Project Number 289706

COLLABORATIVE PROJECT

AMIGA
Assessing and Monitoring the Impacts of Genetically modified plants on Agro-ecosystems

D7.6 Prototype of a GIS-based monitoring information system

Start date of the project: 01/12/2011
Duration: 54 months

Organisation name of lead contractor for this deliverable: GEOSYS

Expected delivery date: 31 May 2016
Actual delivery date: 30 June 2016

Project funded by the European Commission within the Seventh Framework Programme (2007-2013)		
Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

1 Introduction

The AMIGA central GIS-based (Geographic Information System) database, as designed in WP3 (task 3.1) and described in D3.1, aims at storing observations and events and at referencing both them spatially and temporally. This database is transversal to the AMIGA project and based on a common referential. Thus a rich and easy to use source of data has been delivered to AMIGA users. One of the outcomes of this database is to allow researchers to retrieve datasets for new research purposes. The AMIGA database and its associated GIS offers a prototype for a future central point of information for planning, executing and monitoring GM crop trials in Europe.

In parallel, WP7 has been working on the development of spatially-explicit exposure models to help risk managers make decisions on management scenarios as well as to set up optimal Post-Market Environment Monitoring schemes. Two specific crop-trait-pest situations have been considered:

- Design of a spatially-explicit exposure model to assess the impact of *Bt* maize on the mortality of non-target Lepidoptera;
- Effect of cropping systems and of herbicide management regimes on weed abundance and diversity.

These exposure models use input data that can typically be stored in the AMIGA database. Conversely the outputs of the models can also be stored and displayed through the AMIGA database software.

The purpose of this document is to describe those tools that could be built to help interface the AMIGA database and such exposure models. The strategic goal of these tools is to demonstrate to policy makers or stakeholders the added value of connecting database and exposure models that should help them make better decisions.

To access the database, the user can download the software on a FTP server: ftp://Amiga2:Am!g@2$!@livraisons.geosys.com, then get a user and password required to access the database. Delivered with the software, the user will find installation guide, tutorial and contextual help in the interface.

2 GIS prototype and scenario of use

2.1 Database model description

The database model is described in details in D3.1 “A central GIS and associated database”.

In the AMIGA database, there is three main entities:

1. Territorial unit is a geographic entity, which is spatially and temporally defined. It ranges from the highest level (continent) to the lowest level (plant). Territorial units can be linked to each other by specifying a parent (a field trial can be linked to a field, the latter being associated to a farm or a region); the European NUTS (Nomenclature of Units for Territorial Statistics) classification has been implemented to define geographical areas[1];
2. Territorial unit history correspond to a period grouping events that occurs on a given territorial unit: it can be a period of observation, a period of crop growth (from seeding to harvest) or a crop rotation in case of multi-year experiments.
3. Events are the unitary concept for all observations. Events share common properties and might have specific properties depending of their type. Three main types of events are considered:

    Crop management: all events related to field management operations (sowing, crop protection, fertilization, etc);

    Receiving environment characteristics describing the climate or regional cropping systems and their evolution;

    Observations: all other ground observations for example on plants, microbes and invertebrates.

The relations between these three types are explained on Figure 2-1. A territorial unit can have several histories. For example several crop seasons or several crops. Each history can have many events and each can be of different type.

[1] NUTS are administrative units used for statistics at European level. Since each country has its own convention names and levels of administrative units, statisticians splitted them in comparable “levels”. Level 0 is the country, Level 1 can be regions or states depending of the country and so on.
See https://en.wikipedia.org/wiki/Nomenclature_of_Territorial_Units_for_Statistics

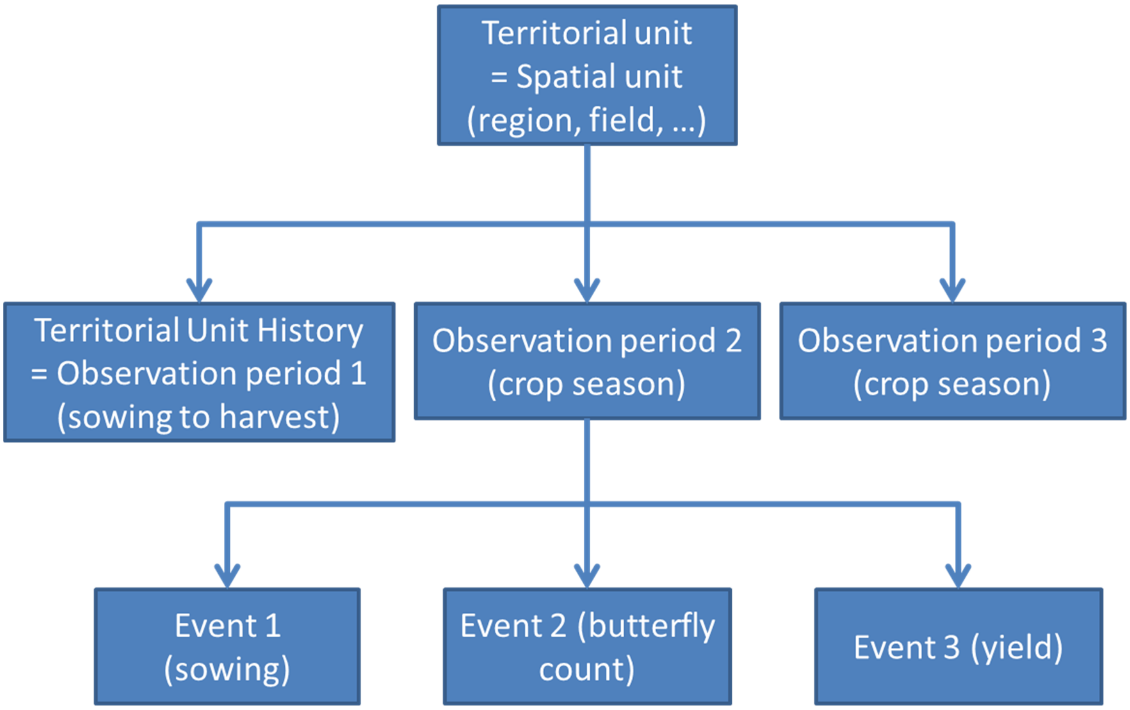

Figure 2-1 Summary of the database model: main architecture

Events can be grouped into entities called datasets. The dataset is a base entity to easily manipulate data for import, query and export.

With this database model, all elements required for both models can be extracted. Context information about fields such as sowing date, source/receptor/neutral status in regards to pollinators can be extracted or computed from Territorial Unit History information. Pollen emission and larvae description can be stored and extracted as events of the corresponding Territorial Unit History.

2.2 Main features of the exposure models

2.2.1 Impact of Ht-based cropping systems on biodiversity: FlorSys

As for the herbicide tolerant case study, the existing generic FlorSys model (Colbach, 2014) has been extended to (i) adapt it to maize-based cropping systems and their specific weed flora, (ii) to consider a multi-field landscape situation and (iii) to be able to use FlorSys to assess weed resistance evolution.

The input variables of FLORSYS consist of:

- the above-ground climate (evapotranspiration, radiation, temperature, rainfall and radiation) for each simulated day;
- a description of the simulated location: soil texture and depth as well as latitude;
- the initial weed seed bank (i.e. seed density for each weed species and for each cm soil down to 30 cm);

- the cropping system during the whole simulated period, comprising the crop sequence including cover and undersown crops, the date of all operations (e.g. sowing, harvest) and their characteristics (e.g. sowing density, depth, pattern and crop variety for a sowing operation).

The heart of FLORSYS is a generic life-cycle consisting of a succession of life-stages chosen for their interaction with cropping system components and light competition.

The initial version of the FLORSYS model was developed at the field scale; it quantified the effects of cropping systems (crop succession, cultural techniques) and pedo-climatic factors (weather, soil texture) on the annual life-cycle of weeds (seed survival, dormancy, germination, plant emergence, light interception, biomass accumulation, seed production) and was initially parameterized for weed species emerging in autumn and in early spring. The following adaptations were made to meet AMIGA purposes:

- parametrize additional maize-related weeds and introduce them into FLORSYS;
- add a Lepidoptera indicator to an already existing series of indicators related to production effects and impacts on biodiversity;
- make it possible to use FLORSYS at the landscape level;
- model weed resistance to glyphosate;

The adaptation of Florsys to AMIGA needs is further described in “D7.4 Adaptation of FlorSys to maize cropping systems” and is not reported here.

2.2.2 Impact of Bt-maize on non-target Lepidoptera: the brisKar package

In the case of non-target Lepidoptera, the concept of the exposure model developed by Perry *et al.* (2010, 2013) has been expanded in order to (i) design a spatially-explicit exposure model for both the pollen dispersal and the spatial dynamics of Lepidoptera and (ii) account for the temporal dimension of the exposure model (phenology of non-target Lepidoptera and different flowering periods of maize.

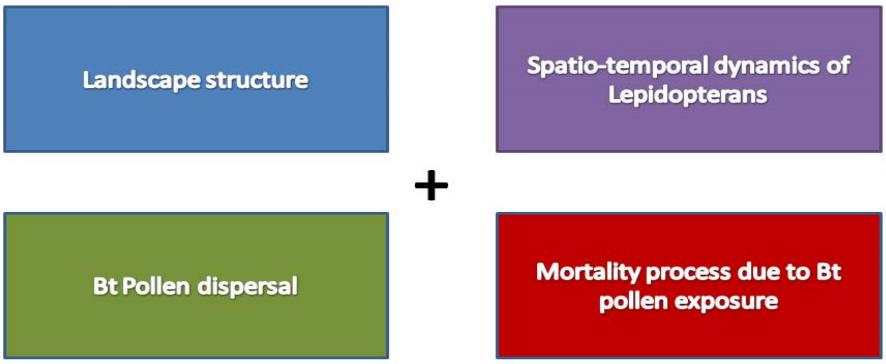

Figure 2-2 Main components for assessing the impacts of Bt maize cultivation on non-target organisms at a regional scale

A generic package has been developed (brisKar) to account for four components (see Figure 2-2):

- Landscape structure : actual landscape patterns (maize fields, field margins, other fields and habitats) are explicitly described ;
- Non-target Lepidoptera dynamics. The exposed larvae are described by a marked spatial point process whose parameters can be adapted to biological data;
- Pollen dispersal. The dispersal of pollen is modelled as a convolution between the sources of pollen (maize fields) and a dispersal kernel; actual pollen deposition on host plants results from accumulation of pollen and loss processes: accumulation results from successive dispersal/loss events and daily climatic conditions (rain) drive loss processes;
- Toxicokine/-toxicodynamic (TKTD)**.** The temporal dynamics of the internal concentration of toxins within individuals (toxicokinetic part) is described by a model based on an ordinary differential equation; the internal concentration of toxins governs the occurrence of lethal or sublethal effects.

The briskaR package has been developed in the R software environment for statistical computing and graphics (R Core Team, 2015). This package is licensed under the GNU General Public License version 2 and available from CRAN (http://CRAN.R-project.org/package=briskaR). The briskaR package is composed of two main S4 classes Landscape and Individuals, and two main functions toxicIntensity() and ecoToxic(). Both classes contain spatial data, which are incorporated with the sp package (Pebesma and Bivand, 2005; Bivand et al., 2013). Temporal structures are implemented in the Individuals class and methods with default R data objects such as array indexed by time. Methods allowing the simulation / loading of objects of the classes Landscape and Individuals are provided in the package. The function toxicIntensity() provides, given a landscape and sources emissions, the spatio-temporal concentration of pollen. The 11 function ecoToxic() provides, given a landscape and a population, the internal concentrations and effects (e.g. survival rates) of pollen within individuals. Furthermore, a generic function plot() allows to visualize data contained in objects of classes Landscape and Individuals. The classes, the associated methods and functions and data contained in the package are further described in Walker et al. (2016).

2.3 Use case scenario

The foreseen use case scenario is in 3 steps:

1. Select and export formatted data;
2. Run exposure models;
3. Import and visualize model outputs.

If this scenario does not include a direct integration of models into the software for database, it allows a better management of models evolution and also to create a generic scenario that can be easily extended to other models without having to manage the complexity and the load of integrating a model in a software. In this scenario, developments are made to create exports of files in a format ready to use with the model and to create import modules for the model outputs and specific tools to visualize these outputs.

The export interface allow user to select data spatially and temporally (see Figure 2-3 and Figure 2-4).

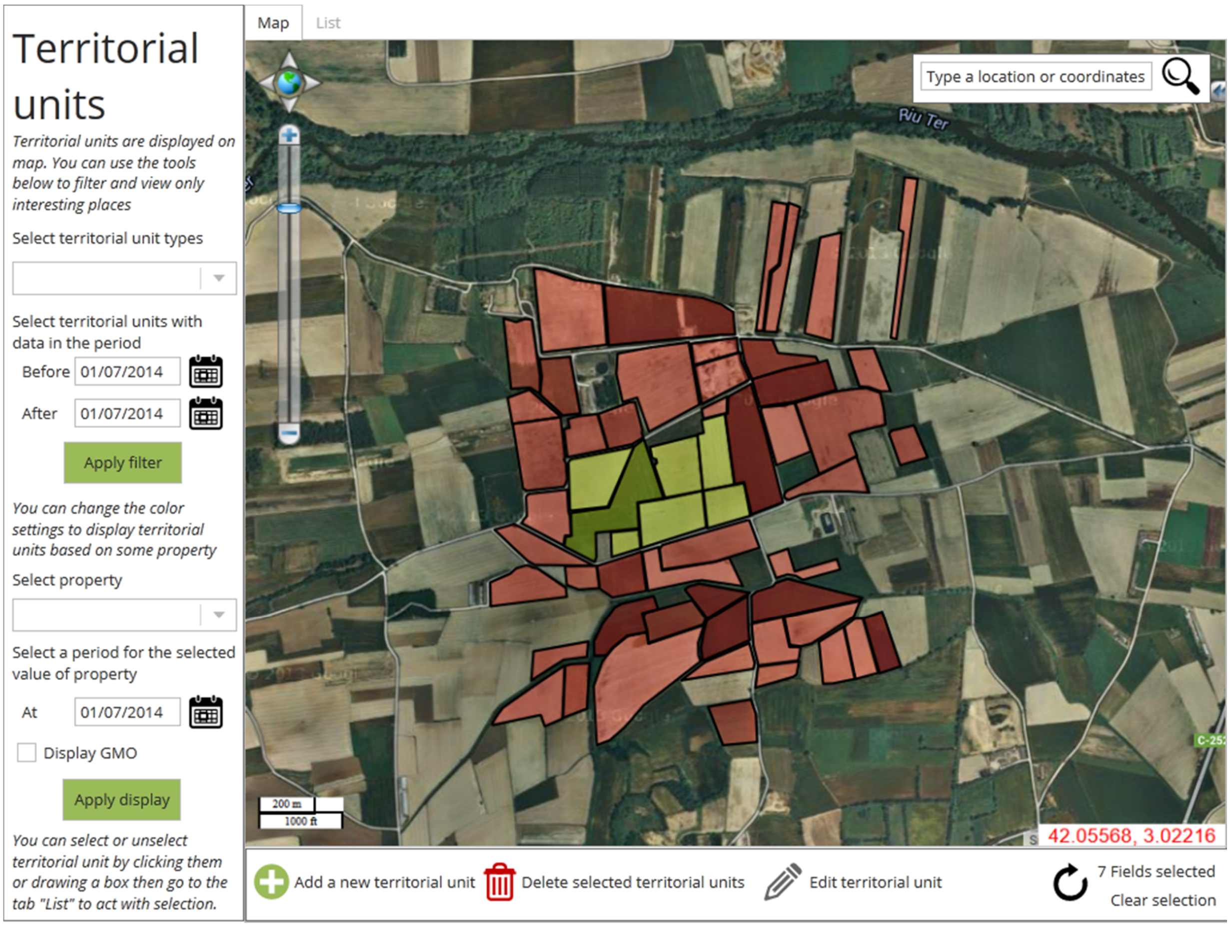

Figure 2-3 Mockup of GIS selection interface to export files for models

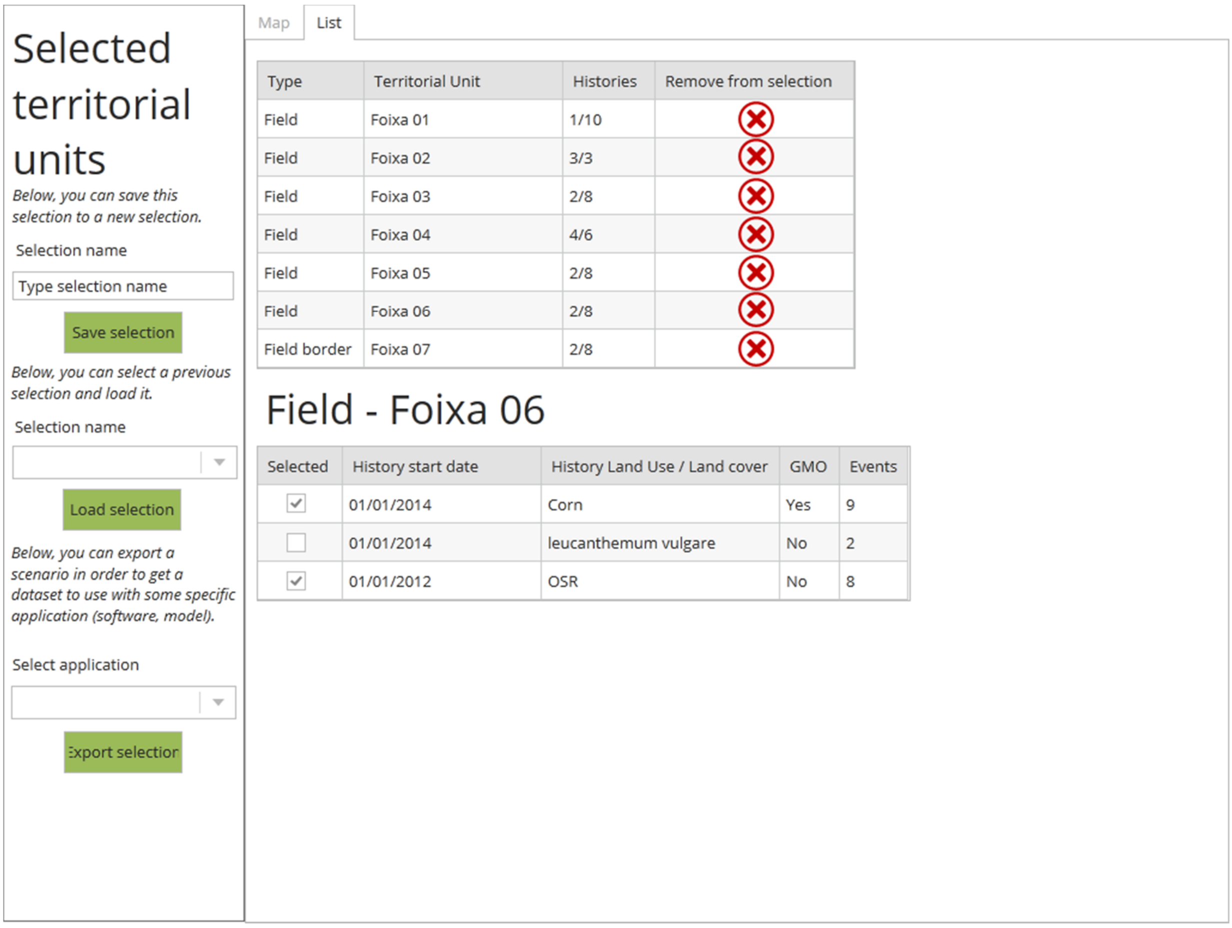

Figure 2-4 Mockup of detailed data selection to export files for models

The import interface allow user to visualize results depending on the selected model

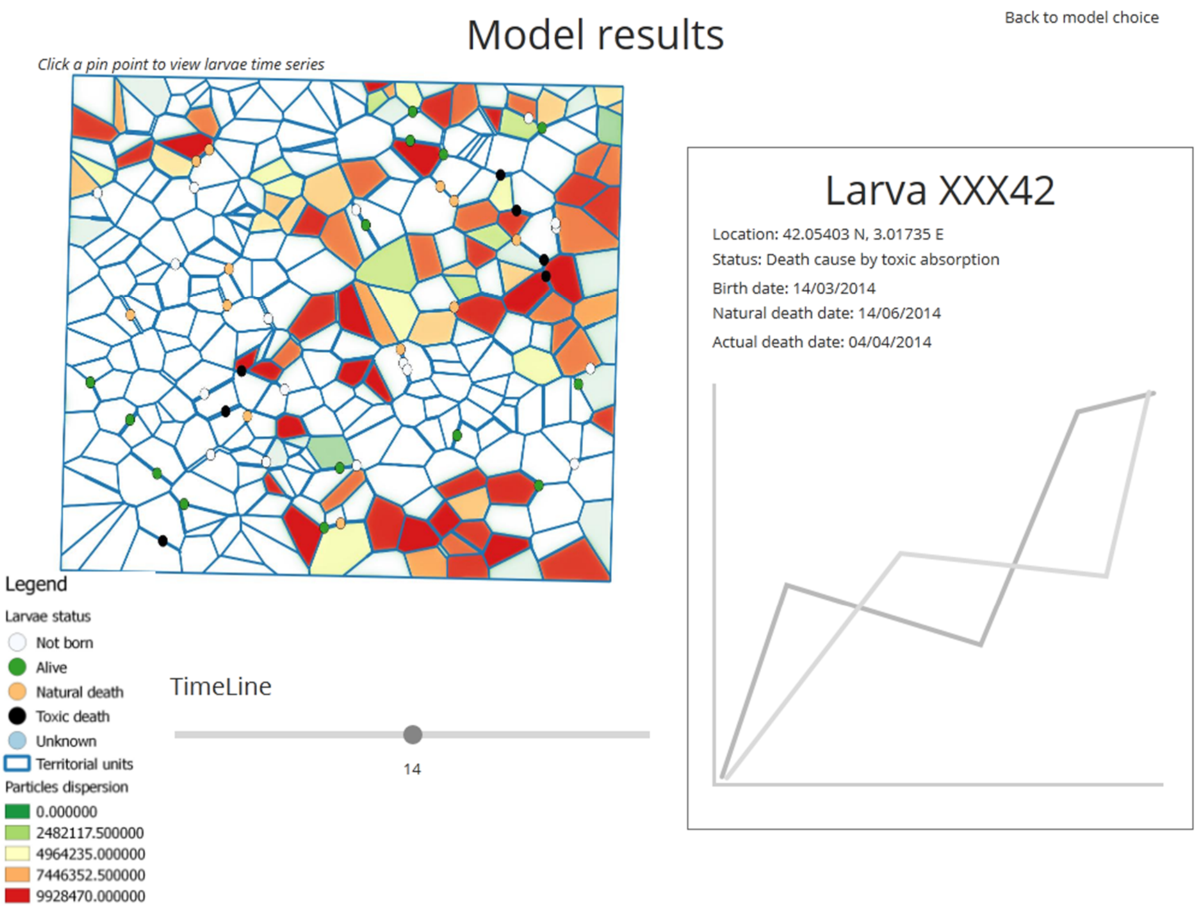

Figure 2-5 Mockup of vizualisation interface for outputs from INRA Bt maize exposure model

Figure 2-6 Mockup of vizualisation interface for outputs from INRA Florsys exposure model

3 Discussion and perspectives

This work was based on the study of possible interactions between the database built for the AMIGA project and two exposure models built by INRA. The database allow to store heterogeneous, spatialized and temporally defined data such as the context of a field (crop, variety, sowing date) and ground observations (larvae, flowering, pollen emission …). The models developed by INRA use such data as input. It is thus possible to create interaction between database and exposure models. This could be achieved either by implementing the models in the database software or by implementing specific exports that create files formatted so as to feed the exposure models.

The solution for creating exports has selected since it is a more scalable way to take into account the fact that models can require further evolution or to easily create and extend a library of models that could interact with the software.

In the same manner, it is possible to implement import module for model outputs that could then be reused by other models or shared with application users for analysis.

Since the two models of INRA have not been validated to be used out of research context, the modules to export and import and visualize results has not been developed. Yet all technical studies has been made and shown that it could be done by adding a new "selection and export" module. In this module, user could search data, select them then select an export type (Florsys model for example) and gets its data. Once model has run, he could upload the results of the model to create new dataset available for other users and also visualize them in an adapted module. If visualization module is rather specific to the model and often not reusable for another model, it is easy to implement new types of exports and/or imports (up to 5 man days of development).

The combination of the database and models can be relevant to increase velocity between researches to industrialized contexts. It is a source of innovation for decision making new tools to help improving landscape organization and crop patterns to lower risks and increase capacity of collaborative use by researchers, crop consultants / advisers or even farmers.