GEODATA: Information System Based on Geospatial for Early Warning Tracking and Analysis Agricultural Plant Diseases in Central Java

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Abstract. The Government of Indonesia is currently faced with the problems of food, especially rice. It needs in large numbers that have to import from neighboring countries. Actually, the Indonesian government has the ability to produce rice to meet national needs but is still faced with the problem of pest attack rice annually increasing extent. One of the factors is that geographically Indonesia located on the migration path of world rice insect pests (called BPH or Brown Planthoppers) (Nilaparvata lugens Stal.) It leads endemic status annually. One proposed strategy to be applied is to use an early warning system based on a specific region of the main pest population. The proposed information system called GEODATA. GEODATA is Geospatial Outbreak of Disease Tracking and Analysis. The system works using a library ESSA (Exponential Smoothing - Spatial Autocorrelation) developed in previous studies in Satya Wacana Christian University. GEODATA built to meet the qualifications required surveillance device by BMKG (Indonesian Agency of Meteorology, Climatology and Geophysics’ Central Java Provinces), BPTPH (Indonesian Agency of Plant Protection and Horticulture) Central Java Provinces, BKP-KP District Boyolali, Central Java, (Indonesian Agency of Food Security and Agriculture Field Supervisor, District Boyolali, Central Java Provinces) and farmer groups. GIS GEODATA meets the needs of surveillance devices that include: (1) mapping of the disease, (2) analysis of the dynamics of the disease, and (3) prediction of attacks / disease outbreaks in a particular region. GIS GEODATA is currently under implementation in the laboratory field observations of plant pest in Central Java province, Indonesia.

1. Introduction
Geographically Indonesia located on the migration path of world rice Rod Brown Planthopper (called BPH) (Nilaparvata lugens Stal.) It leads endemic status annually [1]. The continued impact of insect endemic status BPH is disruption of rice production expected to reach 30% and the rice import requirement for achieving national food sufficiency. History records BPH outbreak in Indonesia has been identified since 1931 in Bogor, 1939 in Mojokerto, and 1940 in Yogyakarta and the following years expanded to the entire Java [2]. The BPH explosive outbreaks continue occur in West Java and Central Java in 1960-1970 damaging 52,000 hectares of rice field and in the year 1976 to 1977, damaging 1.5 million hectares of the field [3]. Between years 1971-1980, the attack of BPH extends
up to 3.1 million hectares. Statistics showed that between the years 2000 - 2011 the BPH attack about 4.2 million hectares and the peak of the attacks occurred in 2011 covering an area of 712,641 ha. Ministry of Agriculture has a special institution to deal with this problem but difficult to control effectively. The BPH population in Indonesia so vast increase occur each year. This is what motivates doing research and development of an early warning system for pests and diseases of plants using geospatial technology with name is Geospatial Outbreak of Disease Tracking and Analysis (GEODATA).

GEODATA technology provides the geographic information about the position prediction endemic regions 4 major pest species, route of migration and early warning of plant pest attack on the unit districts. In general, GEODATA has the capability of storing data, analyze and visualize information in the form of tables, graphs and maps. Data storage is done using a model Relational Database Management System (RDBMS) Microsoft Access. Basic use of this database is Access database platforms already installed in every computer on the market in Indonesia. Analysis of the data in the GEODATA using a combination of Time Series Exponential Smoothing function for forecasting and Spatial Autocorrelation Getis Ord or Gi * statistic for mapping. Combination of these functions are arranged in the form of an algorithm known as algorithms ESSA (Exponential Smoothing - Spatial Autocorrelation) [4,5]. GEODATA developed using the programming language PHP version 5.0 combined with Visual Basic 6.0. The PHP version 5.0 is used for the purpose of encoding the data using algorithms ESSA analysis and visualization of information in the form of tables, graphs and maps using Map Server. Visual Basic 6 used for packing purposes installer application in the form that can be easily installed on a computer without the need for internet connection. Geospatial data used in the application is the data vector shapes with format files (standard ESRI). GEODATA application in principle is early warning system software used to detect the pest attack agricultural crops of all regions in Indonesia.

2. Research Methodology
The study was conducted through a modified procedure of Prasetyo et al. (2015). There are 5 stages (Figure 1):
1. Requirement Analysis and Problem Identification
   Needs analysis and identification of problems of research conducted in order to determine the needs of the main systems and various related parameters. The main needs of users are tools that can be used to detect, predict and identify the location of pests, rainfall distribution forecasts and recommendations cropping patterns.
2. Data Collection, preprocessing & Classification
   The research data is data of local climate from BMKG (Indonesian Agency of Meteorology, Climatology and Geophysics Central Java Provinces. Data incidence of local pest attack from BPTPH (Indonesian Agency of Plant Protection and Horticulture) Central Java Provinces. The duration of the data is 10 years with a period of 2 weekly. All data is stored in the structure and Ms. Access database format. The classification data is done to determine the period of data monthly and annually. Classification of climate data based on the mangsa used fuzzy logic. Mangsa is the period of monthly data based on the traditional calendar of farmers in Central Java.
3. Design & Development of Algorithms
   The algorithm used in the GEODATA application is ESSA (Exponential Smoothing - Spatial Autocorrelation). ESSA algorithm created from the combination of two mathematical functions are functions Exponential Smoothing (ES) as a function of time series data and functions for forecasting Spatial Autocorrelation (SA) to make the spatial correlation between the two variables.
4. Application Design & Development of Geographic Information System Planning and application development Geographic Information System (GIS) include the following activities: (1) the design of the system architecture, (2) the manufacture of modules of data processing and database attributes, (3) manufacture of modules of visualization applications, (4) the manufacturing module data analysis and forecasting, and (5) The decision-making module recommendation.
5. Testing and Implementation of Application of Geographic Information System Application
testing is done in two methods: a laboratory-scale and field-scale testing. Implementation is done
together with the team BPTPH Central Java, Indonesia.

![Diagram of GEODATA Application Stages]

**Figure 1. Stages Research & Development of GEODATA.**

2.1. Conceptual architecture of GEODATA Application

Research and development of geographic information systems as an assistive device visualization of
plant pests and diseases endemic regions has been done by other researchers before. The GIS
development for pest monitoring BPH used linear regression [6]. GIS detects BPH population growth
and invasion using interpolation method [7]. GIS detects the dynamics eco-biology population and
plant pests and diseases using geostatistical methods [8]. Another approach is the Kriging method to
predict unknown pest populations in other areas a [9]. GEODATA has features that are not available
by other GIS, which can be used to: (1) mapping of the disease, (2) analysis the dynamics of the
disease, and (3) prediction of attacks / disease outbreaks in a particular region. This feature developed
from mathematical functions SA, which is part of the method of Exploratory Spatial Data Analysis
(ESDA) [10].

GEODATA Applications used by 3 users with different backgrounds: (1) the officer agriculture
supervisor (under the Indonesian Agency of Food Security and Agriculture Field Supervisor, District
Boyolali, Central Java Province) in Bahasa Indonesia called PPL (Penyuluh Pertanian Lapangan); (2)
POPT is pest observer from Indonesian Agency of Plant Protection and Horticulture) in Bahasa
Indonesia called (BPTPH) and (3) farmers. PPL and POPT users can play a role as an administrator in
charge of updating the attribute data every two weeks. GEODATA application requires two types of
data, the attribute data obtained from the observation process regularly, includes data pests and rainfall.
data. Spatial data in form of vector is data entered at the time of application development and permanent. Vector data in the form of map data is in shape format files (ESRI format).

The main concept of the development of GEODATA Application GUI design is simpler so that users who are not accustomed to using GIS applications can easily access, manage and interpret the data. GEODATA application providing correct information - needed by the user to plan the cultivation of rice farming as a prediction of pest attacks in the next 2 weeks, the prediction region and the source of the invasion of pest invasion, prediction recommended cropping pattern and the local rainfall distribution map (Figure 2).

2.2. GEODATA Application Architecture

GEODATA Application is composed of three layers: a data management layer, a data processing layer and application layer. Data management layer functions in data management that includes: (1) the addition, deletion and modification of data attributes, (2) validation vector data to be used for data analysis attributes. Data processing layer functions for data analysis using software components called libraries ESSA, functions for forecasting, mapping and visualization of graphs and tables. Presentation of information in the form of a map requires a software component known as the MapServer.

MapServer works using three main components, a web server (Apache/IIS), Common Gateway Interface (CGI), and Mapscript Application. The use of PHP programming language in GEODATA make MapServer application and all the components in it could go well, presenting information visually in the form of maps, graphics and tables. The use of Visual Basic programming language make GEODATA applications can be installed in desktop computers without an internet connection need (Figure 3). Application layer is the application of geographic information system that can provide information (1) mapping of the disease, (2) analysis of the dynamics of the disease, and (3) prediction of attacks / disease outbreaks in a particular region. There are 4 types of pest plants are analyzed automatically in a single instruction are: WBC, mice, stem borers and BLB.
Spatially GEODATA use vector data type that consists of point data, lines data and polygon data. Point Data represent areas of the city districts, the line data represents the path information and polygon data represents the boundary districts or district boundaries. The Information area of pest attack and the amount of rainfall, present in the form of shades on the map.

2.3. GEODATA Application Design

Based on users, GEODATA applications classified into two: (1) the administrator that includes agricultural supervisor (PPL) and the pest observer (POPT), and (2) the farmer groups. PPL & POPT administrator user has the ability to configure access maps and attribute data management, while user’s farmer groups are restricted in access to information available on the application.

Based on the features of the application, there are four parameters that are the focus: (1) the attack four major pest species, (2) local rainfall in the districts, (3) local wisdom pranatamangsa, and (4) cropping recommendation. Each information parameter presented in three forms: the form of
visualization, the visualization of a line graph, map visualization and partly in the form of a table. Based on the method of data analysis, can be grouped into two: (1) the presentation of historical data for 10 years, and (2) short-term forecasting data presentation, during the second period in front (Figure 4). Forecasting method used was Exponential Smoothing. Empirical studies of data surveillance monitoring results show the method has an accuracy of prediction of optimal and reliable in trend analysis when compared with other methods [11] [12] [13].

3. Result and Discussion
The goal of the GEODATA GIS application development is to meet the needs of applications in the surveillance process. The goal of this process: (1) predicting potential pests and diseases, (2) tracking the source of pests and diseases, and (3) the identification of pests and diseases [14]. Achievement of the objectives of surveillance carried out through three approaches: (1) mapping of the disease, (2) analysis of the dynamics of the disease, and (3) prediction of attacks / disease outbreaks in a particular region.

Features prediction of potential pest attack on GEODATA Applications can be seen in Figure 6 with the approach of mapping disease. Detailed information is presented on the cover: (1) a map predicting the area pest attack based districts (in Ha) on 1 and 2 coming period, (2) the early warning signs that are connected to the table pest endemic regions, (3) information layer map currently active, and (4) see the position of the area being analyzed in comparison to the entire region of Central Java province (Figure 5).

![Figure 5. Features prediction of potential pest attack on the application GEODATA.](image)

The function of feature tracking the source of pests and diseases is to see the area that became the source of pest attack and stricken areas of pest carried by disease dynamics analysis approach. Conceptually epidemic process always involves two or more spatial objects that are interconnected to one another. The first spatial objects called the source of disease and two spatial objects called party to disease. Connectedness spatial objects between the source and the target disease referred to as the connectivity between the spatial variables. Connectivity between spatial objects is influenced by several factors which include the distance (Euclidean distance), neighborhood and interactions factor [15].
Determination of the area became the source of pests and pest attacks target areas based on the degree of spatial connectivity and using methods of Spatial Autocorrelation. This method works using mathematical equations spatial weight matrix to determine the relation between one area (polygon) to others in the surrounding areas. In this study area polygon represents districts [16]. The next stage is to determine the magnitude of the spatial connectivity using mathematical equations Gi * Statistics [17]. Implementation of source tracking features of pests and diseases on the application GEODATA can be seen in Figure 6. Detailed information presented on map feature connectivity and forecasting outbreaks in principle there are 4 parts. (1) The different colors indicate differences in the degree of spatial connectivity among districts (value Gi *). Interpretation of the value in use metode Getis Ord analysis used indicators Z (Gi). Interpretation Z (Gi) is (-2.0 <Z (Gi) <2.0), the value (Z (Gi) <2.0) represents the distribution of data outliers and random, whereas (Z (Gi) >2.0) represents the data distribution centralized (cluster). The darker the color degradation patterns indicate that the region as a source of pest attack. Local migration of pest occurs from the area with a darker color to the area with a lighter color. (2) Tools to determine the prediction period, served two terms in units monthly, or yearly prey according to user needs. Understanding period of time series prediction is a form of seasonal or periodic non-deterministic, because it is not repeated purely from one period to another. Recurrence occurred due to random variation occurs integral data (eg, 24 hours, 12 months, 52 weeks, etc.) [18]. (3) Tools to see the position of the area being analyzed in comparison to the entire territory of the province of Central Java. (4) Tools icon or menu in a format is easy to understand, making them easier to use by the user.

![Figure 6. Features prediction of potential pest attack on GEODATA application.](image)

The analysis of the endemicity degree the attack source area and the attack target represented in the symbol color and value in the table. Pest endemic regions symbolized by a dark red color and the lower the endemicity degree even brighter. The safest area of pest symbolized with dark blue color. The shades of blue to the light blue indicate the low degree of endemicity. Analysis of accuracy and
validation of production can be done by looking at the ratio between the actual data with the data in the prediction of monthly periods, and annual mangs of each sub districts (Figure 7).

![Figure 7. Analysis of accuracy and validation of predictive pests](image)

The dynamics of pest prediction each district based on these data is expected to be at or near the actual value with 95% probability design. The dynamics of the prediction results were higher when compared with the actual value is estimated as a form of deviation events or outlier or anomaly. The prediction results are right in the range of 95% predictive significance, meaning that this curve represents the actual cycle variation pattern. The important concept is that the data show a pattern or trend tendencies. Table 1 shows the results of the analysis methods Local G (G *) is in the range between (-0.02 <Z (Gi) <0.130), which indicates that the annual term WBC population distribution patterns are coldspot or spread to districts, the habitat. The analysis results using the Geary rate (C) is in the range (0.05 <Z (C) <0.02), indicates that the annual term WBC population distribution pattern centered in most districts, the habitat. The analysis result using Local Moran's show down along the years between 2010 and 2014 occurred concentration of potential attacks against the occurrence of endemcity.

| No | Year | Local Gi (G*) | Local Geary (C) | Local Moran’s |
|----|------|---------------|----------------|--------------|
| 1  | 2010 | 0.001         | 0.030          | 1.956        |
| 2  | 2011 | 0.020         | 0.020          | 1.863        |
| 3  | 2012 | 0.030         | 0.030          | 1.711        |
| 4  | 2013 | 0.130         | 0.050          | 0.083        |
| 5  | 2014 | -0.020        | 0.050          | 1.603        |
4. Conclusion

GEODATA GIS is the answer to the needs of the handling of rice pest’s invasion, especially for four major pest specific regions. This system of surveillance devices in accordance with the qualifications required by BMKG (Indonesian Agency of Meteorology, Climatology and Geophysics of Central Java Provinces), BPPTPH (Indonesian Agency of Plant Protection and Horticulture) Central Java Provinces, BKP-KP Kab. Boyolali, Central Java, (Agency of Food Security and Agriculture Field Supervisor, District Boyolali, Central Java Provinces) and farmer groups. GEODATA GIS meets the needs of surveillance devices that include: (1) mapping of the disease, (2) analysis of the dynamics of the disease, and (3) prediction of attacks / disease outbreaks in a particular region. The third goal is met by the use of surveillance ESSA library in GIS applications, especially in the prediction and mapping of data attributes widely pests and rain distribution data. The architectural design and architectural conceptual GEODATA application is built to work optimally and produce information in accordance with user needs. A comparison of methods between Gi *, C and I indicated that Gi * more optimal method in determining the endemic regions.

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