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DEVELOPMENT OF AN EXPERT GEOGRAPHIC SYSTEM FOR MONITORING OF INFESTATION AND OF CONTROL INTERVENTIONS AGAINST PESTS (CPLAS). APPLICATION TO THE MANAGEMENT OF RPW

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SUMMARY
The Red Palm Weevil (RPW), *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae), is one of the major pest of palm trees in Greece where has been spread mainly in the last seven years. RPW monitoring is difficult and when the pest is detected, its management to save the palm tree is intricate. For an efficient and integrated monitoring of the RPW, Geographical Information Systems (GIS), Location-aware systems combined with the scientific knowledge of experts on the palm trees physiology and the RPW biological cycle can be used. In the current study, a framework for the monitoring of the infestations of palm trees (mainly *Phoenix canariensis*) by the RPW, using the platform CPLAS, is presented under field conditions in “Pedion Areos”, the central park of Athens in Greece,. The proposed framework can facilitate the treatment process of the RPW by utilizing GIS and decision support systems. An algorithm for the estimation of the infestation risk based on a ten scale classification is also presented and incorporated into the CPLAS platform. Finally, the evaluation of the system in real time conditions was performed in ”Pedion Areos“ park and some early results are presented.

Key words: *Rhynchophorus ferrugineus*, Red Palm Weevil (RPW), GIS, CPLAS, Infestation risk.

RESUME
Le Charançon Rouge du Palmier (CRP), *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae), est l’un des principaux ravageurs des palmiers en Grèce où il s’est répandu surtout depuis 7 ans. Surveiller le CRP est difficile ; quand le CRP est détecté, sa gestion pour sauver les palmiers est compliquée. Pour une surveillance intégrée efficace du CRP, on peut associer un SIG (Système d’information géographique), un système de localisation intelligent et les connaissances scientifiques d’experts de la physiologie des palmiers et des cycles biologique du CRP. Nous présentons ici la plate-forme CPLAS mise en œuvre en situation naturelle pour la surveillance des palmiers (principalement *Phoenix canariensis*) infestés par le CRP dans le parc “Pedion Areos” situé au centre d’Athènes. Le système proposé, qui combinant un SIG et un outil d’aide à la décision, peut ainsi faciliter le processus de gestion du CRP. Un algorithme qui permet d’estimer le risque d’infestation à partir d’une échelle à 10 niveaux est associé à la plate-forme CPLAS et est aussi présenté. Une évaluation du système a été réalisée en temps réel dans le parc ”Pedion Areos“ et nous en donnons quelques résultats préliminaires.

Mots-clés : *Rhynchophorus ferrugineus*, Charançon Rouge du Palmier (CRP), GPS, CPLAS, Risque d’infestation.

INTRODUCTION

The Red Palm Weevil (RPW) *Rhynchophorus ferrugineus* (Olivier) (Coleoptera: Curculionidae), is one of the major pest of palm trees in the Mediterranean Basin during the last decade. Specifically, for Greece the RPW has been spread in the last seven years. Although, pheromone is available for its monitoring, the riddling and cryptic behavior of the RPW makes its control difficult. Frequently, the pest or its symptoms are visible when it is difficult to save the palm tree (EPPO, 2008; Dembilio *et al.*, 2009; Dembilio and Jacas, 2011; Dembilio and Jacas, 2012). Several control methods have been used within an Integrated Pest Management strategy, such as the phytosanitation (destruction of the infested palm trees, dendrosurgery or treatment with microwaves), acoustic detection (Soroker *et al.*, 2004; Potamitis *et al.*, 2009; Gutiérrez *et al.*, 2010), use of entomopathogenic nematodes or insecticides and use of pheromone traps for adult monitoring and mass trapping (Faleiro, 2002; Dembilio *et al.*, 2012). For an efficient phytosanitary control of RPW and due the spatio-temporal characteristics of the RPW problem, it is necessary to make a complete and thorough recording of the current infestation parameters, such as the location of each palm tree, the RPW population characteristics, the species of each palm tree, and the infestation risk. Due to the clumped nature of palm weevil population, there is a need of adopting preventive management practices in and around plantations infested by RPW (Faleiro *et al.*, 2002).

Additionally, the data of the recorded palm trees must be available to a wide area and up to date, so as to be possible to estimate the infestation risk and take the necessary measures. After the first record of RPW in Greece in November 2005 (Kontodimas *et al.*, 2005), surveys were conducted in Greece and Cyprus in order to obtain data about the distribution of the infestation. The coordinates of the points of the infestations were recorded with a GPS device (Kontodimas *et al.*, 2006). GPS technology with mobile Geographical Information Systems (GIS) can provide location-aware monitoring and facilitate the collection of real-time agro-environmental data and in particular distribution patterns of a pest population (Sciarretta *et al.*, 2001; Papadopoulos *et al.*, 2003; Hetzroni *et al.*, 2009). Mobile GIS is an integrated technology which combines mobile computing, the Internet and GIS. With a mobile GIS, users can access personally selected spatial, temporal and attribute information unhindered by location limitations. Spatial query and spatial analysis is no longer limited to a fixed environment and can be accessed at any time and at any place (Wenzhong Shi *et al.*, 2009). A Personal Digital Assistants (PDA)-based record-keeping and decision-support system in cucumber production was developed invoking a mobile GIS (Ming Li *et al.*, 2010). Because of the growth of the wireless Internet, PDAs and handheld computers, the focus of research and development has been changed to the real-time mobile GIS to provide services based on the location of the user (Yun *et al.*, 2006, Pontikakos *et al.*, 2008; Pontikakos and Kontodimas, 2010; Pontikakos *et al.*, 2010; Pontikakos *et al.*, 2012). These monitoring systems have also been developed for pest management (Ellison *et al.*, 1998; Mahaman *et al.*, 2002; Cohen *et al.*, 2008; Pontikakos *et al.*, 2010; Pontikakos *et al.*, 2012).

In this paper, a framework for the monitoring of the infestations of palm trees (mainly *Phoenix canariensis*) by the RPW under field conditions in ”Pedion Areos“, the central park of Athens in Greece is presented. This is accomplished by the utilization of the platform CPLAS which is a platform for the digitization, risk estimation, decision support, and optimization of operations, management and web mapping of agricultural and urban areas in real time conditions. In this manner, the infestation risk by the RPW is detected at early stages providing efficient treatment. The proposed framework can facilitate the treatment process of the RPW by providing the necessary technological tools such as GIS and decision support systems. An algorithm for the estimation of the infestation risk based on a 10 scale classification is also presented and incorporated into the CPLAS platform.

MATERIAL AND METHODS

THE GENERAL CONCEPT

The general concept of this paper, in order to monitor the pest - infestation and control the innervations against pests is based in the logical assumption that in order to solve a pest problem, we have to take into account all the main parameters that cause that problem. The first step is the estimation of the infestation of the monitored area using a classification methodology of the infestation at local level. In the case of the RPW, the problem is analyzed taking into account the biological cycle of the pest, the climate conditions, the species of the host palm, the palm physiology and characteristics, the spread of the infestation and the symptoms of the host palm. The problem of the RPW has spatio-temporal characteristics due to the host palms distribution in an area, the dynamics of the RPW population and the variation of the infestations in time. The decisions that the experts must make to control the pest in an area, have to arise after the classification of the infestation of each palm tree of the area. This is not a trivial task and the assistance of the technology such as mobile GIS is absolutely necessary in order to make reliable decisions. The mobile GIS integrated with the expert knowledge can be used as a spatio-temporal information system that provides assistance to people towards the monitoring of the RPW problem in an area, to the estimation of the infestation risk and to the on time decision-making for the control of the pest. The proposed concept is presented in Figure 1

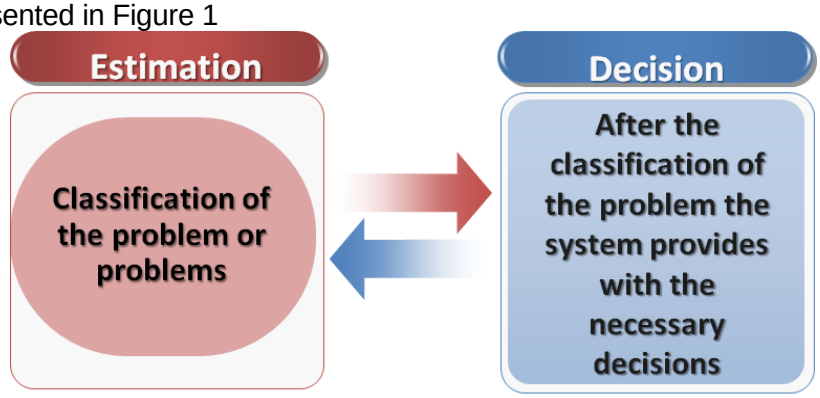

Figure 1. The general concept (Concept général)

MONITORING OF INFESTED AREAS

GIS users create the geographical information layers of the infested area and the decision methodology based on the experience of the entomologists. The information layers include the position and the characteristics of each palm tree and the background maps. The decision methodology includes questionnaires and multimedia content that assist the Mobile GIS users to monitor an area and estimate the infestation risk of each palm tree. To do that, Mobile GIS users use handheld devices such as PDAs to gather any information available and enter the estimation risk to the system. GIS users gather this information via the internet, analyze it and send the analyzed data to the entomologists who take the appropriate control actions. The system is integrated with a Web GIS server that provides the necessary functionality for the storage, analyses and distribute the data. The system design is presented in Figure 2.

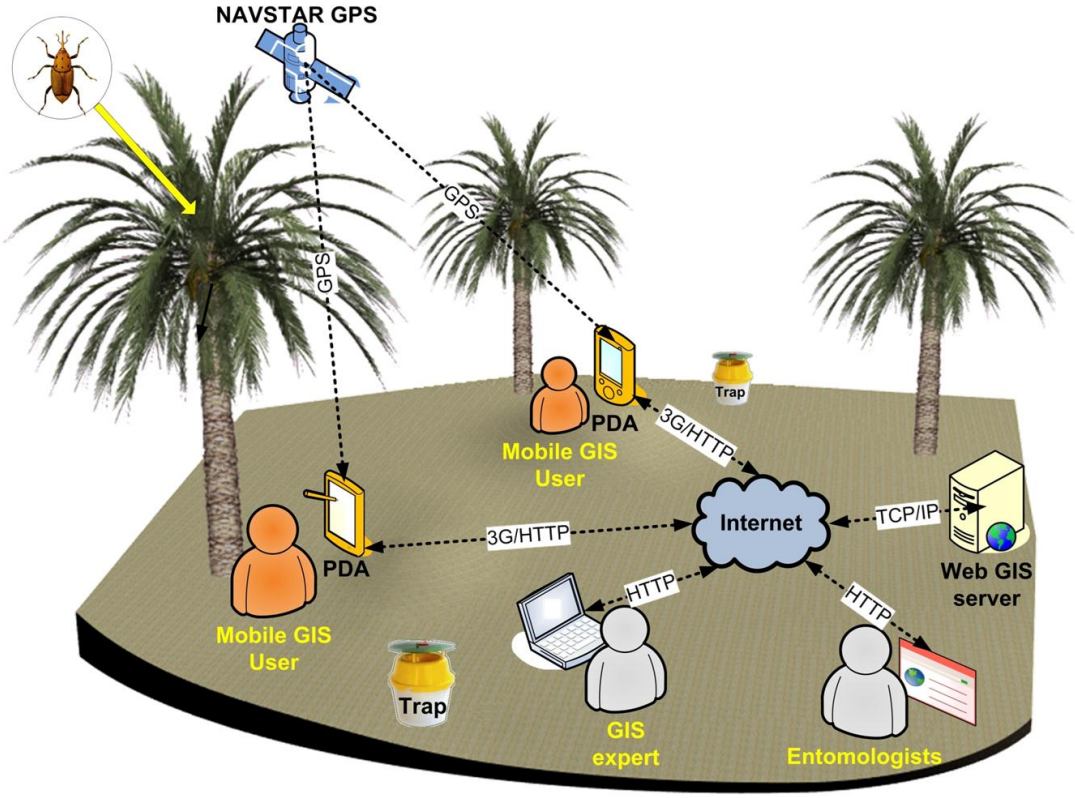

Figure 2. The monitoring system design (Structure du système de surveillance)

The monitoring methodology of the infested areas includes the steps that presented in Figure 3.

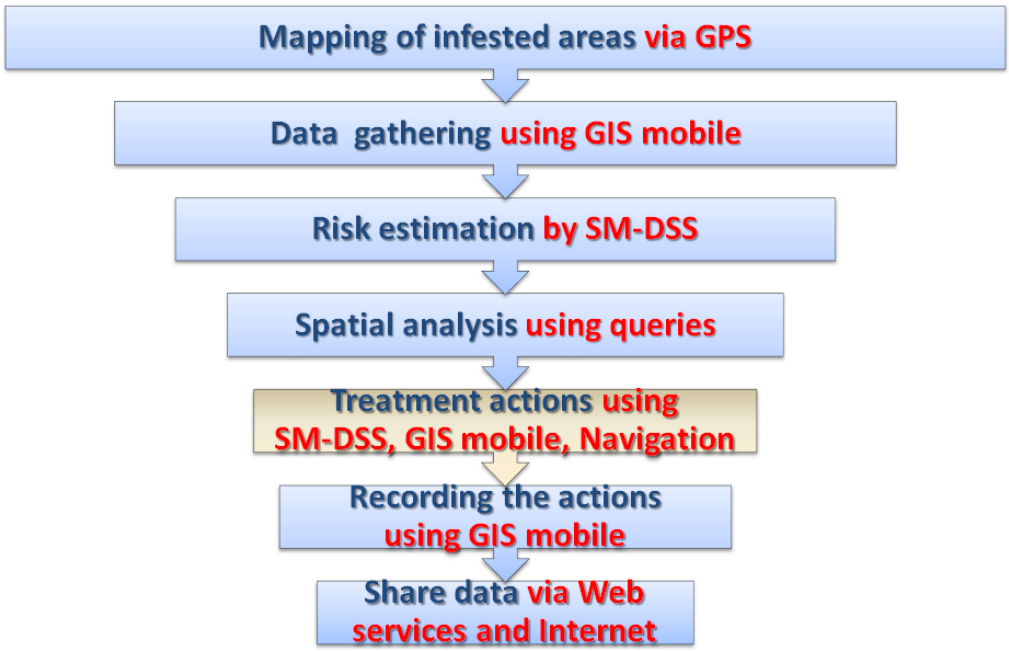

Figure 3. Methodology of the monitoring of the infesteted areas (SM-DSS: Spatial Multimedia Decision Support Systems (Méthodologie de surveillance des zones infestées; SM-DSS : Outil d'Aide à la Décision à Multimedia Spatial)

DATABASE OF THE MONITORING PROCESS

During the monitoring process of the RPW infestations, the collected data are include the palm tree characteristics, actions, findings, remarks, photos, the infestation risk and reports. The database of the monitoring process is presented in Figure 4.

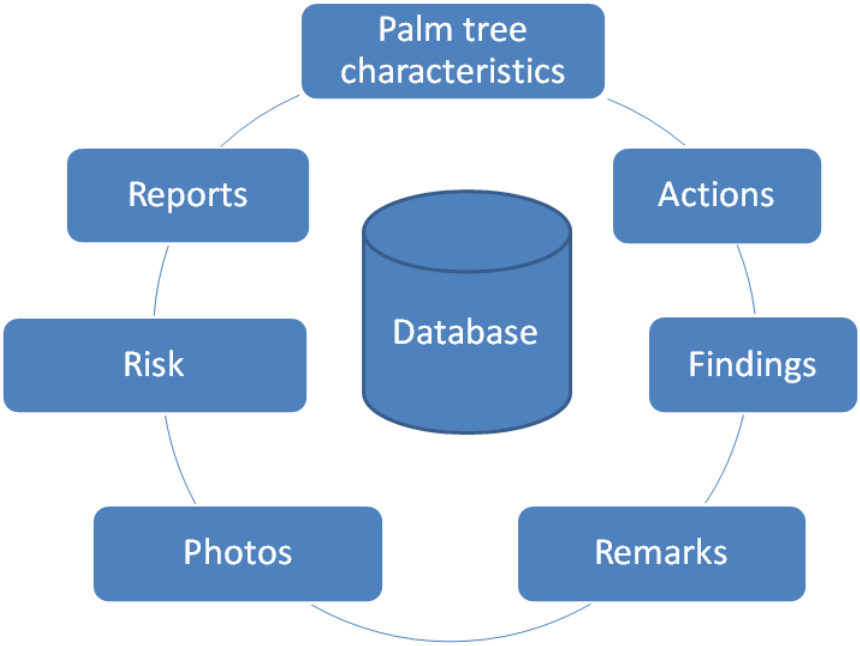

Figure 4. Database of the monitoring process (Base de données pour le processus de surveillance)

The characteristics of the palm trees include information such as the size, the species and the location of each palm tree. The actions include data about the treatments such as dentro-surgery, sprayings and removal of the palm trees. The findings concern the findings of the RPW (adult insects, pupae, larvae, or cocoons) in the infested palm trees or in traps that are located in the infested area. The infestation risk is the classification number that provides the degree of the infestation of each palm tree based on the visual and macroscopic symptoms of the canopy and the trunk of each palm tree. The infestation risk is estimated periodically in time so as to determine the control actions. The system has the capability to take and store multimedia content such as photos of the palm trees and export reports of selected palm trees.

APPLICATION TO THE MANAGEMENT OF RPW

LOCATION AND OBJECTIVE

The main objective of this paper was the implementation of the proposed concept using mobile devices for electronic monitoring of palm trees and the management of the infested palm trees according to their visual symptoms and the degree of the infestation risk. The implementation of the proposed concept was started in the year 2010 at the central park of Athens Greece, ”Pedion Areos” (Figure 5). The park is approximately 30 ha and had about 288 ornamental palm trees mainly *Phoenix canariensis*.

Figure 5. ”Pedion Areos“ park in Athens, Greece (Parc “Pedion Areos” à Athènes, Grèce)

MONITORING THE INFESTATION RISK

The estimation of the infestation risk is based on a 10 scale classification of the infestation risk. The class 1 is the class where the palm tree has no infection, while the class 10 indicates that the palm tree is dead. The decision tree of the classification of the infestation risk by the RPW is presented in Figure 6. For each class of the infestation risk a recommendation about the control strategy that must be followed is provided (spraying, surgery, removal etc.).

SOFTWARE

The software that was used to monitor the palm trees and estimate the risk infestation of each palm tree in ”Pedion Areos“ was the CPLAS Phoenix which is a platform for the digitization, risk estimation, decision support, optimization of operations, management and web mapping of agricultural and urban areas. The CPLAS has capabilities to perform queries, take decisions and create reports. The system provides the user with multimedia content about the visual symptoms of the infestations of PRW on palm trees, assisting in this way to a more accurate estimation of the infestation risk of each palm tree.

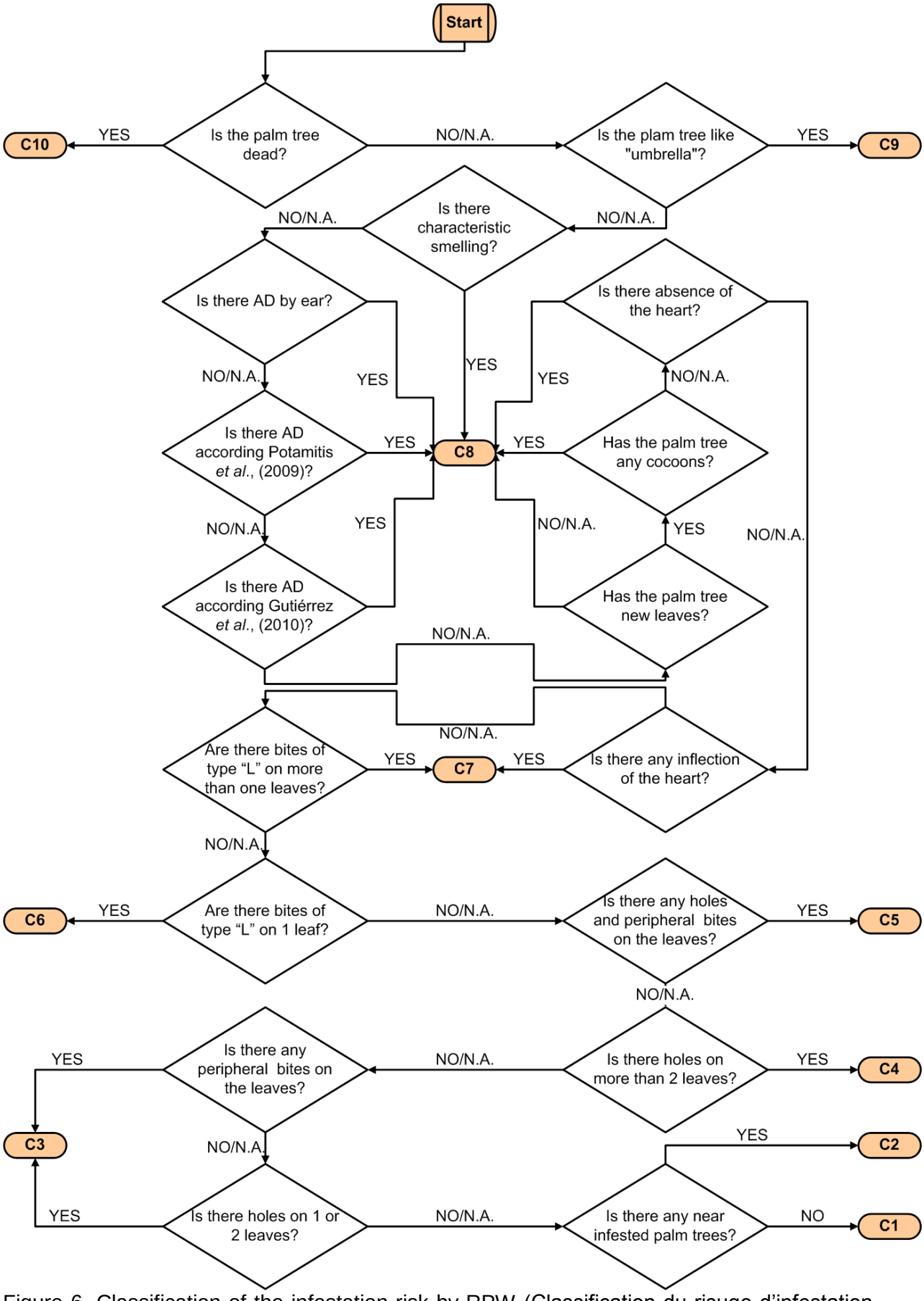

Figure 6. Classification of the infestation risk by RPW (Classification du risuqe d’infestation par le CRP)

RESULTS

GIS LAYERS

The main GIS layers considered in the case study of the park ”Pedion Areos“ were the polygons of the parterres, the background map, the points of the palm trees and the points of the traps. The GIS layers are shown in Figure 7.

Figure 7. GIS layers of the study area (Couches SIG de la zone étudiée)

CHARACTERISTICS OF PALM TREES

The diameter of the trunk of each palm tree was recorded using the CPLAS software. Two categories where used: a) palm trees with trunk smaller than 80 cm and b) palm trees with trunk above 80 cm. The diameter of each palm tree was estimated by measuring the trunk 10-20 cm above the ground using only one measurement. The percentage of each diameter category of the palm trees in the study area is presented in Figure 8.

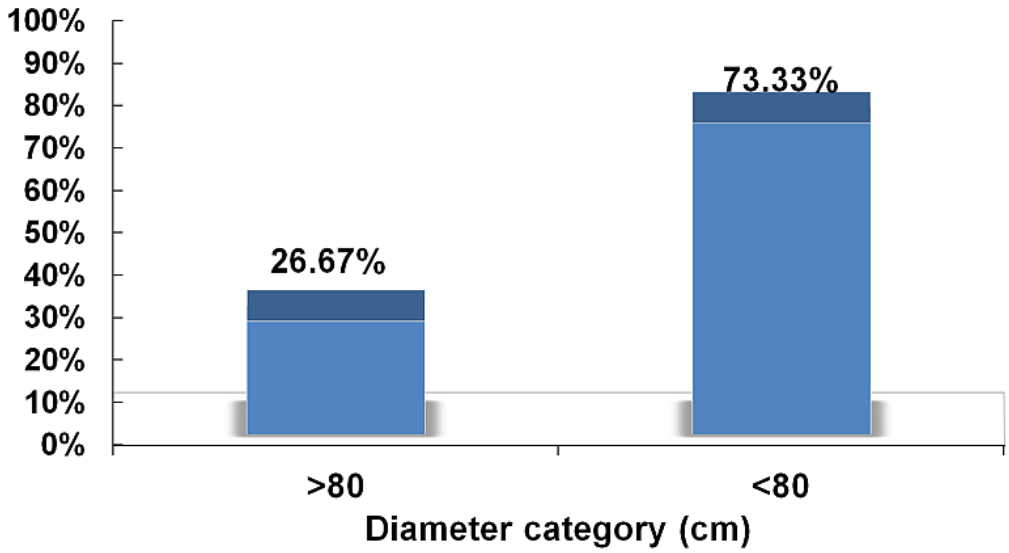

Figure 8. Percentage of the diameter categories of the stems of the palm trees in the study area (Pourcentage des classes de diamètre du stipe des palmiers dans la zone d’étude)

The species of each palm tree was recorded using the CPLAS software. The percentage of each palm tree species in the study area is presented in Figure 9.

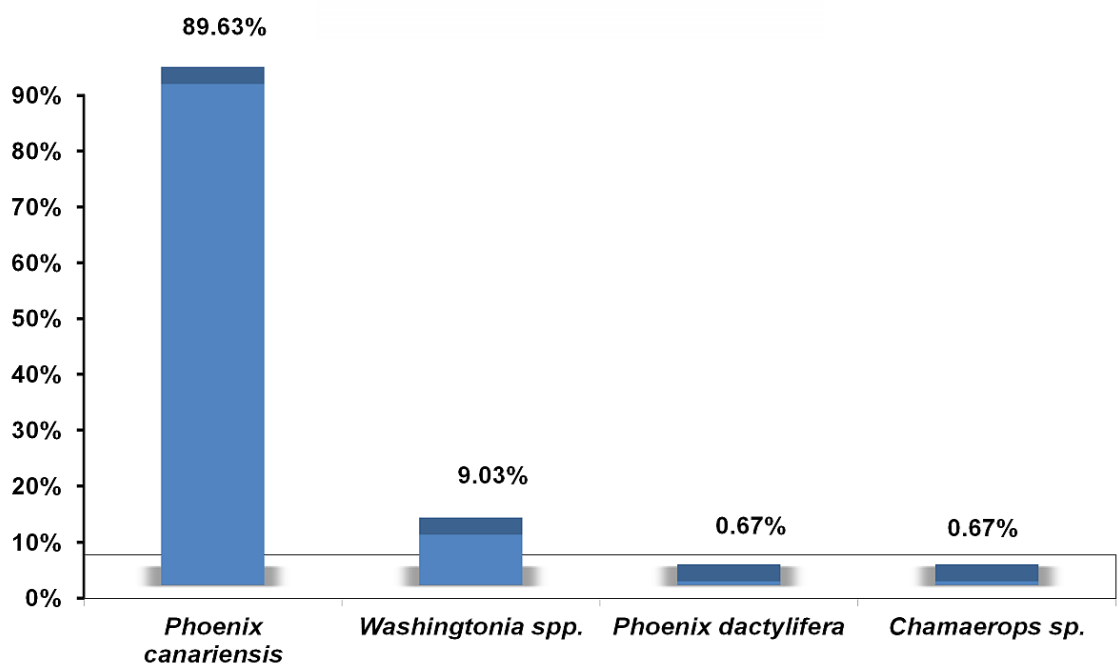

Figure 9. Percentage of each palm tree species in the study area (Pourcentage de chaque espèce de palmiers dans la zone d'étude)

USERS' OPINION

The opinion of the users was recorded using simple questionnaires. The questionnaires concerned the simplicity and the easy use of the Graphical User Interface (GUI), from the user's perspective. The early results indicate that the system is simple and easy to use even from those users who are not so familiar with new technologies or the problem with the RPW. The degree of the assistance that the system provides to the user through the decision support system was also recorded. The users considered that the decision support system helped them greatly in finding the infestation risk for each palm tree using the decision process.

CONCLUSION

This paper describes a framework for the early detection of the RPW on palm trees and for making the appropriate decisions and treatments to avoid the spread of the insect. The proposed framework can facilitate the treatment process of the RPW by providing the necessary technological tools such as GIS and decision support systems. The early results from the evaluation of the system in real time conditions revealed that the system is simple/ easy and helpful/ cooperative to users.

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