Investigation note

Ahuacatl: mobile application to determine the spatial distribution of phytosanitary problems in avocado

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Abstract

The avocado crop has been affected by various pests and diseases, which has limited its commercialization. Because of this, the indiscriminate use of chemical products by producers has been generated, which has caused great environmental pollution, increased production costs and the presence of pesticide residues in the fruits. The objective of the present work was to develop a mobile application to determine the spatial distribution of phytosanitary problems in avocado crops. The application was developed in 2020 and was based on the Rational Unified Process methodology. Formulas and mathematical models were incorporated to obtain and fit the semivariogram. The formula of the ordinary kriging method was also added, in order to obtain density maps of the populations of phytosanitary problems of avocado crops. The application Ahuacatl App can be installed on mobile phones or tablets with the operating systems Android and iOS. The user can obtain their geographical location without the need to be connected to an internet network or mobile data of the cell phone.

Keywords: density maps, ordinary kriging, semivariograms.

Avocado (*Persea americana* Mill.) is one of the main crops worldwide, where Mexico stands out as the main exporter. However, avocado production for export is limited by pests and diseases that limit its commercialization worldwide. This has led producers to the excessive and indiscriminate application of agrochemicals, which leads to the presence of pesticide residues in fruits, environmental pollution, biodiversity losses, health risks (Carbajal and Martos, 2019), pest resistance and high production costs.

In recent years, advanced technologies have been massively incorporated into agricultural practices (Kamilaris *et al*., 2017). The technification and implementation of tools in agricultural fields have transformed the productive structure of several countries. With this they have managed to improve their products in quality and quantity, obtaining greater productivity. Technology implementation is associated with the development of a region (Eberhardt and Vollrath, 2016), through increased economic and environmental adjustments (Chen *et al*., 2017). There are currently a number of mobile applications available for the agricultural sector, which has generated multiple advantages such as: optimization of the use of resources, better agronomic practices, task scheduling (Mbabazi *et al*., 2017), calibration of fumigation equipment, geopositioning of soil samples, among others.

These technologies have been developed and applied as a strategy for crop management and decision-making (Lokers *et al*., 2016) in a timely and effective manner. There are programs that help to determine the type of behavior and distribution of phytosanitary problems in crops. However, these programs are a bit unknown to farmers or technicians since they are only found in research centers. Among them is the program Variowin 2.2 (Software for Spatial Data Analysis in 2D, Springer Verlag, New York), which helps to know the type of behavior showed by pests within the plots.

The program Surfer 16 determines the location of pests and represents them in the form of density maps. These programs are of great help to producers and technicians, as they would make it easier for them the real diagnosis of pests and diseases in crops. The research aims to develop a mobile application to facilitate the management of phytosanitary problems in avocado crops, by drawing density maps, using the interpolation method called ordinary kriging, the development was carried out during the year 2020.

For the application development process, the rational unified process (RUP) methodology was used. This methodology takes the requirements of the user as a central element of the development; that is, each step in the development process is to build an application that addresses the identified needs. Likewise, it incorporates continuous tests that allow identifying possible errors, correcting them as soon as possible, reducing the impact and cost derived from them (Jacobson *et al*., 2000).

The definition of the requirements was carried out by analyzing the process followed to incorporate a geostatistical study in the diagnosis of phytosanitary problems. From which the requirement to be able to collect values for the variable, associated with geolocation data, is derived. In this sense, the first stage is the exploratory analysis of the data to verify the normality of the data collected in the field. Once the databases are integrated, the experimental semivariogram is created and fitted to theoretical models that allow explaining the nature of the phenomenon or variable studied.

The value of the semivariogram can be calculated by means of the following formula (Journel and Huijbregts, 1978; Isaaks and Srivastav, 1978): $\gamma^*(h)= \frac{1}{2Np(h)} \sum_{i=1}^{Np(h)} [Z(Xi)-Z(Xi+h)]^2$ 1). Where: $\gamma^*(h)=$ to the experimental value of the semivariogram for the distance interval h; N(h)= to the number of pairs of sample points separated by the distance interval h; Z(xi)= to the value of the variable of interest at sample point xi; Z (xi + h) = to the value of the variable of interest at sample point xi+h.

The experimental semivariogram must be fitted to the theoretical semivariogram since it is necessary to fit a function to quantify the degree and scale of spatial variation. There are models that are used in geostatistics, with the most commonly used being the spherical model, the exponential model and the Gaussian model. All these models have three common parameters that are nugget effect, sill and range, parameters that serve to fit and validate the semivariogram.

Once the experimental semivariogram was fitted to any of the models described, it was necessary to validate them. The validation of the model was carried out with the procedure called cross-validation (Isaaks and Srivastava, 1978). This method is used to assess the degree of goodness among the data. After performing the cross-validation, the level of spatial dependence is determined, which consists of dividing the nugget effect by the sill and the result is expressed as a percentage, in order to know the degree of relationship between the data (Cambardella *et al*., 1994). If the result is 0% to 25%, the level of spatial dependence is high, if it is between 26%-75%, the level of dependence is moderate, and 76%-100% the level of spatial dependence is low.

Once the semivariogram model is validated, the interpolation method called ordinary kriging is used to create density maps of the populations of phytosanitary problems. This interpolation method allows for unbiased estimation of points where no sampling was performed. To meet this requirement, the following formula was used: $Z^\wedge(So)= \sum_{i=1}^{N} \Lambda_i z(x_i)$ 2). Where: Z(Xi)= value measured at the location; $\Lambda i=$ an unknown weight for the measured value; So= location of the prediction; N= number of measured values.

After the development of the mobile application and the incorporation of the formulas, the application can generate semivariograms, density maps and determine the percentage of area infested by a pest or disease. Likewise, it can obtain the geographical coordinates of the user without the need to be connected to an internet network or cell phone data. However, this application was only developed for avocado crops. Below is a flowchart of the data input and output of the application Ahuacatl App (Figure 1).

To corroborate that the application worked correctly and that the results it yielded were correct, data obtained with desktop programs (Variowin 2.2 and Surfer 16) and those obtained with the application were compared. For this, one of the samplings of armored scale (*Hemiberlesia lataniae* Signoret) was taken. The sampling was carried out in the municipality of Coatepec Harinas, State of Mexico in an avocado orchard whose area was 4 hectares. The crop had an approximate age of 8 to 10 years, from the area of the orchard 400 trees were sampled randomly.
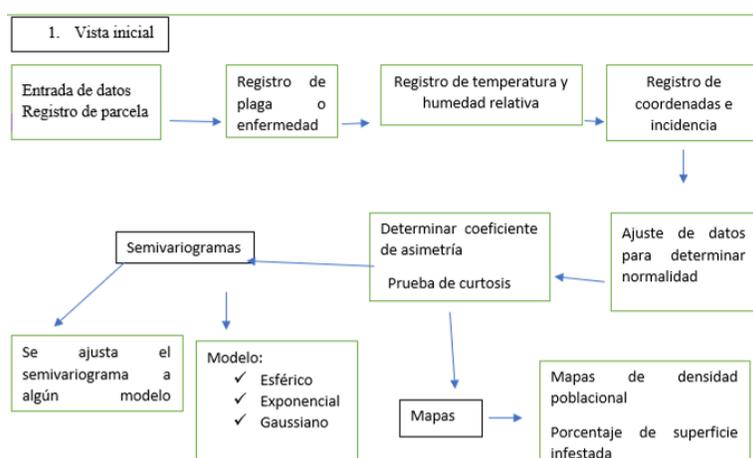
Figure 1. Flowchart of data input and output of the Ahuacatl App.

The data obtained with the application were similar to those obtained with the programs Variowin 2.2 and Surfer 16. With the program Variowin, the semivariogram was fitted to the spherical model, which obtained a nugget effect of zero, sill of 360.8 and a range of 7.2 m. The application yielded the same results. Figure 2 shows the two semivariograms fitted to the spherical-type model.
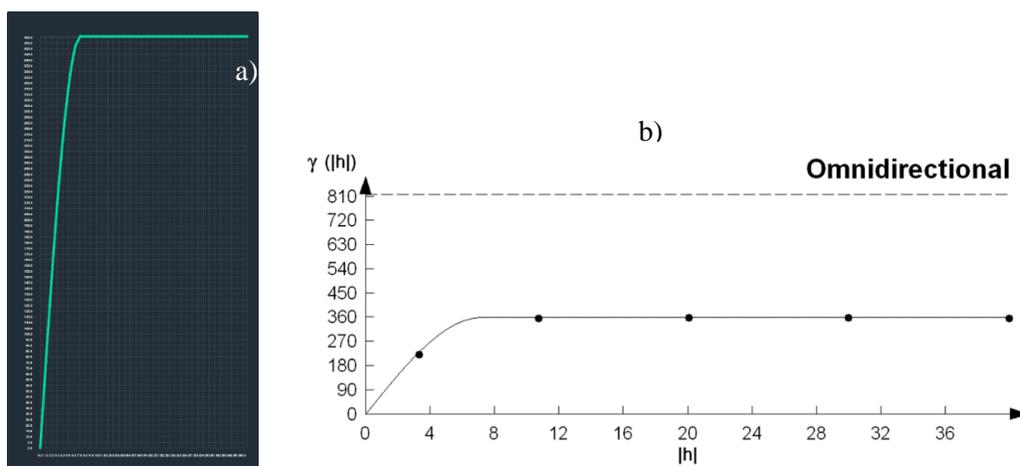
Figure 2. Semivariograms of the sampling of armored scale. a) semivariogram obtained by the mobile application; and b) semivariogram obtained by the program Variowin.

Once the semivariogram was fitted, the density map can be visualized in the application. The map shows the areas where the populations of the insect are distributed. In Figure 3a, the north coordinates along with the color scale can be observed on the left side of the map, and the east coordinates appear at the bottom, and the percentage of area infested by the pest appears below these coordinates. The following colors appear on the map: white which indicates absence or zone free of infestation, red indicates a high incidence of the pest, green low presence and yellow moderate presence.
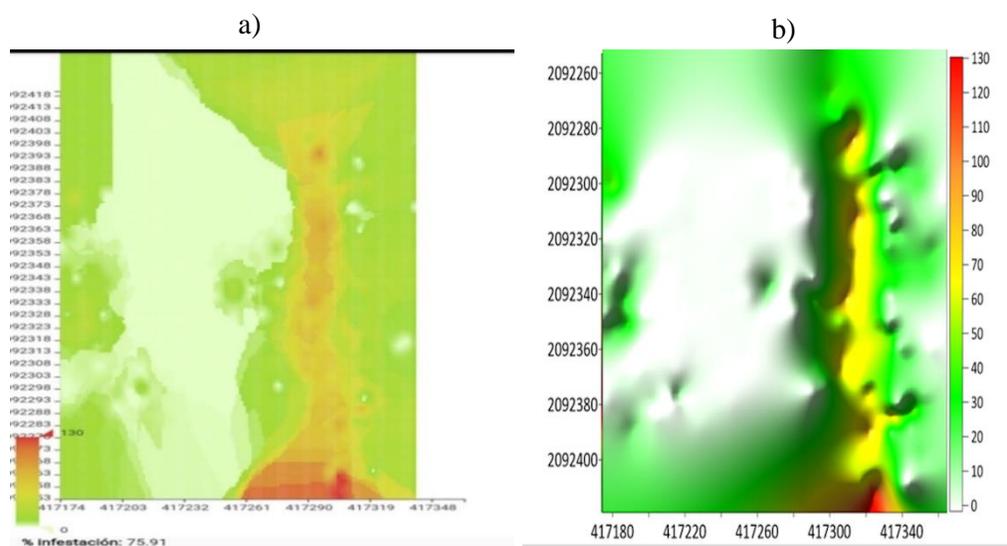
Figure 3. Density maps and percentage of infested area. a) map drawn up with the mobile application; and b) map drawn up using the program Surfer 16.

Figure 3b, the north coordinates appear on the left side of the map and the east coordinates at the bottom of the map. In this case, the scale appears on the right side of the map with the same colors white, red, yellow and green. The maximum value that appears in the scale determines the maximum number of incidences of the insect in the sampling.

Conclusions

Data such as name of the plot, area of the plot, name of the pest or disease being sampled, date of sampling, temperature and relative humidity appear in each sampling. Likewise, the data of the semivariogram: model, values of nugget effect, sill, range, level of spatial dependence. The application can share the sampling data with another user by WhatsApp, email, among others. The document that is sent has a csv (comma-separated values) format, this document can be viewed both on the computer and on the cell phone or tablet.

The data that is shared is only geographic coordinates and incidence. When sending the document by email, the following is sent in the body of the email: study number, date on which the sampling was carried out, relative humidity, total samplings carried out, number of incidences, variance, standard deviation and the sample mean. The application described in this scientific note was released under the name Ahuacatl App and was developed for the operating systems Android and iOS. The application for smartphones was published on the Google Play platform and is available at https://play.google.com/store/apps/details?id=com.uaemex. ahuacatl. The results obtained from the functioning of the application are consistent with those obtained by laboratory software.

The development of the mobile application will allow technicians and avocado growers to control and prevent pests and diseases in a timely manner. It is a tool that allows knowing the areas in which a phytosanitary problem is present. In this way, it will help to implement some more

appropriate control method in a focused way, directing the control method towards the areas that really have high population densities. This will avoid economic losses and high production costs, excessive spending on pesticides, environmental pollution and the presence of chemical residues in the fruits.

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