Prediction Model for Chilli Productivity Based on Climate and Productivity Data

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***Abstract*-The global trade increases the competition in agricultural product export all around the world.The Indonesian Agricultural Industry needs to improve their competitiveness by fulfilling the requirements and restrictions imposed by some countries with regards to traceability information features of the products, such as location of farming field cultivation method, chemical contaminants and supply chain information. Some European countries require the implementation of E-GAP (European Good Agricultural Practices) in order to secure food safety. Food safety provides the control and monitoring during, pre-, and post-harvest stages of agricultural products. This paper describes a prediction model based on the climate and productivity data on Indonesian agricultural products. The prediction model with an iteration of the climate and their possible increase or decrease in productivity. The model relies on historical data and an analytical algorithm. The decision support and early warning system provides the farmer some advice to reduce the crop failure risks due to climate change.**

Keywords: prediction model/iterative model, field monitor, traceability.

I. Introduction

More and more countries in the world now require traceability information in food and agricultural commodities imported into their country to ensure the food safety. This is mainly to provide traceability information regarding the location of farming field, cultivation method and any chemical contamination of the agricultural products. In addition, information about the distribution chain of these agricultural products is also required for tracing and tracking. The tracing and tracking of these agricultural products is mainly to make use of RFID/microchips tags with the corresponding information system infrastructure. For instance, Europe requires the implementation of E-GAP (European Good Agricultural Practices) in order to justify the safety of food.

Food safety performs control and monitoring during pre- and post-harvest phases in the food and agricultural products. This paper describes a preliminary study of developing a traceability system model that consists of field monitor-sensors, decision support-early warning system, prediction model for contaminants and traceability modules. The objective of this research is to provide Indonesian farmers with early warning information based on collected data and prediction/iterative models thereby to reduce the risk of crop failure.

This paper describes a prediction model based on the climate and productivity data on Indonesian agricultural products. In addition, the paper describes a preliminary study on available sensors method and the related traceability system as well is described. The proposed field monitor and traceability model is presented at the end of this paper. The objective of this research paper is to provide sufficient background information of potential effect of climate change to the productivity of agricultural products based on a prediction model. In addition, a model of electronic ID modules for supply chain is discussed to identify and trace food and agricultural products.

II. Objective and Methodology

A conceptual system of a prediction/iterative model for analyzing the effects of climate change on the productivity of indonesian agricultural products especially, chilli is derived from climate and productivity data obtained from NOAA and Indonesian Agency for Statistics respectively. The prediction model is based on macroclimate. At the macroclimate scale historical data of from a region is studied over a year. Meanwhile for a microclimate study historical data is obtained a smaller area and with hourly observation data.

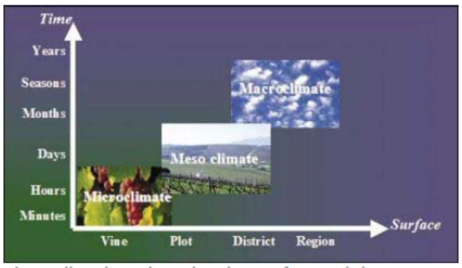

Figure 1: Climate based on region and surface data [1]

The prediction/iterative model will become as a modul in the complete traceability model for agricultural products. The traceability model for agricultural products is designed as a Supply Chain Network Model and it consists of: farmers, distribution channels between the farmers and the markets in Indonesia and export destination countries. The traceability model has two parts namely:

(1) Traceability model I consists of sensors and traceability modules. The sensors employ climate monitoring system. The traceability modules are e-identification for the agricultural commodities with read/write tags to store the information about the origin-cultivation method-contaminants level-distribution chain and the related readers/stations.

(2) Traceability model II consists of prediction model of climate and productivity with related suitable decision support and early warning system for the farmer. The prediction model with an iteration of the climate and their possible increase or decrease in productivity. The model relies on historical data and an analytical algorithm. The decision support and early warning system provides the farmer some advice to reduce the crop failure risks due to climate change.

The research activities in this paper identify mainly an appropriate system for Traceability model II at conceptual level. Initial activities have been undertaken to discuss the concept of prediction model for chilli productivity developed in collaboration between Indonesian researchers from BPPT (Indonesian Agency for Assessment and Application of Technology) and Geoinformatics Research Centre (GRC)Auckland University of Technology (AUT).

III. TRACEABILITY MODEL I:

In order to provide identification for agricultural commodities, different types of electronic ID consisting of analytical data can be utilized. The traceability modules provide information about the origin of agricultural products, cultivation method, the distribution chain, additional information received from the field monitor (climate/contaminants sensors).

There are different technologies available to perform this electronic ID [2]:

1. *2D-barcode:* 2D-barcode or a linear barcode, is a sequence of printed lines, or bars, and intervening spaces. There are 24 types of the linear code, such as Code 39, Code 128, EAN, GS1 Data Bar, ITF14, UPC, etc.
2. *2D Matrix Code:* Two dimensional matrix codes which has almost the same implementation with the 2D Bar Code, The 2d Matrix code stores information along the height and the length of the symbols. The two dimensional code systems can be used for reading using laser scanner or charge coupled device scanner. An example of this method that is using 2d matrix code is called Quick Response Code or known as QR Code.
3. *Biometric:* Biometric is a technology on security that uses part of body/plants for authentication. This technology works by scanning the part of the body/plants that is used for authentication and then store it into the biometric database.
4. *RFID* [3]*:* Radio-frequency identification (RFID) is the use of an object applied to or incorporated into a product, animal, or person for the purpose of identification and tracking using radio waves that has been used around for many years. The majority of RFID tags operate at either 13 MHZ or 900 MHZ.

The following figure shows that the traceability modules that are used along the production-distribution-retail process. Local or national database will be utilized in order to perform the information system infrastructure for the traceability modules. Unique identification number of farmers based on location and type of commodities are used.

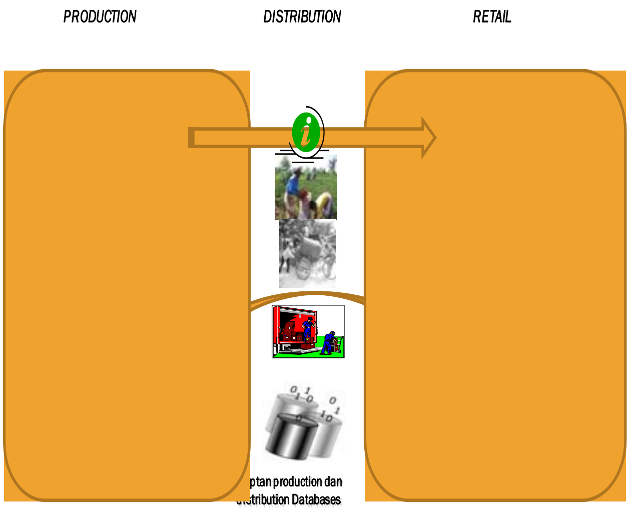

Figure 2: Traceability in Indonesian Distribution Chain with e-identification

The Supply Chain Management (Distribution Chain Management) for agriculture product distribution in Indonesia is a chain of processes from the purchase of post harvest agricultural products and supporting of products for production to delivery of a finished product to an end user. The distribution system of the agriculture system in Indonesia consists of activities which involve seven functions, namely: suppliers of supporting products, farmers, collectors, food Processing Industries, wholesalers, retailers, consumers.

There are three types of distribution systems in Indonesia according [8]:

1. Common distribution is a regular distribution, respectively from the farmer to the collector, wholesaler, retailer and ended to the consumer
2. The Government-ruled distribution system is a special system, which assign by the government for a certain products distribution, like sugar, rice, and crops. The government rules the plantation time, the number of planted products, the distribution area and the transportation system. And also the person whose responsible for these activities.
3. The typical distribution is a system, which doesn't follow any kind of type above. For example, direct order from an industry to the farmer, or the farmers directly distribute and sell the products to the market by themselves.

In this proposed research program, we propose a traceability model for agriculture product distribution in Indonesia based on the common distribution (regular distribution).

IV. Traceability Model II: Prediction Model of Chilli productivity

Prediction model and decision support-early warning system are both related to each other. Based on historical data and information from the field monitor (climate and contaminants sensors) a prediction model of the productivity in agricultural products can be determined. In [9] rules are generated using Clementine to model monthly averages of dew point based on the weather variable for Chilean and New Zealand regions.

A. *The productivity data of West Java, East Java, and Indonesia for chilli products*

The areas of harvesting of chilli in West Java from 7 major productive cities/counties from 2005 to 2009 are varies from 10.920 Hectares to 12.588 Hectares [4] with the productivity of Capsicum Annuum L (cabai merah besar) and Capsicum frutescens (cabai rawit) varies from 9 Ton/Ha to 16 Ton/Ha between 2007 to 2011 [5]

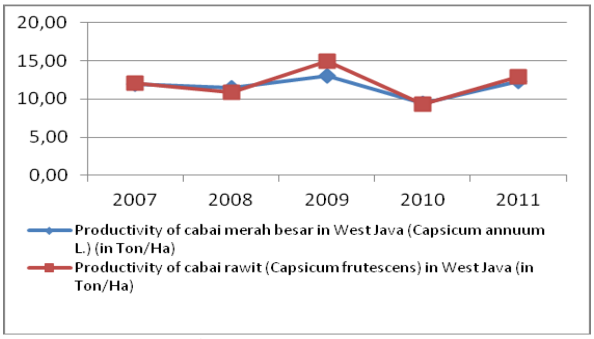

Figure 3: Productivity of chilli in West Java. Source: (Disperta Jabar)[4] and (Badan Pusat Statistik Indonesia)[5]

The productivity of chilli in particular Capsicum Annuum L (cabai merah besar) and Capsicum frutescens (cabai rawit) in East Java variating from 3.2 Ton/Ha to 7.8 Ton/Ha between 2007 to 2011 [5]

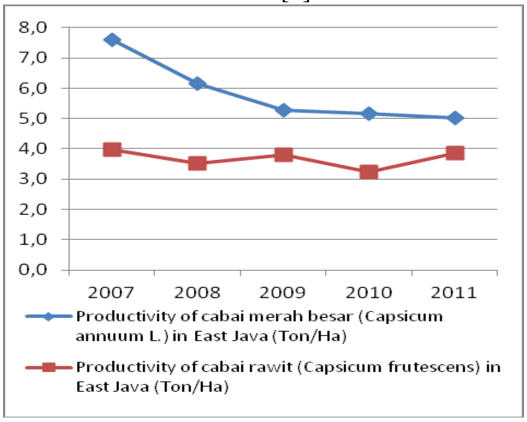

Figure 4: Productivity of chilli in East Java (Badan Pusat Statistik Indonesia)[5]

The productivity of chilli in particular Capsicum Annuum L (cabai merah besar) and Capsicum frutescens (cabai rawit) in Indonesia variating from 4.47 Ton/Ha to 7.34 Ton/Ha between 2007 to 2011 [5].

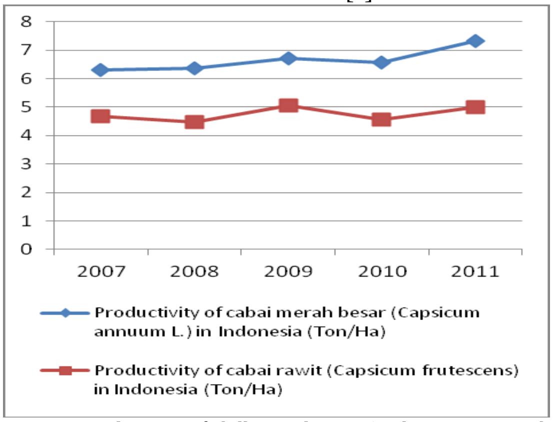

Figure 5: Productivity of chilli in Indonesia (Badan Pusat Statistik Indonesia)[5]

The productivity of chilli in East Java is very low relative to the productivity of chilli in West Java therefore more historical data is investigated starting from 1999 to 2008 [6] which is given in the following graph.

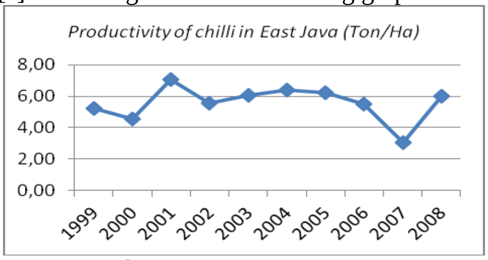

Figure 6: Productivity in East Java 1999-2008 (Ton/Ha)

The graph shows a very deep drop of productivity in year 2007.

B. The climate data of West Java, East Java, and Indonesia

In order to investigate whether the climate in East Java has a significant effect on the productivity then data of climate in East Java is collected from NOAA stations [7]

Figure 7: NOAA Weather Stations locations in Indonesia [7]

The historical data for climate is derived from 2 NOAA weather stations in west and east java of Indonesia, namely Bandung/Husein weather station and Banyuwangi weather station.

TABLE 1: NOAA WEATHER STATIONS IN WEST AND EAST JAVA.

NOAA Station Number	Station Name	Latitude	Longitude
967810	BANDUNG/HUSEIN	-06900	+107583
969870	BANYUWANGI	-08217	+114383

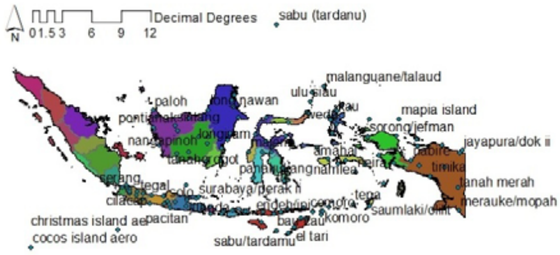

Figure 8: NOAA Weather Stations locations in West Java (Bandung Husein Weather Station) and in East Java (Banyuwangi Weather Station) [7]

V. PRELIMINARY RESULTS

In order to analyse the relationship between climate and chilli productivity, WEKA software is used. WEKA stands for Waikato Environment for Knowledge Analysis[7], which is an open source software issued under GNU License.Weka is a collection of machine learning algorithms for data mining tasks. Weka contains tools for data pre-processing, classification, regression, clustering, generating association rules, and visualization.
In addition a self-organizing map (SOM) from Kohonen is used which is a type of artificial neural network that is trained using an unsupervised learning algorithm to produce a low-dimensional (typically two-dimensional), discretized representation of the input space of the training samples, called a map. SOM is useful for visualizing low-dimensional views of high-dimensional data,

The yield data in West Java is given for the cabai rawit (Cr) and cabai merah besar (Cmb) from 2007 until 2011. Both types of chilli has two yield classes (low and high classes). The classes is defined based on the historical yield data in those region. In west java the yield is between 9.32 Ton/Ha to 14.96 Ton/Ha. Most of the yields is in the range of 11 Ton/Ha to 13 Ton/Ha.
In this paper the chilli productivity classes in West Java is defined as follow. The low class is defined as 9<Low class<=12 Ton/Ha, the medium class is defined 12<Medium class<=14 Ton/Ha and the high class is above 14 Ton/Ha).

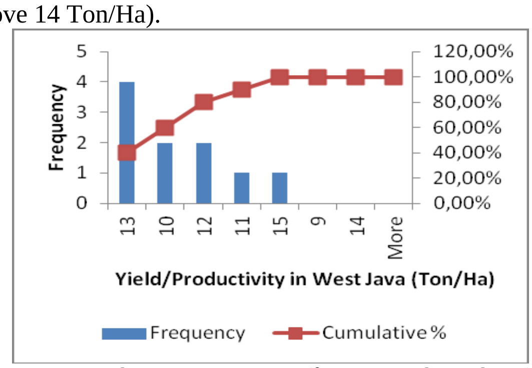

Figure 9: Productivity in West Java (frequency and cumulative)

There are 7 segments derived from West Java yield and climate data for the cabai rawit and cabai merah besar.

Figure 10; Segments of climate data in West Java

The low yield results from two different clusters for both cabai rawit and cabai merah besar, while the medium yield results from one cluster for each type of chilli. The high temperature in May results in low yield of chilli in West Java.

The yield data in East Java is given only for all types of chilli 1999 until 2008. In this paper the chilli productivity classes in East Java is defined based on the historical yield data in those region. In east java the yield is between 3.02 Ton/Ha to 7.05 Ton/Ha. Most of the yields is in the range of 6 Ton/Ha to 7Ton/Ha.

In this paper the productivity classes in East Java is defined as follow. The low class is defined as 3<Low class<=5 Ton/Ha, the medium class is defined 5<Medium class<=7 Ton/Ha and the high class is above 7 Ton/Ha).

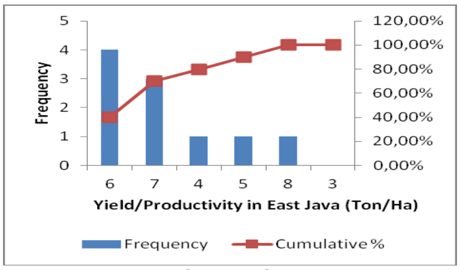

Figure 11: Productivity data in East Java

There are 5 segments derived from East Java yield and climate data.

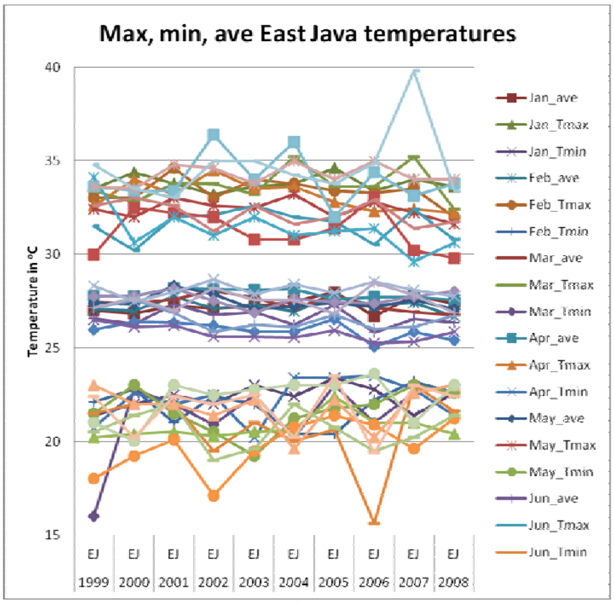

Figure 12: Segments of climate data in East Java

The medium yield results from three different clusters, while the low and high yield results from one cluster. Both west java and east java data a 5 cluster SOM is given below with their corresponding graph of monthly temperatures of each clusters. It shows that the high temperature in May results in low yield in cabai merah besar (cmb) in West Java, but results in high yield in East Java.

Figure 13: 5clusters of SOM in west and east java

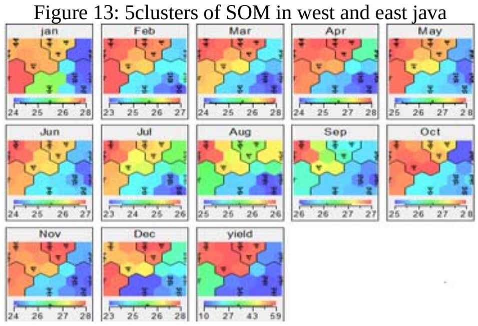

Figure 14: Clusters development monthly

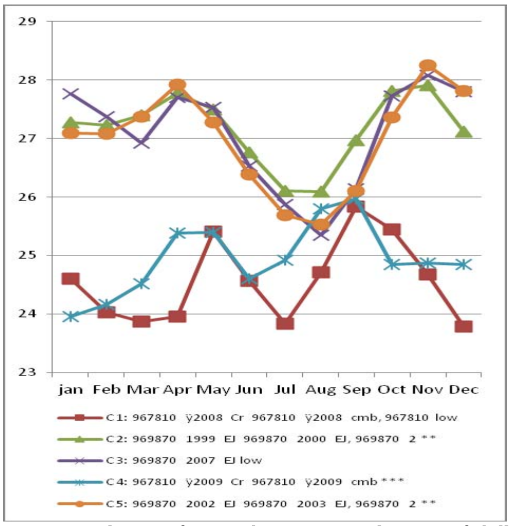

Figure 15: 5Clusters of east and west java productivity of chilli

Based on these results rules for a decision support system as a prediction model can be derived.

- `Rules for high - contains 2 rule(s)`
  - `Rule 1 for high`
    `if Mar_ave > 24.125 and Jun_Tmin <= 21.805 and var in [ "cmb" ] and Apr_ave > 24.565 then high`
  - `Rule 2 for high`
    `if Mar_ave > 24.125 and Jun_Tmin > 21.805 and Nov_Tmax > 4.39 then high`

- `Rules for low - contains 3 rule(s)`
  - `Rule 1 for low`
    `if Mar_ave <= 24.125 and Dec_ave <= 23.455 and var in [ "Cr" ] then low`
  - `Rule 2 for low`
    `if Mar_ave <= 24.125 and Dec_ave > 23.455 then low`
  - `Rule 3 for low`
    `if Mar_ave > 24.125 and Jun_Tmin > 21.805 and Nov_Tmax <= 34.39 then low`

- `Rules for med - contains 3 rule(s)`
  - `Rule 1 for med`
    `if Mar_ave <= 24.125 and Dec_ave <= 23.455 and var in [ "cmb" ] then med`
  - `Rule 2 for med`
    `if Mar_ave > 24.125 and Jun_Tmin <= 21.805 and var in [ "Cr" "EJ" ] then med`
  - `Rule 3 for med`
    `if Mar_ave > 24.125 and Jun_Tmin <= 21.805 and var in [ "cmb" ]and Apr_ave <= 24.565 then med`
- `Default: med`

In the above rules ‘cmb’ represents the Capsicum Annuum L (cabai merah besar) and ‘cr’ represents the Capsicum frutescens (cabai rawit). The productivity is in medium level for default values.

Since the field monitor functions as an early warning system then the most significant rule is the rules for low productivity. In general that if the March average temperature is below 24.125 the productivity is most likely will be low. The productivity is also low when the average temperature in March is higher than 24.125 only if the temperature minimum in June is higher than 21.805 and the temperature maximum in November is less than 34.39. In both cases an early warning of a potential low productivity will be send.

VI. CONCLUSION

A prediction model of chilli in Indonesia based on productivity and climate data in west and east java regions provides rules which can be used to make a prediction of yield in three classes (high, medium, and low). This prediction becomes as an alternative modul in the traceability model II to advise the field monitor whether it will send an early warning to the farmer to undertake some precautions in order to reduce potential losses. By considering the rules for low productivity a warning will be send by the field monitor to the farmer.

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