedex, France	munierj@dijon.inra.fr

Start	Min		E-mail
1600	15	GestInf, Italy Weeds in arable crops Antonio Berti Dipartimento di Agronomia ambientale e Produzioni Vegetali Viale dell'Università 16, 35020 Legnaro (PD), ITALY	antonio.berti@unipd.it
1615	15	WM, UK Weeds in arable crops David Parsons Cranfield University Bedfordshire MK 43 0AL, UK	d.parsons@cranfield.ac.uk
1630	15	Results from analyses of reports on DSS's for weeds Per Rydahl University of Aarhus Faculty of Agricultural Sciences Dept. of Integrated Pest Management, Forsøgsvej 1, Flakkebjerg DK-4200 Slagelse, Denmark	per.rydahl@agrsci.dk
1645	15	Discussion	
1700	20	Small break	
1730		Shuttle bus departs from Research Centre Flakkebjerg to Hotel Antvorskov and Hotel Frederik d. II in Slagelse. Free evening.	

Wednesday 19th March 2008

Start	Min		E-mail
0800		Shuttle bus departs from Hotel Antvorskov and Hotel Frederik d. II in Slagelse to Research Centre Flakkebjerg	

Input from other activities in ENDURE

per.rydahl@agrsci.dk

Moderator: Per Rydahl, AU, Denmark
Room: Auditorium

Start	Min		E-mail
0830	15	Needs for DSS's in different crop/pest systems, in different countries/regions and in different groups of end-users (ENDURE SA 4) Jens E Jensen Danish Agricultural Advisory Service	jnj@landscentret.dk

Start	Min		E-mail
		Udkærsvej 15, Skejby DK-8200 Aarhus N, Denmark	
0845	15	Perspectives for automatic detection of pests and precision spraying in the field as input for DSS's (ENDURE RA 2.2 a and b) Ivar Lund University of Aarhus Faculty of Agricultural Sciences Department of Agricultural Engineering Research Centre Bygholm Schüttesvej 17 DK-8700 Horsens	ivar.lund@agrsci.dk
0900	15	Perspectives for integration of DSS's with Farm Management systems and systems for precision agriculture (ENDURE IA2.5) Iver Thysen University of Aarhus Faculty of Agricultural Sciences Dept. of Agroecology Blichers Allé 20, P.O. BOX 50 DK-8830 Tjele, Denmark	iver.thysen@agrsci.dk
		Identification of 'best parts' of existing DSS's for crop protection for unification on a European level *Moderator: Per Rydahl, AU, Denmark*	per.rydahl@agrsci.dk
0915	60	*Group work* Introduction Per Rydahl, AU Group 1a: Diseases in arable crops *Moderator: Neal Evans, RRES, UK* *Room: Auditorium* Group 1b: Late Blight in potato *Moderator: Josefa Kapsa, IHAR, Poland* *Room: Meeting room 1 (M1)* Group 2: Diseases in horticultural crops and fruits *Moderator: David Gouache, ACTA, France* *Room: Meeting room 3 (M3)* Group 3: Pests *Moderator: Samuel Nibouche, CIRAD, France* *Room: Platform 2 in entrance hall*	

Start	Min		E-mail
		Group 4: Weeds *Moderator: Per Rydahl, AU, Denmark* Input from Per Rydahl Input from Nicolas Munier-Jolain *Room: Meeting room 2 (M2)*	
1015	15	Coffee/tea break *Room: Entrance Hall*	
1030	90	Presentation of results from group work in plenum and discussions 1a: Neal Evans, RRES, UK 1b: Josefa Kapsa, IHAR, Poland 2: David Gouache, ACTA, France 3: Samuel Nibouche, CIRAD, France 4: Per Rydahl, AU, Denmark	
1200	30	Summary and next moves in ENDURE IA2.4. Closure of workshop. (Concluding remarks will be consolidated in ENDURE IA24 work group and published before 15th May 2008)	
1230	45	Lunch at Research Centre Flakkebjerg *Room: Canteen*	
1315	45	Guided tour at Research Centre Flakkebjerg Per Kudsk, head of research unit: Pesticide Research and Environmental Chemistry Shuttle bus no. 1 departs from Research Centre Flakkebjerg to Slagelse railway station Train departs from Slagelse at 13.54, arrival Copenhagen Airport 15.15	
1415		Shuttle bus no. 2 departs from Research Centre Flakkebjerg to Slagelse railway station Train departs from Slagelse 14.54, arrival Copenhagen Airport at 16.15	

Practical information

Presentations

No specific abstracts from the presentations on the workshop will be produced. Most of the presented DSS's have already been described in a common report format, and a joint report (review) will be produced later. Furthermore, Powerpoint slide shows from the presentations on the workshop will be uploaded to ENDURE Workspaces after the workshop.

PowerPoint slide shows must be sent as attachment to email to per.rydahl@agrsci.dk, no later than **10th March 2008**. The file with the slide show should be named: [DSS-acronym].ppt or alternative. In case more than one DSS is included in one presentation, only the first DSS-acronym should be included in the filename. In an emergency, files with slide shows can be brought on a USB-key or CD and installed in a break before the presentation.

Speakers are strongly encouraged to **keep the time** allocated for each presentation. Due to a very compressed workshop programme, **presentations will be interupted** after just a few minutes overrun.

Travel to Flakkebjerg

To Copenhagen:
By air ('Copenhagen Airport') or by train.

From Copenhagen Airport to Slagelse (about 110 km)
By train about every hour in daytime, about 1½ hours travel

From Slagelse to Flakkebjerg (about 10 km):
By public bus (no. 31), by taxi or by workshop shuttlebus.
Shuttlebus will be arranged from Slagelse to Flakkebjerg in the mornings and back in the afternoon.

Time schedules of all trains and all buses in Denmark can be studied from www.rejseplanen.dk, which is also available in English user interfase.

Hotels in Slagelse

The following 2 hotels are recommended:

* * * * 'Hotel Frederik d. II'

Web:	http://www.fr2.dk/internet/fr2/menu/main.nsf
Phone:	+45 58 53 03 22
Email:	hotel@fr2.dk
Single room:	Normal price: DKK 943
Special price:	DKK 798, refer to 'Meeting in Research Centre Flakkebjerg'

* * * 'Hotel Antvorskov'

Web:	http://www.hotelantvorskov.dk/content.asp?ID=121
Phone:	+45 58 50 53 60
Email:	info@hotelantvorskov.dk
Single room:	Normal price: DKK 545
Special price:	DKK 515, refer to 'Meeting in Research Centre Flakkebjerg'

These hotels encourage workshop participants to book hotel rooms within the first 2 weeks in January 2008.

Taxi

The reception at Research Centre Flakkebjerg (phone +45 89 99 35 00) Flakkebjerg can assist.

Hashøj Taxa, phone: +45 58 54 54 65
Slagelse Taxa, phone: +45 58 53 53 53

Workshop expenses

Meeting rooms, materials, coffe/tea, lunches during the workshop, shuttle bus and the workshop dinner 17th March 2008 will be paid by ENDURE IA24. Other expences must be paid indivitually by participants.

Currency

1 Euro = 7,45 DKK ('Danish crowns'). Bancomats are available in Copenhagen Airport and the centre of Slagelse.

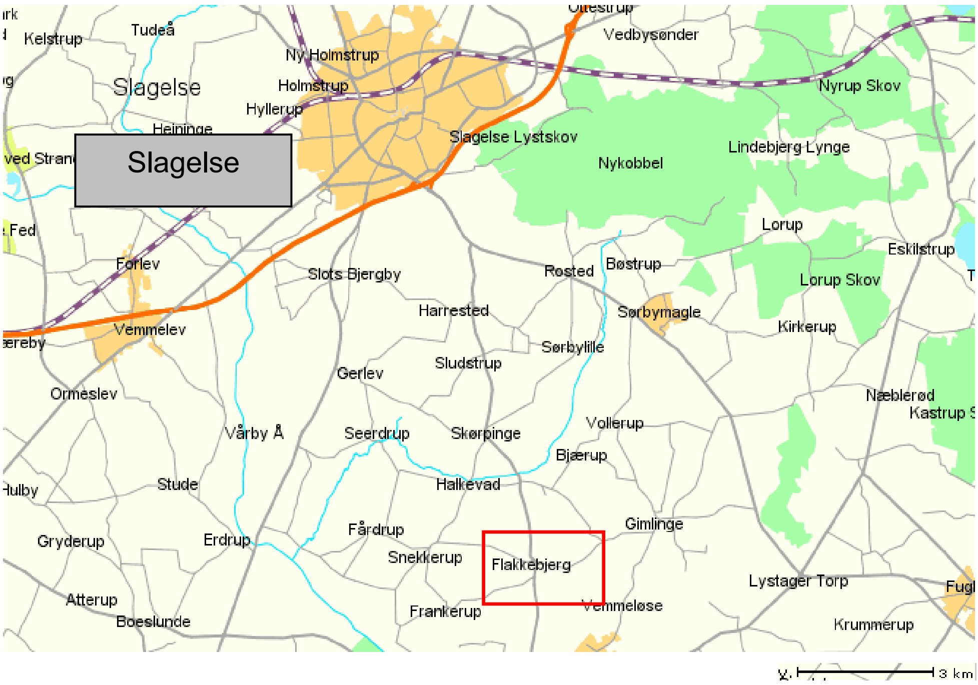
Registration for the workshop

INRA will develop tool (a website) for online registration for the workshop.This wil be ready no later than **21th January 2008.** Registrations will terminate **15th Februar 2008** When this web-site is ready, a link will be sent out by email.

Maps

Maps of Denmark can be studied on maps.google.com.

Location of Copenhagen Airport, Slagelse and Flakkebjerg



Location of Slagelse and Flakkebjerg

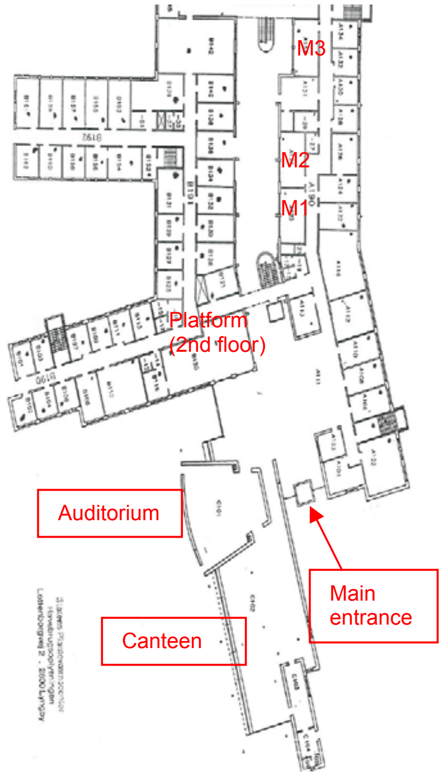
Locations in Slagelse
Railway Station, Hotel Frederik dII and Hotel Antvorskov

Locations in Slagelse
Hotel Frederik dII and Hotel Antvorskov

See you in Flakkebjerg!

Research Centre Flakkebjerg

Semifield facilities



Main building of
Research Centre Flakkebjerg

Annex D2
Pan-European workshop, 17-19 March 2007, list of participants

Progress and prospects with the implementation of DSS for crop protection in Europe 17-19 March 2008

List of participants

Country	Name	Company/institution	E-mail adress
Czech Republic	Frantisek Muska	State Phyosanitary Administration	muska34@volny.cz
Denmark	Bent Jørgen Nielsen	Aarhus University	bent.nielsen@agrsci.dk
Denmark	Ivar Lund	Aarhus University	ivar.lund@agrsci.dk
Denmark	Iver Thysen	Aarhus University	iver.thysen@agrsci.dk
Denmark	Jens Erik Jensen	Danish Agricultural Advisory Service	jnj@lr.dk
Denmark	Jens G Hansen	Aarhus University	jensg.hansen@agrsci.dk
Denmark	Karen E Henriksen	Aarhus University, Denmark	karene.henriksen@agrsci.dk
Denmark	Lise N Jørgensen	Aarhus University	lisen.jorgensen@agrsci.dk
Denmark	Ole Qvist Bøjer	Aaarhus University	ole.bojer@agrsci.dk
Denmark	Per Kudsk	Aarhus University	per.kudsk@agrsci.dk
Denmark	Per Rydahl	Aarhus University	per.rydahl@agrsci.dk
Estonia	Mati Koppel	Jogeva Plant Breeding Institute	mati.koppel@jpbi.ee
Estonia	Veiko Kastanje	Estonian Research Inst. of Agriculture	vogon@hot.ee
France	Christophe Roubal	DRAF-SRPV	christophe.roubal@agriculture.gouv.fr
France	David Gouache	ACTA	d.gouache@arvalisinstitutduvegetal.fr
France	Delphine Bouttet	ACTA	d.bouttet@arvalisinstitutduvegetal.fr
France	Dominique Jacquin	DRAF-SRPV	Dominique.jacquin@agriculture.gouv.fr
France	Marc Raynal	Entav ITV	marc.raynal@itvfrance.com
France	Nicolas Munier-Jolain	INRA	munierj@dijon.inra.fr
France	Pierre Martin	CIRAD	pierre.martin@cirad.fr
France	Samuel Nibouche	CIRAD	samuel.nibouche@cirad.fr
France	Sylvie Jacquin	Accompanying person	samille-jacquin@orange.fr
Germany	Benno Kleinhenz	ZEPP	benno.kleinhenz@dlr.rlp.de
Germany	Manfred Röhrig	ISIP e.V.	roehrig@isip.de
Germany	Thomas Volk	proPlant Ltd.	th.volk@proplant.de
Germany	Volkmar Gutsche	JKI	v.gutsche@bba.de
Hungary	Istvan Terpo	Agromester Ltd.	terpo@freemail.hu
Hungary	Lajos Szoke	KFKFK	szoke.lajos@kfk.kefo.hu
Hungary	Nora Levay	SZIE	Nora.Levay@mkk.szie.hu
Italy	Antonio Berti	University of Padova	antonio.berti@unipd.it
Latvia	Biruta Bankina	Latvian University of Agriculture	biruta.bankina@llu.lv
Latvia	Gunita Bimsteine	Latvian University of Agriculture	gunita.bimsteine@llu.lv
Latvia	Inara Turka	Latvian University of Agriculture	inara.turka@llu.lv
Latvia	Ineta Vanaga	Latvian Plant Protect. Research Centre	ineta.vanaga@laapc.lv
Latvia	Regîna Rancâne	Latvian Plant Protect. Research Centre	regina.rancane@laapc.lv
Lithuania	Kestutis Tamoðiunas	Lithuanian Institute of Agriculture	lziaa@lzi.lt
Netherlands	Corne Kempenaar	Plant Research International	corne.kempenaar@wur.nl
Netherlands	Henco Bouma	Opticrop	info@opticrop.nl

Country	Name	Company/institution	E-mail adress
Netherlands	Thomas Been	Plant Research International	thomas.been@wur.nl
Poland	Josefa Kapsa	Plant Breeding and Accl. Institute	jkapsa@wp.pl
Poland	Malgorzata Jedryczka	Polish Academy of Sciences	mjed@igr.poznan.pl
Spain	Jesus Avilla	University of Leida	jesus.avilla@irta.es
Sweden	Alf Djurberg	Växtskyddscentralen	alf.djurberg@sjv.se
Sweden	Gunila Berg	Swedish Board of Agriculture	gunilla.berg@sjv.se
Sweden	Karin Jahr	Jordbruksverket	karin.jahr@sjv.se
Sweden	Torbjörn Ewaldz	Swedish Board of Agriculture	torbjorn.ewaldz@sjv.se
Switzerland	Joerg Samietz	Agroscope ASW	joerg.samietz@acw.admin.ch
Switzerland	Tomke Musa	Agroscope ART	tomke.musa@art.admin.ch
United Kingdom	David Parsons	Cranfield University	d.parsons@cranfield.ac.uk
United Kingdom	Neal Evans	Rothamsted Research	neal.evans@bbsrc.ac.uk

Annex D3
Pan-European workshop, 17-19 March 2007, concluding remarks

Proceedings of a pan-European conference on the current status and future needs for DSS's for crop protection 17-19 March 2008, Flakkebjerg, Denmark

Consolidated concluding remarks, per 22th May 2008

Contents *Page*

1 Introduction

This document has been written / consolidated by the members of the ENDURE IA24 working group:

- Antonio Berti CNR, Italy
- David Gouache ACTA, France
- Jens Erik Jensen DAAS, Denmark
- Josefa Kapsa IHAR, Poland
- Neal Evans RRES, UK
- Nicolas Munier-Jolain INRA, France
- Nora Levay SZIE, Hungary
- Per Rydahl AU, Denmark
- Samuel Nibouche CIRAD, France
- Thomas Been WUR, Netherlands
- Volkmar Gutsche BBA, Germany

A survey was conducted to identify DSS's for crop protection in EU-countries and Switzerland. An overall objective in this survey is to search opportunities for reducing dependency and use of pesticides. The following questions were asked for each DSS:

- which decisions are supported?
- which modelling approaches have been used?
- how is communication with users being done?
- have the DSS demonstrated some impact?
- have opportunities for integration been identified?
- are procedures for updating been followed?
- have potentials for unification been identified?
- are there restrictions regarding ownership?
- has feedback to research been demonstrated?
- have some 'best parts' been identified locally?

In order to answer these questions in a uniform way, a common data form for collection of data was produced. Filled in data forms have been received on 67 DSS's. 52 of these were presented on the workshop, and analyses of the filled in data forms were presented, too. 50 persons from 15 European countries participated.

The analyses of returned and filled in data forms were grouped for major crop/pest systems covered in the data, and key persons were appointed to lead the work of analysing data forms:

- diseases in arable crops: Neal Evans
- potato late blight: Josefa Kapsa
- diseases in horticultural crops: Nora Levay (previously David Gouache)
- pests: Samuel Nibouche
- weeds: Per Rydahl

The workshop was divided into corresponding sections, each ending with the presentation of results from analyses of data forms from DSS's representing these groups.

Group discussions were conducted in each of these groups to identify some 'best parts' for unification on a European level. These findings were presented and discussed in plenum.

This paper summarizes the concluding remarks from these major crop / pest groups including brief descriptions of 'state-of-the-art' and suggestions for next moves. A draft was sent out for comments in the IA24 working group per 23th April 2008. Revisions from Samuel Nibouche has been incorporated

2 State-of-the-art

2.1 Group 1: Diseases in arable crops

Results from analyses of data forms were presented by Neal Evans.

- The DSS's were classified according to the stage of development and the level of use
- A universal system will probably not be advantageous, instead 'cherry pick' of best models/systems
- Extension of some local system to other countries/region may be possible
- Interaction with end-users must me made in construction phase
- Identified requirements for DSS's:
  - fun / learning to use
  - must make real differences to end users and / or be elements in environmental regulation
- Relative 'best parts' have been identified for each DSS

2.2 Group 2: Potato late blight

Results from analyses of data forms were presented by Josefa Kapsa. To construct at good DSS, a set of 'construction elements' were identified:

- Biological elements:
  - primary inonulum sources
  - pathogen changes
  - characteristics of potato varieties
  - epidemical model of Phytophtera infestans:
  - in leaves and stems
  - in tubers
- Other elements:
  - monitoring of early infestation
  - weather conditions
  - agrotechnonogy
  - performance of fungicides
  - elements not yet identified?
- Identified 'best parts' for construction of DSS:
  - first attacks (Fight against Blight / WEB-BLIGHT / ISIP)
  - characteristics of varieties (EUCABLIGHT)
  - life cycle of pathogen (EUCABLIGHT)
  - performance of fungicides, including: rainfastness, UV-degredation, etc. (EUROBLIGHT)

2.3 Group 3: Diseases in horticultural crops

Results from analyses of data forms was presented by David Gouache.
The main target groups should be advisors and farmers, but researchers and policy makers may also benefit from DSS's. The most efficient ways of disseminating information and construction of DSS's to assist this, should be studied by sociologists and marketing people. To ensure a good uptake, advisors should be 'kept in the loop'.

Major challenges for development of future DSS's:

- to identify biological data:
    - which is required for specific models / DSS's
    - which is publicly available
    - which meet specific standards of quality
- to construct and validate DSS models:
    - which may include a core engine:
        - with different crop/pest systems
        - with different production concepts (conventional, organic)
        - with different user interfaces
    - which have a suitable balance between quality and representativeness (interpolation) of weather data and sensitivity of models to such weather data
    - which include main agronomic factors that diminish risk
    - which demonstrate robustness and hopefully also some potentials
    - examples from Germany, Denmark, Netherlands and France show that some technologies already exist
- to interact with end users:
    - to analyse their needs for DSS's, before and during use
    - to ensure that operational information, terminologies, etc. are used

2.4 Group 4: pests

Results from analyses of data forms was presented by Samuel Nibouche. The main target groups should be advisors and farmers. The major challenges for development of future DSS's are:

- to develop structures at the European level for:
    - construction and updating of DSS's
    - communication languages
    - exchange of biological data
    - exchange of weather data

Several existing DSS's have been identified:

- developed in different countries / institutions
- covering different crop / pest systems

2.5 Group 5: weeds

Results from analyses of data forms were presented by Per Rydahl.

The major target groups will be farmers and advisors. Tools that support tactical decisions on a field level will have farmers as a major target group. Tools that support decisions on general / regional levels should include advisors as a major target group.

'Best parts' were identified in terms of the following 'building blocks' that may be suitable for combination in novel DSS's:

- Evaluation whether control is needed:
  - Density equivalents (GestInf)
  - Crop rotation aspects (VM)
  - Integration of different aspects (yield potential, residual weeds) (Da_CPOWeeds)
- Efficacy of herbicides:
  - Crosstables (Nl_MLHD)
  - Dose/response functions and Additive Dose Model (Da_CPOWeeds)
  - Site-specific applications (Nl_MLHD)
- Environmental impact:
  - Risc factors (Fr_DecidHerb)
- Climatic conditions:
  - Long term (Fr_DecidHerb)
  - Short term (Da_CPOWeeds)

2.6 Input form other activities in ENDURE

2.6.1 Needs from end-users (SA4)

Results from a survey among 'selected persons' on needs from end-users, was presented by Jens Erik Jensen, DAAS. It was concluded that:

DSS's are highly ranked for tactical decisions. Studies in Denmark indicate that:

- farmers are very reluctant to conduct field inspections, before they spray pesticides
- systems must consider farm logistics
- DSS-engines must be strong, but user interfaces should be tailored for specific groups of end-users

2.6.2 Perspectives for automatic detection of pests and precision spraying in the field (RA22 a and b)

Results from reviews on techniques for automatic detection of pests in the field and techniques for precision application of pesticides were presented.

Molecular detection methods, bio-sensors and autonomous sampling techniques are presently being integrated in prototypes. Considering precision application of pesticides, spraying maps and real-time concepts are foreseen in integration with system for digital image analysis and systems based on air- and soil samples.

However, operational systems in these domains are not foreseen in the remaining period of the ENDURE network.

2.6.3 Perspectives for integration of DSS's with Farm management systems and systems for precision agriculture (IA25)

Ideas for integration of DSS's with farm management systems were presented. Development of task-controllers, which are integrated with computers on sprayers were suggested. For such purposes, robust DSS-engines could be integrated.

2.7 Conclusions from plenum discussions

The DSS's presented in this workshop are very heterogeneous with respect to:

- stage of development
- number of crop / pest systems included
- nature and number of questions, which are supported
- number of end-users
- potentials for reducing dependency / use of pesticides

Criteria to constitute a 'best part' for unification on a European level have not been identified.
Inspired by presentations made by Nora Levay, the following working process to construct new DSS's for crop protection was identified:

- Identify the problems / objectives. The following objectives could be relevant:
    - reduce dependency / use of pesticides
    - justify use of pesticides
    - improve productivity for farmers:
        - increase quantity / quality of yield
        - save costs
        - reduce 'environmental load'
- Identify requirements for a DSS. A developed DSS should ensure that:
    - management of weeds, pests and diseases:
        - is performed in a way, where the level of robustness (reliability) reflects the risk of reducing the value of the crop. Robustness should be demonstrated in validation trials for complete models and / or sub-models.
        - holds some potential for reducing dependency / use of pesticides (impact) as compared to 'benchmark' practices
    - pesticides are applied in the best possible time, place and dose rates
    - system integrity is maintained by:
        - current updating
        - clear allocation of responsibilities
    - farmers and advisors are involved to consider:
        - objectives, complexity, terminology, etc. in the construction phase

        - possible integration with existing working procedures and tools on a farm level
        - training programmes

- Construction of DSS prototypes:
    - as many decisions as possible should be integrated for a selected crop / pest system
    - test for robustness and potential
    - when some robust and potent models / structures / systems have been identified, integration with adjacent systems could be considered, e.g. farm management systems, systems for precision agriculture, etc.

3 Suggestions for next moves

3.1 New revision of Part B data forms

The workshop revealed that unfortunately, some DSS's are quite poorly represented in the received Part B data forms, and some DSS's have been completely overlooked in the survey, too.

To correct these errors, it was agreed that existing reports will be revised for major errors and additional DSS will be searched in some countries. This work will be co-ordinated by the persons, who were responsible for the survey in different countries.

New and revised Part B data forms must be sent to Per Rydahl no later than **1st August 2008**. Consequently, the milestone of writing a report titled 'Progress and prospects with the implementation of DSS for crop protection in Europe' will be postponed from M18 to M23.

A workshop in IA24 in connection to the conference 13-15 October in La Grande-Motte should be considered. The agenda should include finalization of the a.m. report and future activities.

3.2 Ideas for activities after M24

Work plans have already been specified in detail until M24.The following activities after M24 could be considered:

A deeper involvement with other groups in ENDURE
Constitutions of new working groups, maybe representing the major crop / pest groups identified in this workshop

Such groups will concentrate on biology, models, algorithms, construction of prototypes, validation tests, etc. Formal organizing of such new groups in ENDURE should be considered

Collaboration between such working groups should be considered, too. This collaboration should ensure that DSS's constructed in these groups will meet certain standards, where ever possible, so that these are suitable for integration with other DSS's and other adjacent systems on a farm level. Organizing of such groups could be made in the existing activity IA24

Set-up of a joint manual describing the working process required when constructing new DSS's (compare to section 2.7) should be considered. This manual should contribute to overcome some of the heterogeneity identified in existing DSS

3.2.1 Group 1: Diseases in arable crops

Ideas for activities after M24 have not yet been specified.

3.2.2 Group 2: Potato late blight

Some major challenges for development future DSS's will be:

- to develop criteria for optimum timing for start of spraying
- to develop strategies for use of different fungicides:
    - preventive / curative
    - contact / systemic

3.2.3 Group 3: Diseases in horticultural crops

Ideas for activities after M24 have not yet been specified

3.2.4 Group 4: pests

Codling moth (*Cydia pomonella*) is suitable as an initial model pest. This pest is present in several countries and robust biological knowledge / models have already been developed. Usable 'best parts' can be picked from the Sz_Sopra and Fr_Tordeuses core models and from GEP Google tools.
Model parameters must be adjusted to local conditions. Some components may be adjusted on national levels, other components on regional levels. Operational systems should be validated for local conditions.
Several other crop / pest systems have potential for unification.
'Common structures' should be established to keep systems alive.

3.2.5 Group 5: weeds

Biological, legal, technical and other relevant features that characterize a 'building block', should be identified.

DSS prototypes that combine different 'building blocks' for different crops and for different countries / regions should be outlined.

Requirements for data, system structures, principles for construction of models and decision algorithms, collaboration structures, validation tests, etc. for such DSS prototypes should identified.

Experimental protocols to supply additional data for such DSS prototypes should be identified.