

Elaboration of a thematic map on the pests that attack banana crops (*Musa x paradisiaca*) using sigma tools

Elaboracion de un mapa tematico sobre las plagas que atacan a los cultivos de banano (*Musa x paradisiaca*) utilizando herramientas sig

Pedro Vélez Duque¹

Abstract: The banana (*Musa x paradisiaca*) is a species in great demand as part of the food supply because it provides many nutrients such as a high content of sucrose, fructose, glucose and fiber; as well as potassium and vitamin B6, it is classified as a fruit of high energy value. Taking this into account we can say that it has a high demand in its production as an export product, the banana contributes decisively to the economy in our country, but can be affected in plants during their stages of development by various pathologies and pests such as Bacteriosis, Black Sigatoka and Black Weevil. Some of these pests are vectors of diseases that spoil the presentation and quality of the fruit for consumption. That is why this work has been developed seeking to represent through GIS tools which will give us the help to plot the pests and diseases in the banana crop delimited to a specific area.

Keywords: Export, Banana, Demand, Production, Pests, Diseases

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Correspondence author

pvelez@uagraria.edu.ec

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¹ Msc. Agrarian University of Ecuador, Faculty of Agricultural Sciences, pvelez@uagraria.edu.ec, <https://orcid.org/0000-0001-5886-4387>

Resumen: El banano (*Musa x paradisiaca*) es una especie con gran demanda al ser parte de la alimentación debido a que aporta muchos nutrientes como un gran contenido de sacarosa, fructuosa, glucosa y fibra; así como también potasio y vitamina B6, se clasifica como fruto de alto valor energético. Teniendo en cuenta ello podemos decir que tiene una alta demanda en su producción como producto de exportación, el banano contribuye de forma decisiva a la economía en nuestro país, pero pueden encontrarse afectaciones en las plantas durante sus etapas de desarrollo por distintas patologías y plagas como son la Bacteriosis, Sigatoka Negra y Picudo Negro. Algunas de estas plagas son vectores de enfermedades que estropean la presentación y calidad de la fruta para su consumo. Es por ello que se ha desarrollado este trabajo buscando representar mediante las herramientas SIG las cuales nos brindaran la ayuda para poder graficar las plagas y enfermedades en el cultivo de banano delimitado a una zona específica.

Palabras clave: Exportación, Banano, Demanda, Producción, Plagas, Enfermedades

Introduction

In Ecuador, banana (*Musa x paradisiaca*) is one of the main production crops in the country and has expanded over the years, maintaining some obsolete and almost unchanged production characteristics. In the last 10 years in commercial banana plantations in Latin America and the Caribbean there has been a considerable reduction in productivity despite the fact that the application of advanced technologies and inputs has been more costly and intensive. This is due to the accelerated change and deterioration of the physical, chemical and mainly biological factors of the soil.

For the banana crop, precision agriculture tools have been developed to meet the needs of monitoring and understanding the state of the product from planting to sale. In recent years, tools have begun to emerge from the perspective of agriculture, such as the implementation of a thematic map showing the main banana crop pests, allowing the analysis of the mutual relationships or the magnitude between the potential supply of bananas, in order to determine conflict levels or categories. For this reason, it is necessary to carry out an intensive and careful field sampling, such as geo-referenced sampling with the help of GIS (geographic information system), since, in this way, a map can be made where the symptoms in the crop can be observed from planting and harvesting.

This article will pretend the elaboration, application and use of didactic maps to demonstrate the delimitations of the diseases that are carried out within the banana production systems using GIS tools. The work presents a theoretical framework containing information about the crop and its properties, the tools and optimal requirements for the elaboration and implementation of the pest map in the crop soils and the benefits that the implementation of this tool will bring.

With the rapid development of information and communication technology, the new farm management system is designed as what is now called precision farming, better defined as location-specific farming. The management system uses global positioning systems and geographic information systems to increase the yield and efficiency of inputs used. This is achieved by accurately determining the spatial variability of soil conditions and crop requirements.

Currently, in banana production, large, medium and small producers do not take into account the importance of phytosanitary maintenance, which must be carried out correctly in cultural activities, as this fruit is in high demand and consumption worldwide, therefore, frequent care is required. Therefore, it must meet the high nutrient requirements of the crop and therefore be able to compensate for the loss of nutrients to the elements.

Within the banana production system there are production standards that must be met, one of the factors that lead to decreased productivity are the pests that attack the banana crop. One of them and the most economically important at national and international level is the fungus *Fusarium R4T*.

In the present research work will seek to expose the importance of the use of satellite images captured by remote sensors mounted on space satellites that will also allow us to analyze our crop to propose an adequate environmental management. The advantages of using these new technologies and how it would increase the profitability of agricultural land will be discussed. This type of tool allows us to manage to bring technology to the agricultural sector. For this, we will develop thematic maps and provide an extremely friendly solution, focused on people in the field who need this type of information, and plan activities, automate processes and report to the surrounding community.

Yellow Sigatoka (*Mycosphaerella musicola*)

According to (Fagiani, 2007) mentions that the development of the disease is linked to temperature and relative humidity content on the leaf surface, being necessary that both act simultaneously. There are two different forms; *Mycosphaerella musicola* (sexual) and *Pseudocercospora musae* (asexual). For germination of conidia (asexual), 25°C, RH 100% for three hours is required. For ascospores (sexual) 25°C, RH 95%, time 8-9 hours. The incubation period is variable and depends on environmental conditions. In general it can be between 15-35 days.

Black Sigatoka (*Mycosphaerella fijiensis* Morelet var. *difformis*)

Black sigatoka is the foliar disease that represents the main limiting factor in banana and plantain production worldwide; in Colombia it was first detected in the Urabá region, from where it has spread to the warmer regions of the country where banana and plantain crops are grown. The disease affects the leaves of the plant and can be recognized by the presence of a large number of stripes and spots, especially under the leaves, which accelerate drying and death. As a consequence, bunches and fruits have a lower weight compared to those obtained from healthy plants. In addition, severe infections of black sigatoka cause premature fruit ripening (URABA, 2020)..

It should be noted that the rapid spread of the disease has been caused by the uncontrolled transport of diseased leaves, winds and rivers that, when overflowing, carry diseased material, which is then deposited on the banks, thus infecting existing host plants (ICA, 2012). The attack on adult plants is recognized by the large number of brown to black stripes and spots, which are most noticeable on the underside or lower part of the leaf, covering the entire leaf area, from the third to the youngest leaf.

According to (DANE, 2016), black sigatoka symptoms can be recognized through six stages:

Small yellowish-white to brownish-white lesions or spots, one millimeter long, called pinches, barely visible on the underside of the leaves, similar to those found in stage 1 of yellow sigatoka.

Initially there are some chlorotic stripes of two to four millimeters long and one millimeter wide, which turn brown to reddish brown, which can be observed at first on the underside and then appear on the upper part of the leaf, turning from brown to black.

Stage 3. The stripes elongate and widen, giving the impression of having been painted with a brush, without defined edges and brown in color, which can reach two to three centimeters in length. In addition, at this stage the formation of conidia begins, which reproduce until the beginning of stage 6.

Recognized by the presence of oval brown spots on the underside and black on the upper side.

State 5. Black spots surrounded by a black ring and sometimes a yellowish halo, with a dry and slightly sunken center.

Stage 6. Spots with a dry, sunken center, light brown to gray, surrounded by a black ring and a bright yellow halo of chlorotic tissue. If the infection is very severe, the leaf blackens, dries and dies within 3 to 4 weeks after the appearance of the first symptoms; in this case, plants before harvest lack green leaves. The highest incidence of the disease occurs when climatic conditions are optimal for the development of the fungus, the banana variety planted is susceptible to sigatoka and crop management is inadequate. The areas most affected by black sigatoka are characterized by an annual rainfall of more than 1,400 millimeters, relative humidity of more than 80% and an average temperature between 23 and 28 °C; its attack is more aggressive during the rainy season, due to the permanent presence of a sheet of water on the leaf, which favors the germination of the spores and the penetration of the fungus into the plant. The spores germinate in less than two hours when the temperature is between 25 and 28 °C, and then penetrate the plant.

Panama Disease (*Fusarium oxysporum*, *Fusarium sp.*)

According to (DANE, 2016) internal symptoms consist of vascular discoloration inside the pseudostem; brown, red or yellow lines are visible only on the external pods or in a very advanced stage may reach the internal pods. In the corm, symptoms are similar to those of the pseudostem; necrotic, dark or bluish streaks can be observed on a white background. Symptoms on inflorescences are varied; in some cases, brown or reddish spots are observed on the edge of the bract or dark spots of various sizes and distributed in different regions of the inflorescence.

It is common to observe how the roots of affected plants become necrotic or die. The rhizomes are not always destroyed; sometimes they

produce shoots that later become diseased and stop growing. In the pseudostem, yellow, reddish or purple beams are seen, with the discoloration appearing first in the outermost sheath of the pseudostem, sometimes with crazing and bad odor (Velásquez, 2016).

Describe the main pests affecting the banana crop.

Black Weevil

Scientific name: *Cosmopolites sordidus*

Description: as an adult, it is a black weevil, about 13 mm long, and its head has the prolongation of the characteristic face of the species. In this state it is not harmful. The female lays between 10 and 50 isolated eggs in holes, which burrow in the rhizomes adults larvae emerge after approximately 8 days. (INIAP, 2019).

Damage: after the larva has emerged, it devours tissues and opens a gallery into the bulb. It soon reaches a length of 12 to 16 mm, yellowish white, with a brown head. It never emerges. In this stage it lasts between two and six months, then it transforms into a nymph and after 5 or 7 days, into an adult. When a large number of larvae are present, general weakening of the plant and production of small and poorly formed bunches is noted and, furthermore, due to weakening of the bulb and pseudostem structure, the plant falls over. (INIAP, 2019).

Flake

Scientific name: *Aspidiotus destructor* and *Diaspisboisduvalii*

Damage: they extract plant tissue fluids from different plant organs such as leaves, roots, pseudostems and fruit nipples. These insects excrete a honeydew substance that facilitates the growth of the fungus "fumagina". It is observed as small concave and chlorotic spots, regardless of the type of damage generated, this can lead to the rejection of the fruit in the packing plant, due to loss of quality in the fruit. (INIAP, 2019).

Mealybug or mealy lice

Scientific name: *Dysmicoccus sp*

Description: once the eggs hatch, the nymphs remain in the capsules for a short time and then move around the plants, mealybugs are an insect pest of importance for banana cultivation, because their presence in the fruit causes the rejection of this in the destination markets; on the other hand, they can also act indirectly as a vector of banana streak virus (BSV). (INIAP, 2019).

Damage: due to its high succession activity in the tissues and the abundant production of sugary exudates that favor the attraction of ants and other insects, in addition to facilitating the development of fungi that produce fumagina, causing the rejection of the fruit in the packing plant in the place where the mealybugs are found or normal ripening is carried out. (INIAP, 2019).

Black Sigatoka

Scientific name: *Mycosphaerella fijiensis*

Causative agent: Fungus.

Symptomatology: it is observed on the underside of the leaf, about 10 to 12 days after infection with reddish colored pinches, the lesions are elongated parallel to the venation and then change to dark brown on the underside and almost black on the beam; these pinches unite giving rise to a dark spot without yellow areas in its contour, when there is high inoculation much of the tissue dries. When Sigatoka is more present, more leaves are lost, a bunch should be harvested with a minimum of 5 leaves if harvested with more leaves the fruit comes out creamy and the bunch will be rejected. (Martinez et al., 2011).

Panama Disease

Scientific name: *Fusarium oxysporum* f. sp. Cubense

Causal agent: Fungus

Symptomatology: Externally, the lower leaves of the plant show a slightly yellow coloration, with a greater prominence around the margins. Affected leaves turn bright yellow with subsequent necrosis of the leaf margins, and there is also the development of a longitudinal crack in the lower portion of the leaf sheaths of the pseudostem (Ministry of Agriculture and Irrigation, 2020). (Ministry of Agriculture and Irrigation, 2020)..

Materials and methods

The type of research that was carried out to carry out this scheme was documentary, since theses, experience articles, portfolios and reliable sources were used, which helped us a lot to improve the argument and the objectives of the knowledge integration plan. The implementation

of Geographic Information Systems (GIS), images, maps, photos by drones, these incorporate the study on the ground and the locations of the diseases in which the study of a thematic map will be carried out.

It is based on data collection, foundations for the creation of a thematic map of the symptomatology of diseases within the banana crop in CUM implementing the use of GIS tools. To obtain the thematic map, the following data must be collected: delimit and quantify areas where the productive aptitude of the land and the current use given by man are not compatible for our banana crop, taking into account the evaluation obtained from the requirements of our crop with the aforementioned data, since it has been proven that the implementation of GIS has improved the performance of crops in which it is implemented, and not only yield improvement, but also the reduction of expenses and waste.

Content analysis techniques were used following a scientific method in a systematic, objective and replicable way to carry out documentary research on how to carry out and implement the use of GIS tools in the creation of a pest map and thus be able to obtain results from it, so that we can have greater control with specific data and achieve greater performance and lower production costs.

The techniques used to develop the knowledge integration project were the creation of data, data representation, advantages and disadvantages of a pest map, non-spatial data, data capture. Projections, coordinate systems, through tutorials, to cite correctly in the APA 6th edition style and to look for valid sources for the information, in this way it will be sought to investigate and finish with all the specific objectives in a valid way using all the techniques already described.

To make a thematic map of pests it will be necessary to use various programs such as ArcGIS version 10.5 and a Google extension called Google Earth so that the data are captured in a GIS system that allows us to generate a map that allows us to identify the main pests that attack the banana crop.

Result

The work carried out by the GIS is done with special emphasis on the most economically important areas.

(Ruiz, 2014) In the formulation of an Agricultural Geographic Information System, based on the use of satellite images, thematic cartographic information, in situ surveys (GPS), different subsystems

must be considered, whose development, in some cases simultaneously and in others sequentially, will allow achieving partial results that converge in obtaining the final result: the operational functioning of the GIS. The methodology described in general terms responds to the concept of using sequential information provided by Landsat TM, ERS and/or SPOT satellites for the survey and classification of NRNR and sample segments to be selected.

This proposal is related to the possibility of using the thematic cartography produced and satellite data in an operational way in the Agricultural Geographic Information Systems: to be able to survey extensive regions through the simplified processing of a reduced volume of data and information produced or derived and from the field. To have valid statistical alternatives available to solve the deficit of updated information and make efficient use of satellite information, reducing the operating cost of the system. (Bosques, 2017).

- Definition of parameters and priority areas.
- Field study and recording of information.
- Cabinet work. Information analysis.

(Schschny, 2015) states that the method of information analysis will depend on the results obtained in the test stages, the computer discrimination of the data (digitized mapping) and recognize the spatial distribution of vegetation cover, agricultural and livestock farms, forestry and occupational trends of NRNR in a natural way. The digital analysis of information in several dimensions-fields (bands in the images) is a method that makes it possible to discriminate between different surface elements and to identify and quantify different types of vegetation and crops. The high spatial resolution of certain satellites makes it possible to visually observe, on enhanced and conveniently enlarged images, elements such as crop design pattern, shape, lot size, texture features, color, associations, etc., which in many cases have proven to be important for the identification and recognition of a particular crop pattern. The automatic analysis of these parameters, although it has begun to be incorporated as part of the processing software, is not yet definitive, so the analysis that includes the knowledge and orderly reasoning process of the professional can be very helpful and will have to be taken into consideration. The data obtained for the analysis will come from an Analysis Model used to carry out the Use, Management and Conservation Plan of the NRNR

and the estimation and subsequent management at the national level. Field information will establish the accuracy of the model and estimate the coefficients of variation or reliability of the computerized information. Several models can be tested to perform the analysis and expansion of the data (Schschny, 2015).

Comparison of results: Estimated data vs. observed data, published cartography vs. computerized cartography. Verification of the monitoring results is foreseen, through the confrontation of results obtained by estimation and data that will be obtained by actual observation. Discrepancies will allow the calibration and adjustment of the developed methodology or its rejection as an element of the information system. (Ruiz, 2014).

(Sierra, 2016) establishes that a metadata can be made, which will assist in the development of the Information System, with the multitemporal reception of images and files, the same that will be analyzed and processed in coordination and with the participation of experts, where it will proceed to carry out the applicative work for:

- Estimation of banana cultivated areas.
- Quantification of banana planted area.
- Quantification of areas affected by natural events (droughts, floods).
- The information obtained will be made available to the various users, authorities and organizations involved in policy making in the country.

Short term: develop a reliable methodology that allows the use of digitized information for the purpose of providing quantitative spatial information on: cultivated areas, areas covered with natural forests, slopes, soils, agricultural aptitudes, climate, hydrology, etc. (Jensen, 2018).

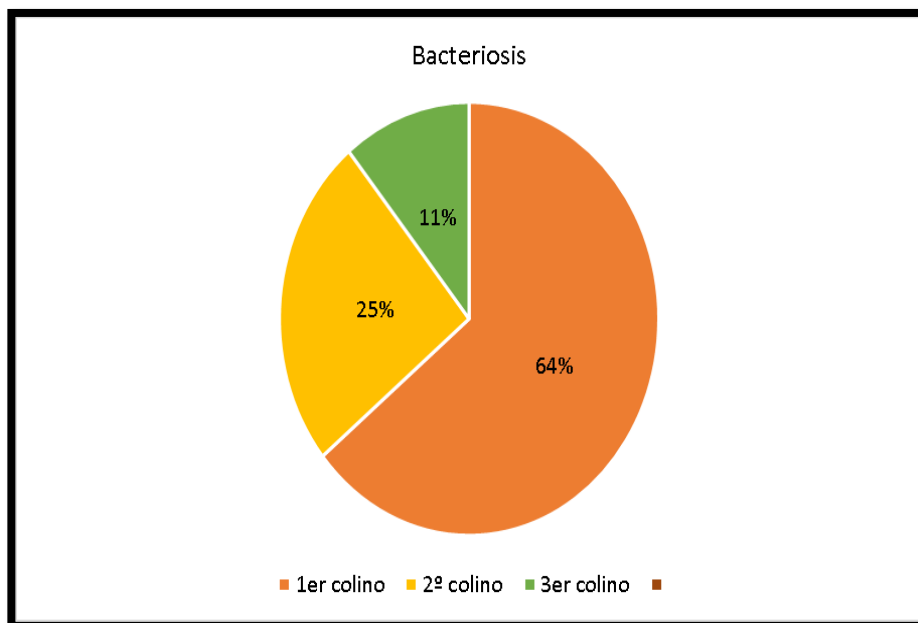
Long term: Establish a monitoring system for renewable natural resources, agricultural estimates (based on the use of satellite information). baseline information for various agricultural resource assessment and management studies or projects (Sierra, 2016).

To obtain the results of the investigation based on the first objective, to identify that there was presence of bacteriosis because and plants were observed initially and a kind of exclamation on the edge of the oldest leaves that after that advanced to the foliar lamina this gave way to the total yellowing of the same, This was followed by a total yellowing of the leaf lamina, which led to a watery translucent stain that affected the basal part of the plant, producing a certain weakening that in the long

run could cause the bending of the plant, producing a foul odor in which the tissues were affected.

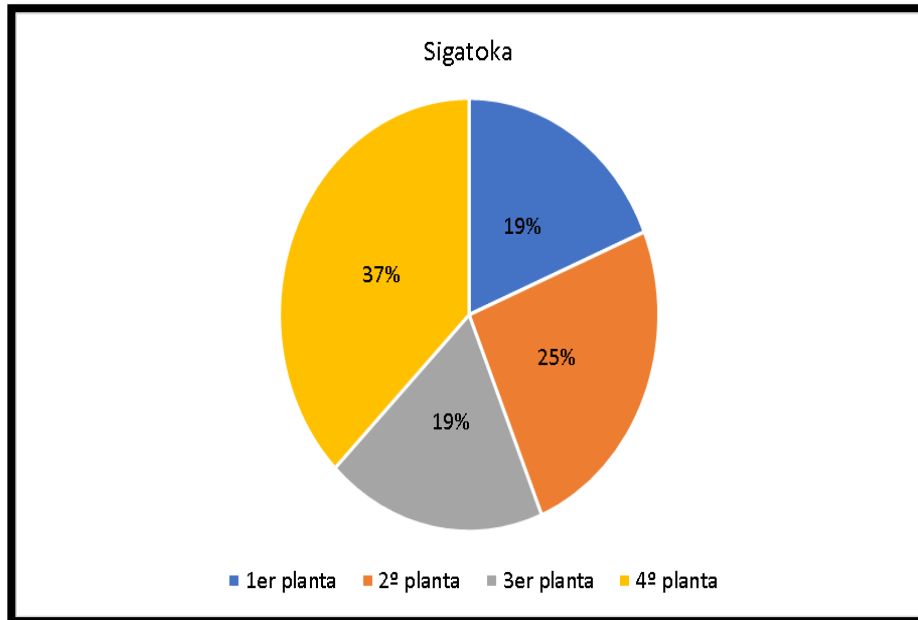
One of the causes of its affection is the bad selection of the seed or it is also caused by the tools used to generate the cultural labors within the banana production system.

Figure 1. Percentage of the cabbages affected by Bacteriosis (Vélez, 2023).



Another of the diseases that could be visualized in the research in the study area was the destructive foliar disease that attacks all the musa genus is characterized by the presence of stripes and spots that are totally noticeable in the leaf organ of the silver crop, which accelerate the cessation and subsequent death of the leaf, taking into account that if there is no leaf in the banana production system, the vital function of the plant, which is photosynthesis, cannot be generated, The maximum number of leaves for banana production not to decrease is from 8 to 12.

Figure 2. Percentage of plants affected by Sigatoka (Vélez, 2023).



Although the *Fusarium* fungus is present in Ecuador, so far no cases of R4 have been reported, which is considered one of the most dangerous diseases in banana cultivation. It causes serious damage to plantations, such as vascular wilt, root rot and stem rot.

Within the explanatory analysis of the project, it was found that the banana production system in the study area is immersed in the incidence of the weevil in the adult stage.

When a lethal disease such as AR, PC, lethal wilt or surprise wilt is present in the crop, the elimination or management of the cabbages, in the case of PC, plays an important role, since incorrect management creates conditions that favor the development of high populations of *C. sordidus*. If the insect is not controlled, the chances of new healthy emissions on diseased plants with PC are diminished and affected by direct damage from the insect.

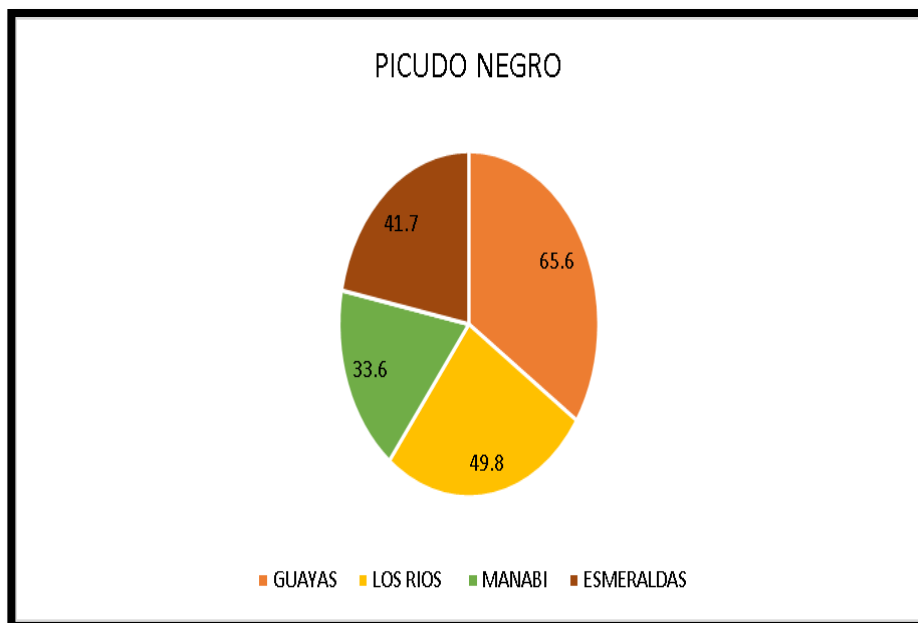
The presence of the black weevil (*Cosmopolites Sordidus*) was observed because at the moment of making an incision in the corm of the plants, the presence of galleries was observed that extended throughout the entire area studied, causing a reduction in the vigor of

the banana plantation and increasing susceptibility to other pests and diseases.

One of the causes of the presence of the black palm weevil is the lack of phytosanitary practices that allow a pest to increase its level of infestation in the plants, reaching levels that produce a reduction in fruit size and therefore yield losses.

Because the black palm weevil needs tropical climates to develop, this pest is present mostly in the coastal provinces. Among the main provinces with the highest infestation we have Guayas, Los Ríos, Manabí and Esmeraldas represented in the following graphic (Valarezo, 2019).

Figure 3. Percentage incidence of black palm weevil. (Valarezo, 2019)



Once this data has been obtained, it is then taken to a sheet in order to unify it and add it to the next step, which is the preparation of the map showing the presence of this insect pest in the study area.

Pests such as mealybug and scale were not found at significant levels in the banana crop, but were included in general.

The necessary tools for the elaboration of a thematic map of pests in the banana crop, an Excel sheet is generated where it contains the collected information of the different pathogens and pests that lead to the decrease of the production of the banana crop, we right click on the layer and we go to properties, The symbology layer is where we are going to make the map, categorizing it in order to add unique values, choose in the column where we are going to take the information either for the pathogens or for the insect pests, and click on add all the values that are in that layer. Automatically we click on apply and we visualize that our map represents the information spatially with the colors that we have already indicated by default. Now how we are going to make qualitative and quantitative maps we go to the Quantity option in which we are going to work with numerical values breaking down range numbers and number of classes which we can alter to taste. The GIS is a georeferenced tool that helps in the establishment of a soil conflict map. These tools help to analyze different maps such as the map detailing and marking the pathogens that are currently present in the banana and plantain production systems, and a suitability map that tells us the incidence of each one of them, In this way we can superimpose both maps to establish under agronomic criteria which are the areas that are most affected by these common pathogens of banana and plantain cultivation, so we were able to determine that the conflict maps to determine each analysis map using tools such as the creation of layers, polygons, polylines and the use of Google Earth to determine coordinates and time zone correctly delimiting the terrain.

Taking into account the previously described parameters, we proceeded to elaborate the thematic map of pests in the banana crop, which consisted of a data representation process using ArcMap 10.5 software in which we used several layers or shapefiles.

As a first step to make the respective thematic map on banana crop pests, it was done with the shapefile corresponding to the map of provinces of Ecuador and then place the layers corresponding to America and the Ocean having a representation to scale.

We used Excel to extract the information corresponding to the effects of the pests that affect the banana crop in the different provinces of Ecuador by creating a table with two columns of data: the first shows the provinces of Ecuador and the other shows the incidence of pests with their level of affectation.

This file was saved in XLS format so that it could be inserted into the data table with the name pests.

To insert it in the ArcMap we open the File option in the tools window and choose AddData, where a window opens and we select the file called pests.

Next, the Ecuador province attribute table opens: right click on the Provinces layer and choose Open Attribute Table.

The table of banana crop pests in Ecuador also opens. To do so, click on the Pests layer and select the Open option.

Then we look at the two tables separately, verify that the names of the provinces of Ecuador are spelled correctly so that they match at the time of joining the tables.

Then join the tables by clicking on the Equator provinces layer and choosing Joins and Relates> Join.

In the window that opens automatically the pest table appears, so in parameter 1 select the field DPA_DESPRO and in parameter 3 the field provinces. Finally, click on data validation and a box appears on the right side verifying that everything is correct and click on Close.

After this, the table of attributes of the provinces layer opens again and the pests field can be observed. To keep the data, the provinces layer must be exported and choose Data and then Export Data. Next, a window appears where the name INSIDENCIAS DE PLAGA should be routed and click on save and then on ok.

Then a new shapefile called PEST INSIDENCES is automatically created and the properties option is chosen to symbolize. In the field pest symbology 4 classes will be applied to the symbology and click on Classify.

Again in the symbology window click on the first symbol and a window will open where the fill and outline will be modified, then click on ok. Then the colors to be chosen are the following: green for none, cream for low, light green for medium and red for high which correspond to the incidence of the following pests: Fusarium RZ4, Scale, Mealybug, Black Weevil and Sigatoka. This will be reflected in the legend.

Consequently, a new dataframe is created where a light blue outline will reflect the provinces that are affected by the pests belonging to the banana crop. The maps made will be shown below:

Conclusions

The broad spectrum of GIS applications illustrates its value as a tool for conflict mapping and development planning. As has been demonstrated, geographic information systems can improve the quality and power of analysis in precautionary measures and control of pathogens and pests affecting the crop under study.

Much of the benefit of such an automated system lies in the ability to perform repeated spatial calculations. Therefore, before making a decision to acquire a GIS, planners need to determine which planning activities can be supported with this system and carefully evaluate whether the amount of spatial calculations and analysis to be performed justifies automating the process.

For that reason each area to work is identified and as a benefit of this is achieved identification, pest monitoring, crop prediction, precision agriculture, disease control, field data collection through mobile devices, irrigation mapping and modeling in real time among others. Applying this tool as he (ARCGIS) we can obtain great benefits by making a map in which the changes obtained since the increase of this method are distinguished.

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