Fuzzy Logic and Geographic Information Systems for Pest Control in Olive Culture

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Abstract: Combining an open source Geographical Information System like GRASS-GIS, Mapserver, and the computer languages Perl and PHP it was developed a flexible Decision Support System (DSS) based on fuzzy logic. The DSS researched use data gathered from a current research and demonstration project, concerning the distribution of the Olive fruit fly (Bactrocera oleae) according to several environmental conditions like soil cover, temperature, topography. This data-set continues to be collected for Integrated Pest Management (IPM) purposes. Fuzzy clustering helped to found the most important biophysical parameter that influences the development of the disease into a specific space. The DSS system researched is flexible enough to be applied in Agricultural services with similar problems, in an effort to decrease use of pesticide and to comply with more agro-environmental measures. The present DSS can be applied in similar environmental modelling problems like pollution, population behaviour and ecosystem change.

Key-words: Spatial Variability; Integrated Pest Management; Fuzzy Logic; Decision Support System; Geostatistics.

1 Introduction
Integrated Pest Management (IPM) implemented recently worldwide in an attempt to reduce the use of pesticides and improve food quality. To apply IPM is necessary an accurate knowledge of the plague's biology, ecology and local conditions.

Geographical Information Systems (GIS) is a broad field of scientific research [1, 2] and with given proves for modelling situations like: urban development, impact of pollution in human population [3], hydrology [4] or pesticide in environment [5]. The impact of GIS in certain fields like agriculture has been so intense that in present days the use of GIS is considered a different branch of procedures known as Precision Agriculture [6]. The success of GIS is due to its ability to store, display, present and model data, this ability have also evolved as computers have evolved in the past 20 years. The major objective of Precision Agriculture is to increase the productivity of yield with a more rational approach on resource consumption, to achieve such objective, a considerable amount of field data should be gathered so that scarce resources will be directed to the most needed parts of the production field [7]. This should reduce nutrient surpluses and environmental pollution [8], aside from the used of chemicals like pesticides and herbicides.

Recent advances in GIS are in the direction of developing platforms that run from the Internet, were users can use the common browser to accesses a specific GIS platform to perform the same tasks previously done in Desktop computers (commonly referred as Web 2.0), some examples of this potential have been applied to, monitor dust storms [9], exploration and analysis of ecological phenomena [10], collect information and monitor the evolution of disease in trees [11]. These systems have a big potential to model several environmental situations and to report situations "on-the-fly".

One recurring tool used in GIS is fuzzy logic [12], this has been used to model situations where imprecision, uncertain or ambiguous data exists [13, 14]. Fuzzy logic either alone or using the resources of a GIS platform, has been applied in a variety of ecological and environmental applications, ranging from mapping to modelling, evaluation and
prediction tasks. Application examples include the mapping of agroecozones [15], degraded soils [16], modelling of regional drought [17], environmental degradation [18], population dynamics [13, 14, 19], evaluation of land resources [20], landscape regionalization [21], environmental impact evaluation [22, 23] and temporal and spatial changes of salinity [24].

Many of the classifiers, models and expert systems discussed by these authors use fuzzy logic to capture and integrate expert knowledge about the phenomena being studied using heuristic IF-THEN rules. One practical application of fuzzy logic/GIS to plague modelling has been the system SOYPEST in India [25], another practical example was the use of neuro-fuzzy to cluster populations of the olive fruit fly (Bactrocera oleae) [26].

Objective of this work was to use tools such as geographic information systems and geostatistics to generate information that helps to optimise Integrated Pest Management of olive orchards, creating a decision support system based in fuzzy logic model and using the web.

2 Methodology
The present study was divided in three stages: Creation of a flexible and easy to establish decision support system based on a fuzzy model/WebGIS approach. The second stage is to determine the fuzzy logic rules using a cluster methodology so that the plague’s behaviour can apply to a model. The third stage is the culmination of all the initial research determining on how to control successfully the plague using environmentally friendly mitigation measures.

The olive orchards used for this study were located in southeast Alentejo, Portugal. The area is commonly known as the "bread basket" of Portugal, a region of vast open countryside with undulating plains and rich fertile soil. All the major towns are mainly reliant on agriculture, livestock and wood. Data sets of the biophysical parameters of the study area were used to create the decision support system and the modelling rules. The reason for this data-set is due to its availability from the AGROS 802 project: "Coberturas do solo no olival em produção biológica e convencional. Estabilicimento de campos de demonstração", which gathered data for Integrated Pest Management in olive orchards of the study area. The local olive fruit cooperatives will continue monitoring the plague even after the end of the present study.

A network of traps was established and surveyed with a Global Positioning System (GPS) to develop digital maps of the study area using geostatistics. Aerial photographs integrated with the GPS maps as a series of data layers using the ArcGIS software. This data-set is currently being gathered from 21 georeferenced locations using pheromone traps, but in the future more olive fruit cooperatives will be used to acquire data in an effort to increase the number of sampling points and precision of predictions.

GRASS-GIS and ArcGIS was used create weekly maps of the appearance of the plague for southeast Alentejo. Was investigated also the most important biophysical parameters that influence plague behaviour. The study used some freely available GIS information like the Environmental Atlas of Portugal or the soil use/type/capacity maps. Digitalized topographic military maps of the region used to create other GIS layers like 3D-topography (Digital Elevation Model. Other information like current agricultural practices and vegetation cover gathered from aerial photos of the area.

The next stage of this work is the creation of a GIS-Mapserver-Fuzzy Logic system (Figure 1). The GIS layers will be stored and organized in a spatial database (PostGIS) which connects to the GRASS-GIS software. To optimize the system will be researched interactions between programs. The Mapserver software will allow accessing the system from the Internet and that all the operations performed from a GUI (Graphical User Interface) run from a common Internet browser.

Figure 1- Decision support system diagram.

3 Results
The olive fruit fly (Bactrocera oleae GMEL.) and olive moth (Prays oleae BERN.) were the two most troublesome pests for olives in the study area. The olive fruit fly adults were very active from
September until October with the maximum of catches during the first week of October. Olive fruit fly infestations this year started at the beginning of September and did not reach high levels until the second week of October.

Ordinary kriging was the geostatistical method used to create weekly prediction maps of olive orchard plagues. The data was normalised and after trend removal, we choose the most appropriate semivariogram that fits the data.

Figure 2 is showing the prediction map of olive fruit fly after ordinary kriging. It can be seen that a large area at the northeaster part of the experimental zone present higher risk of olive fruit fly appearance. Crossing with information from environmental factor maps it can be concluded that the higher the temperature and the lower the humidity in the summer may increase the plague presence. The maps of hours of sun or frost did not influence the spatial distribution of the plague.

![Figure 2 – Prediction map after ordinary kriging of olive fruit fly in South Alentejo (darker colour indicate higher presence of the pest in traps).](image)

In figure 3 it can be seen that two areas of olive moth appearance exist in the study area. Both of them were away the river influence, at low altitude, low evapotranspiration and higher precipitation in relation with their surroundings. The probability to find olive moth in high altitude or close to the river was low proving that spatial distribution of plagues and other spatial information like topography can be important to determine relations between microclimates and plague and to identify problematic locations.

Unlike conventional models, fuzzy models are generally based on IF...AND...THEN rules, IF population_plague=low AND temperature = high THEN risk_for_plants=medium. Fuzzy sets and fuzzy rules have been considered a useful framework for data modelling as it describe data using linguistic terms representing concepts. Furthermore, each rule has the possibility to correctly describe several instances. Experts are able to formulate the required fuzzy rules. However, this method of knowledge acquisition suffers from several drawbacks including inefficiency [19].

![Figure 3 – Prediction map after ordinary kriging of olive moth in South Alentejo (darker colour indicate higher presence of the pest in traps).](image)

Fortunately, fuzzy rules can be elucidated automatically. Among the available tools, clustering, as a general tool to find structure on an otherwise unstructured data, emerge as a most useful methodology [27, 28, 29]. Our goal includes an analysis of clustering role in the overall design process, i.e., to understand what role it plays and how the results – information granules - facilitate further detailed development of models or enhance interpretation aspects.

4. Discussion and conclusion

The study of olive orchards that use cover crops as organic method of pest control show that they are disperse. This pest control method show moderate effectiveness because of the disconnected and
scattered distribution of orchards. Although, is a low cost and ecologically favourableness method making it a promising alternative to synthetic pesticides and ploughing. It was studied the creation of a biological barrier zone using the existing cover crop orchards in Moura area and connecting them with seminatural areas using alternative production species.

Simple geographically restricted amendment treatments like pheromone traps, species selection, cover crops and more could be decided for specific locations of the heterogeneous landscape. Localized high-risk areas could be treated without spending money for the whole area and damaging the environment with unnecessary use of chemicals [30]. The understanding of the spatial distribution pattern of pests is important to determine strategies of pest control in an economic and environmentally friendly way.

Olive plague maps can supplement local knowledge and further georeferenced data will furnish the necessary information to the grower to orient protection and production according to environmental conditions. The implementation of spatial data manipulation techniques, such as GIS and Geostatistics, to create weekly plague maps for olive orchards at regional level, can give the possibility to identify high-risk areas, which may not otherwise been identified. Estimated plague behaviour can provide to the grower relevant information.

Localized physical barriers can give an additional value to the combat strategy for plagues in olive culture. Taking into consideration the location of biological production orchards it could be created a biological barrier zone around high-risk areas that could save money and decrease environmental impact. Site-specific plague management methods will decrease environmental impact of excessive use of pesticides and improve product quality.

Similar results found in Azores [31] showing that spatial distribution of plagues and spatial information establish relations between microclimate and plagues. Although, more study in the relationship between geographic conditions and plague behaviour are necessary.

This decision support system can be used by the Agricultural cooperatives of the study area in an effort to decrease use of pesticides and to comply with more agro-environmental measures. It is expected that the system developed could be used in other situations were environmental modelling is necessary, like crop/plague management, forest management, fire prevention, study of pollution dispersion, population relationships, ecosystem change, etc.

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References


