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Real time pest modeling through the World Wide Web: decision making from theory to praxis

Petros Damos[1,2], Sotiris Karabatakis[2]
[1]Laboratory of Applied Zoology and Parasitology, Department of Plant Protection, Faculty of Agriculture, Aristotle University of Thessaloniki, Greece; [2]WebScience Research Group, Mathematics Department, Faculty of Sciences, Aristotle University of Thessaloniki, Greece
e-mail: damos@agro.auth.gr

Abstract: In this work we present the way in which information technology can be used to support Integrated Pest Management (IPM). In particular we have developed simple handling software that crawls through the *www* and performs weather data mining and storage. In a second stage we extend the already developed software and develop a forecasting system to perform real time pest forecast through the *www*. At the current stage of development the system performs trial predictions for three fruit orchard key pests in 100 distinct geographical regions distributed all over Greece. The software and the related forecast system can virtually extend its functionality for any pest of interest given its species specific temperature thresholds for development. Functionality of the data mining software can potentially extend and mine open weather data at any location globally through the *www* and further stores them for any use (*i.e*. crop, pest and disease modeling and forecasting, precise farming etc.). The system was launched on January 2012 and its prediction performance passes currently an evaluation phase.

Key words: Integrated Pest Management, Information systems, pest forecasting, smart phone application, linked data, information technology, precise farming

Introduction

Apple, peach and pear are all worldwide deciduous fruit trees and of major economic importance in Southern Europe and the Mediterranean regions and usually all of these crops share common problems in pest management. Particularly, Lepidoptera larvae in fruit orchards are the most important pests, followed by aphids and mites. Among the most serious Lepidoptera species are the codling moth *Cydia pomonella* Linnaeus, the oriental fruit moth *Grapholitha molesta* (Busck), the summer fruit totrix moth *Adoxophyes orana* (Fisher von Röslerstamm) (Lepidoptera: Tortricidae) and the peach twig borer *Anarsia lineatella* Zeller (Lepidoptera: Gelechiidae).

In order to reduce yield losses due to the above species, farmers go for calendar based chemical sprays rather than need based applications. The traditional use of non-selective insecticides is associated to a variety of problems including: environmental effects, insecticide resistance, negative impacts on natural enemies, and safety for pesticide applicators and the food supply.

Integrated Pest Management (IPM) is a decision-based process, involving coordinated use of multiple tactics for optimizing the control of all classes of pests (insects, pathogens, vertebrates and weeds) in an ecologically and economically sound manner.

Traditionally, IPM programs use current, comprehensive information on the life cycles of pests and their interaction with the environment. From a practical standpoint this relies on the development and application of accurate monitoring techniques, action thresholds and the use of phenology models (Welch *et al*., 1978; Dhandapani *et al*., 2001; Samietz *et al*., 2006; Damos & Savopoulou-Soultani, 2012a).

Phenology models serve to predict the exact time of the phenological development of pest populations. However, most existing approaches in modeling insect phenology are theoretical and manual based. This means that although thresholds and phenology models are available for several pests, they are not used on a regular basis due to the absence of automatic real time forecasting services.

Professionals in the agricultural field, such as growers, extension agents, and researchers, need a facility to predict region specific pest population emergence and forecast its dynamics throughout the season. In this work we describe the functionality of a pilot real time pest forecasting and information system that has been developed. In particular we developed a web interface which provides real time prediction for *A. lineatella*, *G. molesta* and *A. orana* and address the limitation of supporting users with precise forecast of adult emergence, by browsing cumulative moth captures associated with formal temperature recordings throughout Greece.

Material and methods

Phenology models

Several non-linear regression functions (logistic and or/sigmoid) that relate accumulated degree-days and cumulative moth emergence were tested and incorporated to the system (refer to Damos and Savopoulou-Soultani, 2010; 2012a for details). The lower temperature threshold (LTT) for *A. lineatella* was set at 11.4 °C (Damos & Savopoulou-Soultani, 2008), at 7.2 °C for *A. orana* (Milonas & Savopoulou-Soultani, 2000) and at 10 °C for *G. molesta* (Damos & Savopoulou-Soultani, 2012b).

The method of Baskerville & Emin (1969) was used to calculate daily degree-days from minimum-maximum air temperature data. Degree-days accumulated after the 1^{st} of March.

Software development

The technical procedure of software development was divided in two phases. The first consists of the acquisition of the weather data, while the second performs daily population projections through the web. We use the open NOA (National Observatory of Athens) meteorological stations network to gather weather data. The network consists of about 200 automated Davis type meteorological stations connected through the web providing real time hourly open weather data. We further use custom PHP data miner and constructed a simple algorithm, having as core the phenology models and which draws weather data and performs region specific real time moth population projections.

In particular we have developed a customized WebGrabber (WG), written in PHP for data harvesting. The WG performs connections to all the available weather stations of the NOA’s network and downloads .txt data files. Data are further stored on a local MySQL server for future use and archiving.

On a second stage we developed a simple HTML web interface where the user can choose his area of interest from a list, or make use of a Smartphone GPS sensor, to make real time region specific population projections based on the free available empirical models.

Decision process model and forecasting algorithm

In order to integrate the empirical based phenology models into a decision system the following algorithm was developed (Figure 1). The first step involves the definition of BIOFIX (which usual falls at specific time points or is related to specific developmental event of the species). All information is stored on local MySQL server and is related to the daily temperature recordings. In the next step, temperature recordings are 'transformed' to Degree-days and according to predefined methods (*i.e*. average method, modified averaged, modified sine wave method or other) and are further summated when higher than the lower species specific developmental threshold.

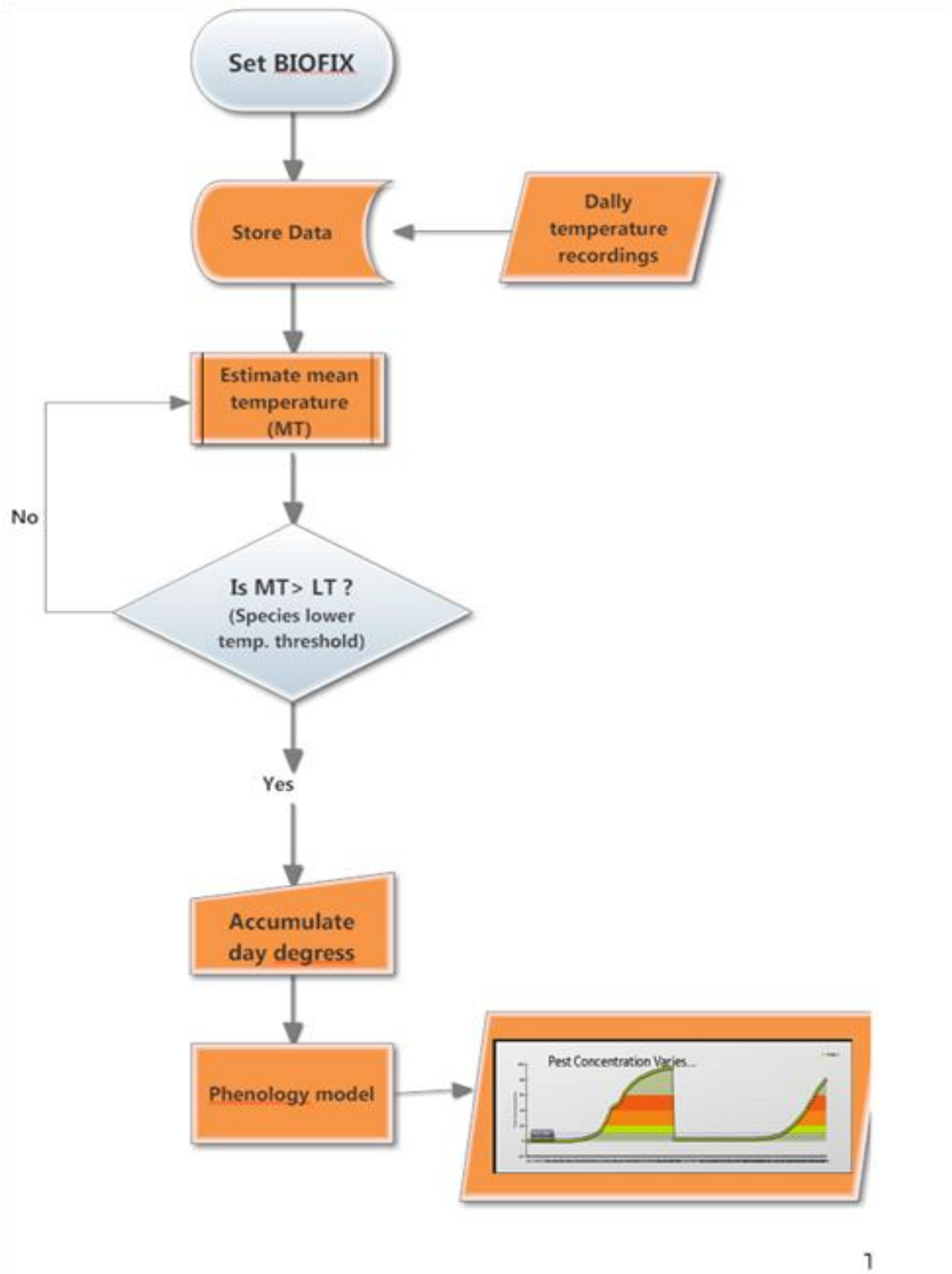

Figure 1. Chart flow of the decision process model and the related algorithm that was developed for the deployment of the real time forecast and pest information system.

The final step includes the input of accumulated degree-days into the core (phenology) equation and to generate daily outputs (moth emergence for each generation). Additionally, if cumulative emergence is higher than some predefined thresholds (*i.e.* 15%, 50%, and 85%) an alert indication appears which notifies the user to take management pesticide type related actions.

Results and discussion

We developed a pilot weather data mining software and information acquisition forecasting system useful for real time decision making for Integrated Pest Management.

The system is simple handling and uses current *web-3* technologies and open access weather data instead of conventional remote sensing which is traditionally been used in precise agriculture and pest management. Currently a pilot version incorporates the data mining software the degree-day phenology algorithm and performs daily population projections for Lepidoptera moths, providing daily warnings if populations exceed thresholds.

The software and related forecasting system has relatively low cost, is simple handling and uses current *web-3* technologies to link and access open weather data. Additionally, its architecture is based on the use of already available data from governmental and related meteorological agencies and institutions instead of the development of cost expensive weather remote sensor networks.

The system is currently passing an evaluation period and runs on a private shared server provided by 000webhost. The web interface of the developed forecasting system is depicted in Figure 2.

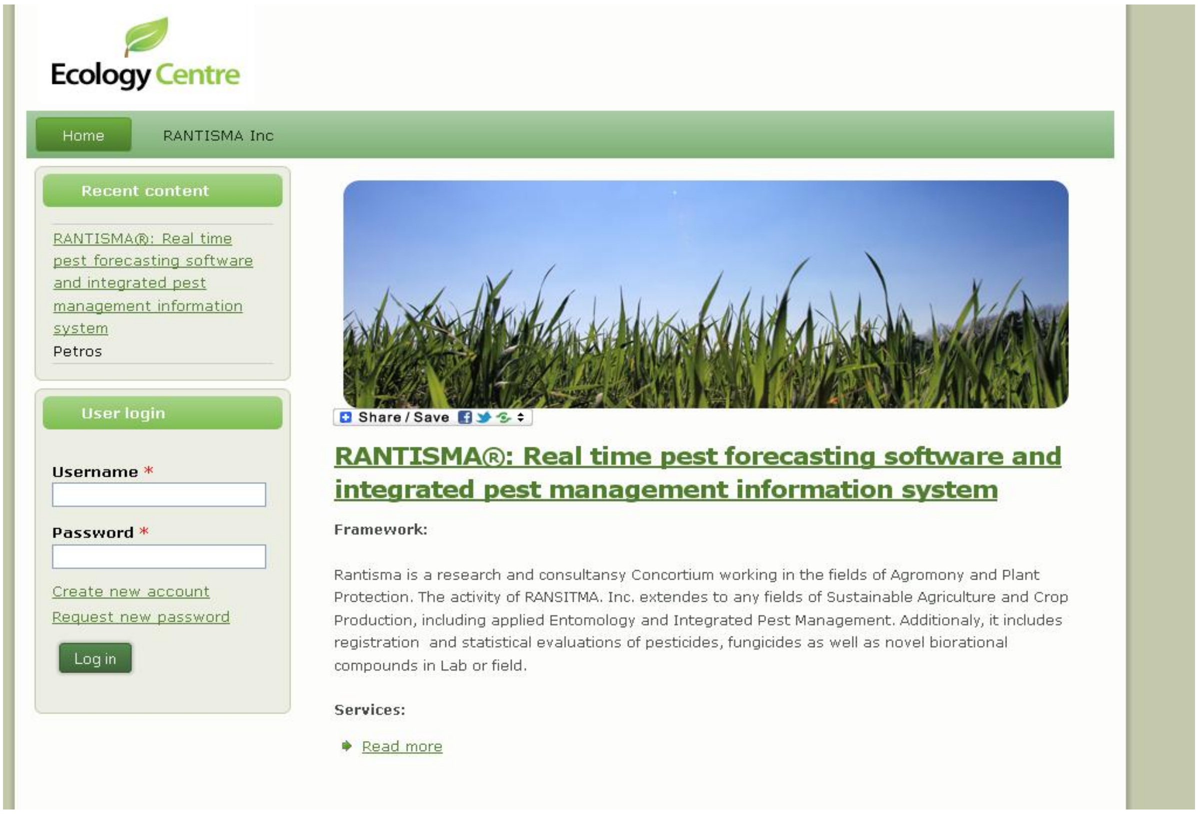

Figure 2. Web-Interface of the pilot pest forecasting system (accessible at www. rantisma.gr).

Moreover, we have run some benchmarks to test reliability on stress periods like simultaneous access requests and reached acceptable results. The architecture of the system is quite simple and can be virtually extended to incorporate population projections for any species of interest given its temperature thresholds for development.

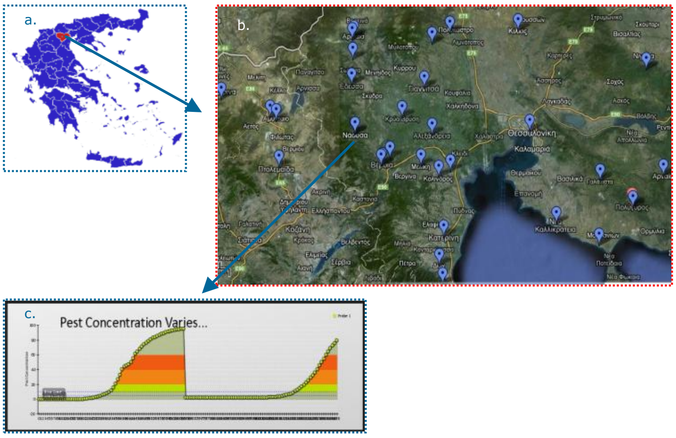

Figure 3. Representative agricultural region in Northern Greece (a), in which the ERMES® smart phone location aware system application (b), performs daily forecast for test key-pests.

Insight interest we further developed a software application called: EmeRgency MEssage System (ERMES®) and is compatible with the *www* data mining software (Karabatakis & Damos, 2012). The projection scheme of the system is presented in brief in Figure 3. The user can either register through the webpage or have access to the forecasting service and thereby be regularly informed via e-mail or through SMS having the related Smartphone android application.

Although efforts to provide local forecasts based on weather data have been made in previous and other related studies, in most cases the delivery of automatic forecast system having wider applicability stubs on high costs for procurement, complexity and maintenance and/or, on non continuous ‘feed’ of the system with weather data. Based on the above framework IPM can be significantly improved by the use of new emergent information web technologies. The pest information system can be used by extension agents, consultants, growers, and other clientele providing forecast along with effective decision support for managing agricultural commodities. Thus, real time forecasting and decision making systems can assist at the farm level crop growers in determining whether pesticides or other measures should be applied.

Conclusion

IPM is an essential component of Integrated Fruit Production (IFP) since it provides an economical and high quality fruit production framework, giving priority to ecologically safer methods, minimizing the undesirable side effects and use of agrochemicals, to enhance the safeguards to the environment and human health. However, many millions of EU Integrated Fruit Production Orchards that would have received accurate pesticide application are not treated in precise times due to the lack of formal pest information forecast and related treatment information disseminated. To the best of our knowledge the current pilot software consists of the first real time pest forecasting system that uses current web-3 technologies and free access weather data instead of traditionally-conventional remote sensing. Evaluation of the software performance and prediction accuracy are currently in progress. The later is considered as an important prerequisite for wider applicability in Integrated Pest Management. Additionally, potential population distribution and the development of pest risk mapping modules, in which the phenology models are implemented in a GIS environment that allows for spatial – global or regional – simulations of species spatial distribution and mapping is our next goal.

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