UNIVERSITI PUTRA MALAYSIA

PROSPECTS FOR BASAL STEM ROT DISEASE BASED ON SOIL APPARENT ELECTRICAL CONDUCTIVITY IN OIL PALM PLANTATION

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

August 2020

DEDICATION

This Thesis is Dedicated to:

Those Individuals Who Have the Courage to Change Themselves Instead of Others

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Doctor of Philosophy

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Faculty : Engineering

Basal stem rot (BSR) disease is the most common manifestation of *Ganoderma* infection in the region. Losses begin to have a financial effect once the infection affects more than 10% of the stand. On average there is a decline of the yield of the fresh fruit bunch (FFB) of 0.16 t/ha per year for every palm lost, and when the stand had declined by 50%, the average FFB yield reduction was 35%. The route of BSR colonization is unpredictable and seems that there is no tools or mechanism available in the market to identify the threat at the initial stage. This study was conducted to look at the relationship of BSR disease which may be significant to soil nutrients and soil apparent electrical conductivity (ECa). It was conducted at three different areas namely Jenderata Estate, Seberang Perak, and Kluang. The soil series for both Jenderata and Seberang Perak was in the Jawa series with the age of nine years of the oil palm tree. Meanwhile, Kluang had Melaka soil series with the age of 25 years of the oil palm tree. The soil sample was taken at all study areas with grid sampling method and Veris EC sensor was pulled across the oil palm field with Trimble AG132 DGPS system used for geo-referencing. Besides, the incidence level of BSR infection both in a healthy or infected tree was observed and recorded by the Malaysian Palm Oil Board (MPOB) expert team. Interpolation techniques were done for all data by using ArcMap to identify the soil variability. The relationship of soil parameters, soil ECa, and soil nutrient contents was analysed using the statistical method in the SPSS software package. The result showed that low magnesium (Mg) located in the infected area at Seberang Perak and Kluang although both areas had different soil series. Besides, an independent t-test at both studies showed Mg had significance effect on BSR infection level. However, the independent t-test showed only phosphorus (P) had significant effect on BSR infection level in Seberang Perak. It can be concluded that Mg and P had significantly correlated to the BSR infection. The algorithm was developed based on the Mg and P as it had a correlation with soil ECa and had a significant independent t-test. A predicted model using regression was used for both Mg and P to develop a predicted spatial variability map for both soil nutrients with soil ECa as the independent variable. Furthermore, the software was developed by using MATLAB to

produce a predicted BSR map in oil palm plantation based on the developed algorithm. The results obtained from the software shows that the map pattern was slightly different while the data between software and conventional method using ArcMap was slightly different at ± 0.0003 cmol/kg for both Mg and P. Therefore, this software is expected to be a reliable method to predict thus to prevent the BSR infection at the initial stage in oil palm plantation.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PROSPEK PENYAKIT REPUT PANGKAL BATANG BERDASARKAN PENAMPILAN KEKONDUKSIAN ELEKTRIK TANAH DI LADANG KELAPA SAWIT

Oleh

EZRIN MOHD HUSIN

Ogos 2020

Pengerusi : Aimrun Wayayok, PhD
Fakulti : Kejuruteraan

Penyakit reput pangkal batang (BSR) adalah penyakit yang paling mudah dijangkiti pada pokok kelapa sawit di rantau ini. Kerugian disebabkan penyakit ini akan mula memberi kesan apabila pokok dijangkiti lebih daripada 10%. Penurunan hasil buah tandan segar (FFB) sebanyak 0.16 t/ha setahun bagi setiap pokok sawit akan hilang apabila dijangkiti sebanyak 50% dan purata pengurangan hasil FFB adalah 35%. Cara penyakit BSR ini dijangkiti tidak dapat diramalkan kerana tiada alat atau mekanisma yang berada di pasaran yang dapat mengenal pasti ancaman pada peringkat awal. Kajian ini dijalankan untuk melihat hubungan antara penyakit BSR dengan sifat tanah dan kekonduksian elektrik tanah (ECa). Ia dijalankan di tiga kawasan yang berbeza iaitu Ladang Jenderata, Seberang Perak dan Kluang. Siri tanah untuk Jenderata dan Seberang Perak berada dalam siri Jawa dengan usia pokok kelapa sawit adalah sembilan tahun. Sementara itu Kluang mempunyai tanah siri Melaka dengan usia pokok kelapa sawit adalah 25 tahun. Sampel tanah diambil di semua kawasan kajian dengan kaedah pensampelan grid dan sensor Veris EC ditarik di ladang kelapa sawit dilengkapi dengan sistem Trimble AG132 DGPS yang digunakan untuk rujukan koordinat. Selain itu, tahap penyakit BSR di antara yang sihat atau dijangkiti diperhatikan dan direkodkan oleh pakar dari Lembaga Minyak Sawit Malaysia (LMSM). Teknik interpolasi digunakan bagi semua data dengan menggunakan perisian ArcMAP untuk mengenal pasti kebolehubahan tanah. Hubungan parameter tanah, ECa tanah dan kandungan nutrien dianalisis menggunakan kaedah statistik menggunakan perisian SPSS. Keputusan yang diperolehi menunjukkan kandungan magnesium (Mg) rendah di kawasan yang dijangkiti bagi kawasan Seberang Perak dan Kluang walaupun kedua-dua kawasan mempunyai siri tanah yang berbeza. Ujian *'independent t-test'* di kedua-dua kawasan kajian dapat membezakan Mg dengan tahap penyakit BSR. Walaubagaimanapun, 'independent t-test' hanya dapat membezakan fosforus (P) dengan tahap penyakit BSR di Seberang Perak. Kesimpulannya, Mg dan P mempunyai korelasi dengan penyakit BSR. Algoritma telah dibangunkan berdasarkan korelasi antara Mg dan P kerana ia mempunyai korelasi yang signifikan dengan ECa tanah dan

‘independent t-test’. Model ramalan menggunakan regresi digunakan untuk kedua-dua Mg dan P untuk menghasilkan peta kebolehubahan spatial bagi kedua-dua sifat tanah dengan ECa tanah sebagai pembolehubah bebas. Lebih lanjut lagi, sebuah perisian telah dibangunkan menggunakan MATLAB untuk menghasilkan peta ramalan BSR di ladang kelapa sawit berasaskan kepada algoritma yang dibangunkan. Keputusan diperoleh dari perisian menunjukkan bahawa corak peta sedikit berbeza sementara data antara perisian dan kaedah konvensional menggunakan ArcMAP sedikit berbeza pada ± 0.0003 cmol/kg untuk kedua-dua Mg dan P. Oleh itu, perisian ini dijangka menjadi kaedah yang baik untuk meramalkan dan mencegah penyakit BSR di peringkat awal dalam ladang kelapa sawit.

ACKNOWLEDGEMENTS

First, I would like to extend my deepest gratitude to ALLAH for making all things possible. There are numbers of people without whom this thesis might not have been written, and to whom I am greatly indebted.

A very special thank you for my dearly wife, Mashitoh Abd Aziz who always gave me trust, emotional support and advices to me during my struggle in desiring something that unbelievable to be achieved and contribute for better world. To my beloved children, Amir Syafiq, Akiff Amani, Aqill Farhan and my little princess, Aisy Sofea whose have been sources of encouragement to me during my study time and for brighter future life.

I am greatly indebted to my supervisor, Dr. Aimrun Wayayok, for his excellence guidance, patience, advice and trust to complete this study. I am very grateful to the members of my supervisory committees; Assoc. Prof. Dr. Ahmad Fikri Abdullah and Assoc. Prof. Dr. Siti Khairunniza Bejo for their valuable suggestions and advices during the study.

I am very thankful to SMART Farming Technology Research Centre, Soil Analysis Laboratory, Machinery Laboratory, Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia (UPM) and not forgetting FELCRA Seberang Perak and United Plantation Berhad staffs for their assistance, kindness and valuable support in completing the research study.

I also would like to express my special thanks to all my laboratory friends and colleagues, who are not mentioned here, for their helps and moral support during the study.

The last, to my late parents, Allahyarham Haji Mohd Husin Baharuddin and Allahyarhamah Hajjah Rogayah Yassin, whose constantly support and inspired me to continue to strive to complete my study during their lifetime. May Allah forgive them and accept their deeds and grant them Jannah. AL-FATIHAH.

Ezrin Mohd Husin

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LIST OF ABBREVATIONS

%	Percentage
°C	Degree Celcius
BSR	Basal Stem Rot
C	Carbon
Ca	Calcium
CEC	Cation Exchange Capacity
CI	Cone Index
Cm	Centimeter
CV	Coeffiecient of Variation
DGPS	Differential Global Positioning System
DNA	Deoxyribonucleic Acid
EC	Electrical Conductivity
ECa	Apparent Electrical Conductivity
Elev.	Elevation
ER	Electrical Resistance
FFB	Fresh Fruit Bunch
GIS	Geographical Information System
GSM	Ganoderma Selective Medium
hp	HorsePower
K	Potassium
kHz	KiloHertz
mc	Moisture Content
Mg	Magnesium
mS/m	Milisiemen per Meter

N	Nitrogen
P	Phosphorus
PCR	Polymerase Chain Reaction
RSS	Reduced Sum of Square
S	Sulphur
TEM	Transmission Electron Microcopy
Ω	Ohm

CHAPTER 1

INTRODUCTION

1.1 General

Malaysia currently accounts for 32% of world oil palm production. The country is now the second world's largest exporter of oil palm and becomes one of the world's leading oil palm producers, with 17.3 million tonnes of oil palm produced in 2017 (USDA, 2016; MPOB 2017). The major threats to oil palm sustainability are pests and infection. However, a basidiomycete fungus, species of Ganoderma, which cause Basal Stem Root (BSR) infection in oil palm plantation. The fungus infects oil palm trees, initially causing yield loss and finally killing the trees.

Infection outbreak in oil palm plantation is the major factor contributing to the profit losses in the oil palm industry. This infection was caused by *Ganoderma boninense* and was considered a great threat to sustaining the oil palm production for the South East Asia region; especially in Malaysia and Indonesia. Besides, the irregular management system in oil palm plantations may contribute to the infection outbreak development especially during enrichment soil nutrient task or fertilization task. Inadequate information on soil parameters or available nutrients which influenced the infection is very crucial to control the infection in oil palm plantation. Therefore, a proper management system is urgently needed to overcome all the emphasized issues to sustain the industry.

1.1.1 Basal Stem Rot (BSR) in Oil Palm Plantation

Generally, commercial oil palm plantation suffers from multi harmful infection in each of the different environments. Basal stem rot (BSR) infection had caused by species of *Ganoderma Boninense* greatly affected oil palm production. It has been regarded as a facultative parasite, living saprophytically on food base on stumps and roots. If not detected early and no control measures are taken, death of the affected trees may occur six to 12 months after the developments of the symptoms, though in some affected plants they may live on for several years. Such observations indicate that the root and bole system of oil palm has been infected, which resulted in the decay of tissues and causes restriction of water and nutrient supply to the aerial parts of the plants. In young palms, external symptoms can be observed by the appearance of length reduction in the young unfolded leaves and mottling of lower fronds, sometimes with necrotic tips. As the infection progresses, spear leaves remain unopened and palms suffer from retardation in growth and take on a pale appearance.

These infected crops affect nutrient supply and availability by retrieving nutrients from below the rooting zones of crops, reducing nutrient losses from leaching and erosion, and enhancing nutrients released from soil organic matter. Crops take up nutrients from different soil layers and utilize them for metabolic activities. At present, effective and sustainable management strategies to control BSR are hampered mainly by a lack of understanding of mechanisms of infection establishment, development, and spread.

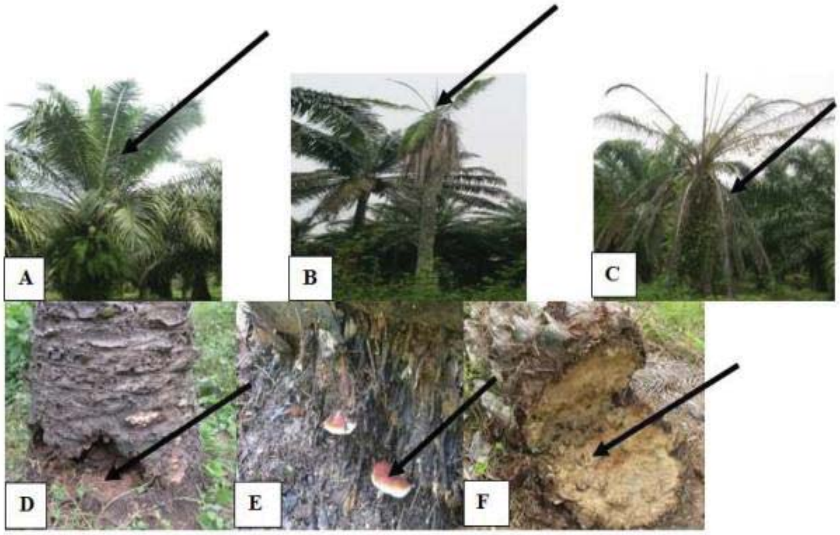

Figure 1.1: Field symptoms of BSR infection in oil palm plantation; (A) symptomatic plant, (B) unopened spear leaves, (C) skirt-like appearance, (D) basidiocarp formation, (E) bole creation and (F) death of tree (Source: Afui and Tonjock, 2015).

1.1.2 Apparent Soil Electrical Conductivity Sensor (ECa)

The field-scale application of apparent soil electrical conductivity (ECa) to agriculture has its origin in the measurement of soil salinity, which is an arid-zone problem associated with irrigated agricultural land and with areas having shallow water tables. This ECa is influenced by a combination of Physico-chemical properties including soluble salts, clay content and mineralogy, soil water content, bulk density, organic matter, and soil temperature. Consequently, measurements of ECa have been used at field scales to map the spatial variation of several edaphic properties: soil salinity, clay content or depth to clay-rich layers, soil water content, the depth of flood deposited sands, and organic matter. Besides, ECa has been used at field scales to determine a variety of anthropogenic properties: leaching fraction, irrigation and drainage patterns, and compaction patterns due to farm machinery. ECa is a quick, reliable, easy-to-take soil measurement that often, but not always, relates to crop yield. For these reasons, the measurement of ECa is among the most frequently used tools in precision agriculture research for the Spatio-temporal characterization of edaphic and anthropogenic properties that influence crop yield.

Veris 3100 sensor was used as a soil detector with electrical conduction. In this series, the electrodes were replaced by rotating discs which were placed around six cm into the soil. As the cart was pulled through the field, one pair of electrodes passes electrical current into the soil, while two other pairs of electrodes measure the voltage drop.

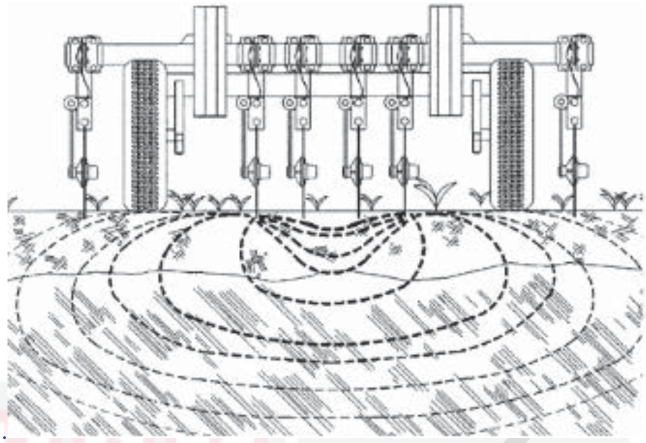

Figure 1.2: The system components of Veris 3100

The system was set up to switch between two configurations, denoted as configuration (A shallow) and (B deep).

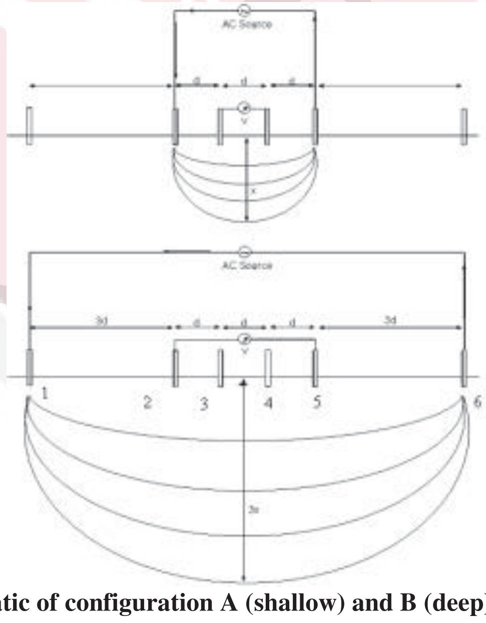

Figure 1.3: Schematic of configuration A (shallow) and B (deep)

Configuration A has used the four inner discs (2, 3, 4, and 5). The voltage drop was measured between the two innermost discs (3 and 4) which were d (unit m) apart. In Configuration B, the four outer discs (1, 2, 5, and 6) were used and the voltage drop was measured between discs 2 and 5. When the electrodes (discs) were d meters apart, the conductivity was measured to the depth of roughly 1.5d meters (Amin et al., 2004).

From the review, the typical signal contributions for a "Wenner array" (very similar in principle and to the Veris) revealed the following figure from John Milsom's 1989 book, Field Geophysics. It has been seen from this illustration that the signal contribution between different electrodes and through the various depths reached by the array was complicated. Indeed, it appears that the signal contribution is ridiculously complicated when different regions in the array at the same depth contribute readings of opposite sign. However, Milsom (1989) points out that in relatively homogeneous soil with a short separation distance between the electrodes (as is the case with the Veris), the opposite signs returned near the electrodes "cancel quite precisely". The importance is the fact that despite the complexity of the physics, the array returns the signal which is the net result of relatively linearly weighted contributions through the signal depth. Each electrode contributes relatively equally, as does each depth within the soil profile. Subsequently, the Veris 0-300mm and 0-900mm readings should closely match the soil average of apparent electrical conductivity (ECa) within these soil volumes. The Veris achieves two separate depth readings by switching between the six available discs to increase or decrease the distance "d" separating the "excite" and "measure" discs.

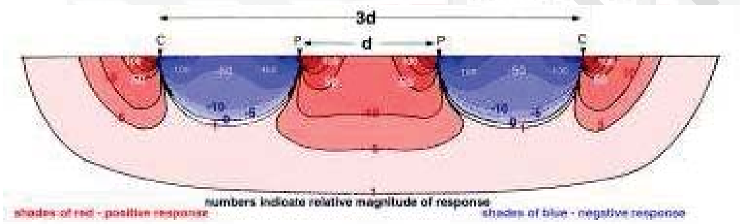

Figure 1.4: Contour plots of the measured signal by each unit soil volume (Source: VerisTech)

The contour plots of the contribution were made to the measured signal by each unit volume of soil. In this illustration, the red regions have positive contributions and the blue regions have negative contributions.

According to VerisTech, some benefits of the soil conductivity map which being derived by Veris 3100 were (a) determination of the layout of the site, (b) interpolation of yield maps, (c) soil sampling guide, (d) on-farm trials design and (e) nutrients, crop protection chemicals and seed recipes inputs.

1.2 Problem Statement

Losses begin to have a financial effect once the infection affects more than 10% of the stand (Mercière, 2017). On average there is a decline of the yield of the fresh fruit bunch (FFB) of 0.16t/ha for every palm lost, and when the stand had declined by 50% the average FFB yield reduction was 35% (Subagio and Foster, 2003). Primary infection of Ganoderma infection was occurred by contact of living palm roots with colonized debris within the soil. To understand the soil condition which may influenced to the Ganoderma infection, the soil samples must be collected and send to the laboratory for data analysis. Collecting the soil samples by using traditional methods is very tedious and time-consuming especially for the oil palm plantation areas. However, all those methods were difficult, time-consuming, and costly to conduct. The ECa sensor is a promising tool that is reliable to assist in data acquisition to identify soil variability to study the soil nutrients. By using ECa sensor that can measure the soil nutrients while on-the-go, it is believed that the problem could be solved. Many researchers reported that the usage of ECa sensor is the best option to describe the field condition and soil variability. Soil variability map was enabled to describe the soil condition in terms of its fertility and nutrient requirement. I, Nur Aini et al. (2014) showed that ECa sensor can produce a very detailed soil zoning map as collected at every one meter and delineated rapidly with higher contrast. The results from ECa sensor were correlated with yield soil nutrients either with positive or negative correlation (Sudduth et al., 2001) and it proved that ECa sensor can serve as a soil quality indicator for soil productivity (Jung et al., 2005). Therefore, ECa sensor was selected as a tool to identify the soil condition since its technology was proven in this study.

1.3 Objectives

The main objective of this study is to investigate the usage of soil nutrients measurement as a mean for preventive action for BSR infection. The specific objectives are:

I. To find the significant of the mathematical relationship between the measured real time ECa by Veris system with the measured soil nutrients by laboratory analysis.

II. To quantify the prediction accuracies of the earlier developed mathematical soil nutrients equations and the measured soil nutrient contents had affects in controlling the BSR infections.

III. To develop an algorithm and its real time GUI system that enable to classify the oil palm plantation area which have high prospects for BSR infections.

1.4 Scope of Study

This study proposed to establish a comprehensive information system for detection, identification and quantification of BSR infestation in oil palm plantation using integrated engineering approach namely soil apparent electrical conductivity (ECa) measurements system. The system is able to perform an ECa data which able to be associated with other soil nutrients that probably influence to the BSR disease. This study shall able to find the significant of the mathematical relationship between the measured real time ECa obtained from the system with the evaluated soil nutrients from laboratory analysis throughout the experiment. Apart from that, this study shall produce accurate procedure in quantify the prediction of the earlier developed mathematical soil nutrients equations and the measured soil nutrient contents in controlling the BSR infections at the field level.

1.5 Limitation and Importance

This study is limited to identify the soil elements and soil nutrients which expected to have influence to the Ganoderma disease. The soil parameter is limited to the Cation Exchange Capacity (CEC), Exchangeable Magnesium (Mg), Exchangeable Calcium (Ca), Exchangeable Potassium (K), Available Phosphorus (P), Soil Acidic level (pH), Sulphur (S), Total Carbon (C) and Total Nitrogen (N). The parameter was choosen based on the first priority of the fertility level for oil palm cultivaton. Apart from that, the experiment have pre & post processing time for the soil laboratory analysis and unable to perform the real time analysis due to limit capability of the tools usage in the experiment. Other elements such as water, environment, weather and plantation management factor which probably influence to the Ganoderma disease breakout are not included in the scope. Last but not least, the soil sensor used in this study is a sensor which able to provide others soil data and sampling coordinates in real time basis. The only soil parameter that can be measured in-situ in real time is apparent soil electrical conductivity (ECa) and the system available in the market that capable to provide ECa data and sampling coordinate in real time basis is only Veris 3100 sensor. The study able to provide early measurement procedure in identify the BSR infections by using soil ECa and soil nutrient contents to quantify the relationship of both parameter and spatial variability map. Besides, for the real-time detecting, the study could develop a new algorithm and software to predict the BSR infected area in the oil palm plantation areas by understanding the soil soil ECa and soil nutrient contents data povided. Moreover, the software developed through the study can become a reliable tool for early detection management in detecting BSR infection and the data produces can act as a reference before oil palm replanting.

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APPENDICES

APPENDIX A

Ganomapper Source Code

Ganomapper software was developed for Mg and P as both soils had a significant correlation with soil ECa. Besides, Mg and P also had significant independent t-test. This software was developed to predict the BSR disease on a real-time basis as the spatial variability map for both Mg and P can show the predicted infected area.

ENTER WINDOW

1. SYSTEM STARTING

```
function varargout = GanoMapper(varargin)

gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                   'gui_Singleton',  gui_Singleton, ...
                   'gui_OpeningFcn', @GanoMapper_OpeningFcn, ...
                   'gui_OutputFcn',  @GanoMapper_OutputFcn, ...
                   'gui_LayoutFcn',  [] , ...
                   'gui_Callback',   []);
if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State, varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
```

GANOMAPPER WINDOW

1. SYSTEM STARTING

```
function GanoMapper_OpeningFcn(hObject, eventdata, handles, varargin)

warning('off','MATLAB:HandleGraphics:ObsoletedProperty:JavaFrame');
javaFrame = get(hObject,'JavaFrame');
javaFrame.setFigureIcon(javax.swing.ImageIcon('GanoMapper-New.jpg'));
handles.output = hObject;
```

```
set(handles.disconnect,'Enable','off');
set(handles.cubo,'String','');
set(handles.groupselect,'SelectionChangeFcn',@groupselect_SelectionChangeFcn);
set(handles.groupselect,'Tag','Deep');
handles.method  = 1;

handles.minc    = 0;
handles.maxc    = 40;
handles.value   = 1;
handles.connect = 0;

axes(handles.logo1);
imshow(imread('GanoMapper-New.jpg'));
axes(handles.soilprologo);
imshow(imread('GanoMapper-New.jpg'));
handles.key = 2;

set(handles.strt,'Enable','off');
set(handles.stop,'Enable','off');
set(handles.reset,'Enable','off');
set(handles.save,'Enable','off');
set(handles.calibration,'Enable','off');

set(handles.ECad,'Enable','off');
set(handles.ECas,'Enable','off');
set(handles.deepFilter,'Enable','off');
set(handles.shallowFilter,'Enable','off');
set(handles.eqinterval_edit,'Enable','off');

handles.FilterButton = 0;
guidata(hObject, handles);
```

2. GANOMAPPER OUTPUT

```
function varargout = GanoMapper_OutputFcn(hObject, eventdata, handles)

varargout{1} = handles.output;
guidata(hObject, handles);
```

3. CONNECT BUTTON

```
function connect_Callback(hObject, eventdata, handles)

Val = handles.value;
if Val == 1
   com = 'COM1';
else if Val == 2
```

```
    com = 'COM2';
    else if Val == 3
        com = 'COM3';
      else if Val == 4
          com = 'COM4';
        else if Val == 5
            com = 'COM5';
          else if Val == 6
              com = 'COM6';
            else if Val == 7
                com = 'COM7';
              else if Val == 8
                  com = 'COM8';
                else if Val == 9
                    com = 'COM9';
                  else if Val == 10
                      com = 'COM10';
                    else if Val == 11
                        com = 'COM11';
                      else
                          com = 'COM12';
                      end
                    end
                  end
                end
              end
            end
          end
        end
      end
    end
end

set(handles.disconnect,'Enable','on');
veris = [];
handles.veris = veris;
status = 'No Device';
set(handles.checkConnection,'string',status);
veris = serial(com,'BaudRate',9600);
handles.veris=veris;
fopen(veris);
a=fscanf(veris);


%% New Code
if isempty(a)
    errordlg('Device not found, Please use another port','Device Connection Error');
    fclose all
    delete(veris)
```

```
    clear veris
        else if a(1:3)  == '$EC'
            status = 'Found Device';
            handles.connect = 1;
            state  = 'Connected';
            else
                status = 'No Device';
                errordlg('Device not found, Please check port communication','Device
Connection Error');
                set(handles.disconnect,'Enable','off');
                delete(instrfindall);
        end
end

set(handles.checkConnection,'string',status);
set(handles.strt,'Enable','on');
set(handles.stop,'Enable','on');
set(handles.reset,'Enable','on');
set(handles.save,'Enable','on');

guidata(hObject, handles);
```

4. **DISCONNECT BUTTON**

```
function disconnect_Callback(hObject, eventdata, handles)

veris = handles.veris;
fclose(veris);

set(handles.checkConnection,'string','Closed');
guidata(hObject, handles);
```

5. **START BUTTON**

```
function strt_Callback(hObject, eventdata, handles)

valuePlotSelection = handles.valuePlotSelection;

%% Calibration
def1 = handles.def;
minc = def1(1);
maxc = def1(2);

mincal    = str2double(minc);
maxcal    = str2double(maxc);

kelas     = 5;
```

```
minintrvl = maxcal/kelas;

for i=1:kelas
   if i==1
       miniint  (i) = mincal;
       maxintrvl(i) = minintrvl - 0.1;
       else if i==5
          miniint  (i) = miniint(i-1)+ minintrvl ;
          maxintrvl(i) = maxcal;
          else
             miniint  (i) = miniint(i-1)+ minintrvl ;
             maxintrvl(i) = maxintrvl(i-1)+ minintrvl;
       end
   end
end

veris = handles.veris;
flag  = 1;
k     = 1;
xx    = 1;
mm    = 1;

longref = 0;
latref  = 0;
Zref    = 0;

while flag

       w = fscanf(veris);
        if w(1:3)=='$EC'
           w   = fscanf(veris);
         idx = str2num(w(4:end));
          [v bildata] = size(idx); %399 - 395

             longnew = idx(1);
             latnew  = idx(2);
             shallow = idx(3);
             deep    = idx(4);

          if ~isempty(idx) && bildata >= 4 && longnew ~= longref || latnew ~= latref
&& deep >= -4 && shallow >= -4

          handles.datacorr{mm} = [longnew latnew shallow deep];
          mm = mm+1;

%% Formula yang terlibat - Semua Formula utk On The Go

   if valuePlotSelection == 1
          Znew = idx(4); %ECad
```

```
        else
            Znew = idx(3);%ECas
    end

%% On the Go Plotting Ikut Kelas

        color = {'bs-','rs-','ms-','gs-','cs-'};
        axes(handles.graph);

for i=1:kelas
    if Znew >= miniint(i)&& Znew < maxintrvl(i)
                plot3(longnew, latnew, Znew, color{i},'LineWidth',2,...
                    'MarkerFaceColor',[0 0 0],...
                    'MarkerSize',10);
                n=get(gca,'xtick');
                set(gca,'xticklabel',sprintf('%.3f |',n'));
                grid on
                m=get(gca,'ytick');
                set(gca,'yticklabel',sprintf('%.3f |',m'));
                view([0 90]);
                hold on

                %% Save Data
                dataFilter{xx} = [longnew latnew shallow deep Znew];
                handles.dataFilter = dataFilter;
                handles.Datanew    = dataFilter;
                handles.data       = dataFilter;
                handles.Dataload   = dataFilter;
                xx=xx+1;
            end

        k=k+1;
        longref = longnew;
        latref  = latnew;
        Znewref = Znew;

        end
            end
        guidata(hObject, handles);

end

end
```

6. SELECTION (STOP BUTTON)

```
function stop_Callback(hObject, eventdata, handles)
uiwait();
```

7. SELECTION (RESET BUTTOM)

```
function reset_Callback(hObject, eventdata, handles)

cla(handles.graph);
```

8. SELECTION (LOAD DATA BUTTON)

```
function loadData_Callback(hObject, eventdata, handles)

[filename, pathname, filterindex] = uigetfile( ...
{  '*.xls','Excel-files (*.xls)'; ...
  '*.*',  'All Files (*.*)'}, ...
  'Pick a file');

set(handles.edit11,'string',filename);
set(handles.cubo,'String','Data');
if filterindex == 0
   return
else
set(handles.save,'Enable','on');
set(handles.ECad,'Enable','on');
set(handles.ECas,'Enable','on');

cd (pathname);

Data            = xlsread(filename);
handles.data     = Data;
handles.dataload = Data;

guidata(hObject,handles);

long    = Data(:,1);
lat     = Data(:,2);
z       = Data(:,4);

cla(handles.graph);
axes(handles.graph);
plot3(lat,long, z, 'rs','LineWidth',1,'MarkerFaceColor',[1 1 1]);
Xtix=get(gca,'xtick')';
set(gca,'xticklabel',num2str(Xtix,'%.4f'));
Ytix=get(gca,'ytick')';
set(gca,'yticklabel',num2str(Ytix,'%.4f'));
view(0, 90);

end
```

9. SELECTION (CLASS BUTTON)

```
function class_Callback(hObject, eventdata, handles)
```

10. SELECTION (CLASS CREATE)

```
function class_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

11. SELECTION (MANUAL CLASS BUTTON)

```
function manualclass_Callback(hObject, eventdata, handles)

function manualclass_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

12. SELECTION (MAXIMUM INTERVAL BUTTON)

```
function maxinterval_Callback(hObject, eventdata, handles)

function maxinterval_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

13. SELECTION (MINIMUM INTERVAL BUTTON)

```
function mininterval_Callback(hObject, eventdata, handles)

function mininterval_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

14. SELECTION (MANUAL INTERVAL BUTTON)

```
function manualinterval_Callback(hObject, eventdata, handles)

function manualinterval_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

15. SELECTION (ECas BUTTON)

```
function ECas_Callback(hObject, eventdata, handles)

set(handles.cubo,'String','Plot ECas');
Datanew = handles.dataload;

longnew = Datanew(:,1);
latnew  = Datanew(:,2);
shallow = Datanew(:,3);
deep    = Datanew(:,4);

axes(handles.graph);
cla (handles.graph);

plot3(latnew, longnew, shallow, 'rs','LineWidth',1,'MarkerFaceColor',[0 0 0]);
Xtix=get(gca,'xtick')';
set(gca,'xticklabel',num2str(Xtix,'%.5f'));
Ytix=get(gca,'ytick')';
set(gca,'yticklabel',num2str(Ytix,'%.5f'));
view(0, 90);

[r c] = size(shallow);

for i=1:r
    data1{i} = [longnew(i) latnew(i) deep(i) shallow(i)]; %% terbalik kan shallow jd
column 4 deep jd column 3
end

handles.key   = 2;
handles.data1 = data1;

minshallow = min(shallow);
maxshallow = max(shallow);

handles.mindata = minshallow;
handles.maxdata = maxshallow;
```

```
handles.plotname = 'Shallow';
handles.filterSelection = 2;

set(handles.filtermin,'string',2);
set(handles.filtermax,'string',150);

guidata(hObject, handles);
```

16. SELECTION (ECad BUTTON)

```
function ECad_Callback(hObject, eventdata, handles)

set(handles.cubo,'String','Plot ECad');
FilterButton = handles.FilterButton;

Datanew = handles.dataload;

longnew = Datanew(:,1);
latnew  = Datanew(:,2);
shallow = Datanew(:,3);
Znew    = Datanew(:,4);

cla(handles.graph);
axes(handles.graph);
plot3(latnew,longnew, Znew, 'rs','LineWidth',1,'MarkerFaceColor',[1 1 1]);
Xtix=get(gca,'xtick')';
set(gca,'xticklabel',num2str(Xtix,'%.5f'));
Ytix=get(gca,'ytick')';
set(gca,'yticklabel',num2str(Ytix,'%.5f'));
view(0, 90);

[r c] = size(Znew);

mindeep = min(Znew);
maxdeep = max(Znew);

for i=1:r
   data{i,:} = [longnew(i) latnew(i) shallow(i) Znew(i)]; %%data(i,:) = [longnew(i)
latnew(i) shallow(i) Znew(i)];
end

handles.key  = 1;
handles.data = data;
handles.mindata = mindeep;
handles.maxdata = maxdeep;
handles.plotname = 'Deep';
handles.filterSelection = 1;
```

```
set(handles.filtermin,'string',2);
set(handles.filtermax,'string',60);

guidata(hObject, handles);
```

17. SELECTION (SAVE BUTTON)

```
function save_Callback(hObject, eventdata, handles)

cnct = handles.connect;

if cnct == 1

        data  = handles.dataFilter;
        [r c] = size(data);

        for i=1:c
          longit(i) = (data{1,i}(1));
          lati(i)   = (data{1,i}(2));
          shlw(i)   = (data{1,i}(3));
          deep(i)   = (data{1,i}(4));

        end
        warning('off', 'MATLAB:xlswrite:AddSheet');
        [filename, pathname] = uiputfile(...
          {'*.xls','Excel formats'},...
          'Save as');

        if pathname == 0
          return
        end

        file  = [pathname, filename];

        data1 = longit';
        data2 = lati';
        data3 = shlw';
        data4 = deep';

        xlswrite(file, data1, 'Sheet1', 'A1' );
        xlswrite(file, data2, 'Sheet1', 'B1' );
        xlswrite(file, data3, 'Sheet1', 'C1' );
        xlswrite(file, data4, 'Sheet1', 'D1' );
        xlswrite(file, data3, 'Shallow', 'A1' );
        xlswrite(file, data4, 'deep', 'A1' );

else if cnct == 0
```

```
filterSelection = handles.filterSelection;
if filterSelection ==1 %deep

    Datanew = handles.dataFilter;
    longnew = Datanew(:,1) ;
    latnew  = Datanew(:,2);
    shallow = Datanew(:,3);
    deep    = Datanew(:,4);
    [r c]   = size(deep);

    warning('off', 'MATLAB:xlswrite:AddSheet');
    [filename, pathname] = uiputfile(...
       {'*.xls','Excel formats'},...
       'Save as');

    if pathname == 0
       return
    end

    file  = [pathname, filename];

    data1 = longnew;
    data2 = latnew;
    data3 = shallow;
    data4 = deep;

    xlswrite(file, data1, 'Sheet1', 'A1' );
    xlswrite(file, data2, 'Sheet1', 'B1' );
    xlswrite(file, data3, 'Sheet1', 'C1' );
    xlswrite(file, data4, 'Sheet1', 'D1' );
    xlswrite(file, data3, 'Shallow', 'A1' );
    xlswrite(file, data4, 'Deep', 'A1' );

else

    Datanew = handles.dataFilter;
    longnew = Datanew(:,1) ;
    latnew  = Datanew(:,2);
    shallow = Datanew(:,3);
    deep    = Datanew(:,4);
    [r c]   = size(deep);

    warning('off', 'MATLAB:xlswrite:AddSheet');
    [filename, pathname] = uiputfile(...
       {'*.xls','Excel formats'},...
       'Save as');

    if pathname == 0
       return
```

```
        end

        file  = [pathname, filename];

        data1 = longnew;
        data2 = latnew;
        data3 = shallow;
        data4 = deep;

        xlswrite(file, data1, 'Sheet1', 'A1' );
        xlswrite(file, data2, 'Sheet1', 'B1' );
        xlswrite(file, data3, 'Sheet1', 'C1' );
        xlswrite(file, data4, 'Sheet1', 'D1' );
        xlswrite(file, data3, 'Shallow', 'A1' );
        xlswrite(file, data4, 'Deep', 'A1' );
      end

   end

end
```

18. SELECTION (GROUP SELECT BUTTON)

```
function groupselect_SelectionChangeFcn(hObject, eventdata, handles)

handles = guidata(hObject);
```

19. SELECTION (LIST INTERVAL BUTTON)

```
function listinterval_Callback(hObject, eventdata, handles)

function listinterval_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function manual_KeyPressFcn(hObject, eventdata, handles)
```

20. SELECTION (NEXT BUTTON)

```
function next_Callback(hObject, eventdata, handles)

uiresume();
```

21. SELECTION (MENU BUTTON)

```
function popupmenu1_Callback(hObject, eventdata, handles)

Value = get(handles.popupmenu1, 'Value');

handles.value = Value ;

guidata(hObject, handles);

function popupmenu1_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

guidata(hObject, handles);
```

22. SELECTION (EDIT BUTTON)

```
function edit8_Callback(hObject, eventdata, handles)

function edit8_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

23. SELECTION (PUSH BUTTON)

```
function pushbutton24_Callback(hObject, eventdata, handles)
```

24. SELECTION (EDIT BUTTON)

```
function edit7_Callback(hObject, eventdata, handles)

function edit7_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

25. SELECTION (PUSH BUTTON)

```
function pushbutton23_Callback(hObject, eventdata, handles)
```

26. SELECTION (EQUAL CLASS BUTTON)

```
function eqclass_Callback(hObject, eventdata, handles)

function eqclass_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

27. SELECTION (EQUAL INTERVAL EDIT BUTTON)

```
function eqinterval_edit_Callback(hObject, eventdata, handles)

hh = handles.key;

if hh == 2
    a = 'Plot Shallow';
    dataNPK = handles.data1;
    set(handles.cubo,'String','Map Mg');
    [r c] = size(dataNPK(1,:));
    for i=1:c
        long(i,:) = dataNPK{1,i}(1);
        lat(i,:)  = dataNPK{1,i}(2);
        zMap(i,:) = dataNPK{1,i}(4);
    end
else
    dataNPK = handles.data;
    b = 'Plot Deep';
    set(handles.cubo,'String','Map P');
    [r c] = size(dataNPK(1,:));
    for i=1:c
        long(i,:) = dataNPK{1,i}(1);
        lat(i,:)  = dataNPK{1,i}(2);
        zMap(i,:) = dataNPK{1,i}(4);
    end
end

xlin  = linspace(min(lat),max(lat),c);
ylin  = linspace(min(long),max(long),c);
[X,Y] = meshgrid(xlin,ylin);
```

```
v = variogram([X Y],zMap,'plotit',false,'maxdist',1,'anisotropy',true);
% [dum,dum,dum,vstruct] = variogramfit(v.distance,v.val,[],[],[],'model','exponential');
[dum,dum,dum,vstruct] = variogramfit(v.distance,v.val,[],[],[],'model','exponential');

[Zhat,Zvar] = krigingvar(vstruct,lat,long,zMap,X,Y);

class = get(handles.eqclass,'String');
class = str2double(class);

axes(handles.graph);
cla (handles.graph);

% set(hFig, 'Name',['Equal Interval: ','Mg']);
[c,h] = contourf(X,Y,Zhat,class-1);
Xtix=get(gca,'xtick')';
set(gca,'xticklabel',num2str(Xtix,'%.5f'));
Ytix=get(gca,'ytick')';
set(gca,'yticklabel',num2str(Ytix,'%.5f'));
view(0, 90);

colormap(hsv(class));
colorbar
```

28. SELECTION (PLOT P BUTTON)

```
function plotP_new_Callback(hObject, eventdata, handles)

set(handles.cubo,'String','Plot New');
Datanew = handles.dataload;

longnew = Datanew(:,1);
latnew  = Datanew(:,2);
shallow = Datanew(:,3);
Znew    = Datanew(:,4);

[r c] = size(Znew);

for i=1:r
   ZN(i)  = Znew(i);%New P
   data{i} = [longnew(i) latnew(i) shallow(i) ZN(i)];
end

axes(handles.graph);
cla (handles.graph);

plot3(longnew, latnew, ZN,
'ys','LineWidth',1,'MarkerEdgeColor','k','MarkerFaceColor',[0.1 0.1 0.1]);
n = get(gca,'xtick');
       set(gca,'xticklabel',sprintf('%.5f |',n));
```

```
    grid on
    m=get(gca,'ytick');
    set(gca,'yticklabel',sprintf('%.5f |',m));
view([0 90]);

handles.key  = 3;
handles.data = data;
```

29. SELECTION (PUSH BUTTON)

```
function pushbutton31_Callback(hObject, eventdata, handles)
```

30. SELECTION (EDIT BUTTON)

```
function edit11_Callback(hObject, eventdata, handles)

function edit11_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
   set(hObject,'BackgroundColor','white');
end
```

31. SELECTION (EDIT BUTTON)

```
function edit12_Callback(hObject, eventdata, handles)

function edit12_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
   set(hObject,'BackgroundColor','white');
end
```

32. SELECTION (EDIT BUTTON)

```
function edit13_Callback(hObject, eventdata, handles)

function edit13_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
   set(hObject,'BackgroundColor','white');
end
```

33. SELECTION (PLOT SELECTION BUTTON)

```
function popupPlotSelection_Callback(hObject, eventdata, handles)

popupValuePlotSelection = get(handles.popupPlotSelection, 'Value');
handles.valuePlotSelection = popupValuePlotSelection;
set(handles.calibration,'Enable','on');

if popupValuePlotSelection == 1
   set(handles.cubo,'String','Plot Deep');
   def = {'0','40'};
   handles.def = def;
   cla(handles.graph);
else popupValuePlotSelection == 2
      set(handles.cubo,'String','Plot Shallow');
         def = {'0','45'};
         handles.def = def;
         cla(handles.graph);
   end

guidata(hObject, handles);

function popupPlotSelection_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
   set(hObject,'BackgroundColor','white');
end
```

34. SELECTION (CALIBRATION BUTTON)

```
function calibration_Callback(hObject, eventdata, handles)

prompt    = {'Minimum:','Maximum:'};
dlg_title = 'Insert Range';
num_lines = 1;
def = handles.def;

answer    = inputdlg(prompt,dlg_title,num_lines,def);

cal       = answer;

mincal    = cal(1);
maxcal    = cal(2);
mincal    = str2double(mincal);
maxcal    = str2double(maxcal);

handles.minc = mincal;
```

```
handles.maxc = maxcal;

kelas     = 5;
minintrvl = (maxcal-mincal)/kelas;

for i=1:kelas
   if i==1
      miniint  (i) = mincal;
      maxintrvl(i) = mincal + minintrvl - 0.1;
      else if i==5
      miniint  (i) = miniint(i-1)+ minintrvl ;
      maxintrvl(i) = maxcal;
         else
      miniint  (i) = miniint(i-1)+ minintrvl ;
      maxintrvl(i) = maxintrvl(i-1)+ minintrvl;
      end
   end
end

set(handles.class1, 'String', miniint(1));
set(handles.class2, 'String', miniint(2));
set(handles.class3, 'String', miniint(3));
set(handles.class4, 'String', miniint(4));
set(handles.class5, 'String', miniint(5));

set(handles.class11, 'String', maxintrvl(1));
set(handles.class22, 'String', maxintrvl(2));
set(handles.class33, 'String', maxintrvl(3));
set(handles.class44, 'String', maxintrvl(4));
set(handles.class55, 'String', maxintrvl(5));

guidata(hObject, handles);
```

35. SELECTION (CLASS BUTTON)

```
function class1_Callback(hObject, eventdata, handles)

function class1_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
   set(hObject,'BackgroundColor','white');
end
```

36. SELECTION (CLASS BUTTON)

```
function class2_Callback(hObject, eventdata, handles)
```

```
function class2_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

37. SELECTION (CLASS BUTTON)

```
function class4_Callback(hObject, eventdata, handles)

function class4_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

38. SELECTION (CLASS BUTTON)

```
function class3_Callback(hObject, eventdata, handles)

function class3_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

39. SELECTION (CLASS BUTTON)

```
function class5_Callback(hObject, eventdata, handles)

function class5_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

40. SELECTION (CLASS BUTTON)

```
function class11_Callback(hObject, eventdata, handles)
```

```
function class11_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

41. SELECTION (CLASS BUTTON)

```
function class22_Callback(hObject, eventdata, handles)

function class22_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

42. SELECTION (CLASS BUTTON)

```
function class33_Callback(hObject, eventdata, handles)

function class33_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

43. SELECTION (CLASS BUTTON)

```
function class44_Callback(hObject, eventdata, handles)

function class44_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

44. SELECTION (CLASS BUTTON)

```
function class55_Callback(hObject, eventdata, handles)

function class55_CreateFcn(hObject, eventdata, handles)
```

```
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

45. SELECTION (FILTER BUTTON)

```
function FilterButton_Callback(hObject, eventdata, handles)

filterSelection = handles.filterSelection;
filtermin = get(handles.filtermin,'String');
filtermin = str2double(filtermin);

filtermax = get(handles.filtermax,'String');
filtermax = str2double(filtermax);

Datanew = handles.dataload;

longnew = Datanew(:,1);
latnew  = Datanew(:,2);
shallow = Datanew(:,3);
Znew    = Datanew(:,4);

[r c] = size(shallow);
w = 1;
if filterSelection ==1 %deep
  for k = 1:r
    if Znew(k) >= filtermin && Znew(k) <= filtermax
        Filt(w,:) = Datanew(k,:);
        w = w + 1;
        set(handles.cubo,'String','Filter ECad');
    end
  end
else %shallow
     for k = 1:r
    if shallow(k) >= filtermin && shallow(k) <= filtermax
        Filt(w,:) = Datanew(k,:);
        w = w + 1;
        set(handles.cubo,'String','Filter ECas');
    end
      end
end

axes(handles.graph);
cla (handles.graph);

plot3(Filt(:,2),Filt(:,1), Filt(:,3), 'gs','LineWidth',1,'MarkerFaceColor',[0 0 0]);
```

```
Xtix=get(gca,'xtick')';
set(gca,'xticklabel',num2str(Xtix,'%.5f'));
Ytix=get(gca,'ytick')';
set(gca,'yticklabel',num2str(Ytix,'%.5f'));
view(0, 90);

key = handles.key;

if key == 1
set(handles.deepFilter,'Enable','on');
set(handles.shallowFilter,'Enable','off');
set(handles.eqinterval_edit,'Enable','on');

else
set(handles.shallowFilter,'Enable','on');
set(handles.deepFilter,'Enable','off');
set(handles.eqinterval_edit,'Enable','on');

end

handles.dataFilter = Filt;
handles.FilterButton = 1;
guidata(hObject, handles);
```

46. SELECTION (MINIMUM FILTER)

```
function filtermin_Callback(hObject, eventdata, handles)

function filtermin_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

47. SELECTION (MAXIMUM FILTER)

```
function filtermax_Callback(hObject, eventdata, handles)

function filtermax_CreateFcn(hObject, eventdata, handles)

if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

48. SELECTION (DEEP FILTER)

```
function deepFilter_Callback(hObject, eventdata, handles)

set(handles.cubo,'String','Plot P');
Datanew = handles.dataFilter;  %Filter data

longnew = Datanew(:,1);
latnew  = Datanew(:,2);
shallow = Datanew(:,3);
deep    = Datanew(:,4);

[r c] = size(deep);

%%Perubahan Terkini
for i=1:r
   Ecad(i) = 15.321+(23.171/deep(i));
   data{i} = [longnew(i) latnew(i) deep(i) Ecad(i)];
end

minN = min(Ecad);
maxN = max(Ecad);

handles.mindata = minN;
handles.maxdata = maxN;

axes(handles.graph);
cla (handles.graph);

plot3(latnew, longnew, Ecad, 'rs','LineWidth',1,'MarkerFaceColor',[1 1 1]);
Xtix=get(gca,'xtick')';
set(gca,'xticklabel',num2str(Xtix,'%.5f'));
Ytix=get(gca,'ytick')';
set(gca,'yticklabel',num2str(Ytix,'%.5f'));
view(0, 90);

handles.key  = 1;
handles.data = data;
handles.mindata = minN;
handles.maxdata = maxN;
handles.plotname = 'Deep';
guidata(hObject, handles);
```

49. SELECTION (SHALLOW FILTER)

```
function shallowFilter_Callback(hObject, eventdata, handles)

set(handles.cubo,'String','Plot Mg');
```

```
Datanew = handles.dataFilter; %Filter data

longnew = Datanew(:,1);
latnew  = Datanew(:,2);
shallow = Datanew(:,3);
deep    = Datanew(:,4);

[r c] = size(shallow);

for i=1:r
   ZN(i)  = shallow(i);
   Ecashallow(i) = -0.011*ZN(i);
   ECas(i) = 2.3583+Ecashallow(i);
   data1{i} = [longnew(i) latnew(i) shallow(i) ECas(i)];
   latnew1(i) = latnew(i);
   lattick{i} = latnew(i);
   longnew1(i)= longnew(i);
   longtick{i} = longnew(i);
end

minN = min(ECas);
maxN = max(ECas);

handles.mindata = minN;
handles.maxdata = maxN;

axes(handles.graph);
cla (handles.graph);

xlin  = linspace(min(latnew),max(latnew),c);
ylin  = linspace(min(longnew),max(longnew),c);

plot3(latnew1, longnew1, ECas, 'ys','LineWidth',1,'MarkerFaceColor',[.8 0 .8]);
Xtix=get(gca,'xtick')';
set(gca,'xticklabel',num2str(Xtix,'%.5f'));
Ytix=get(gca,'ytick')';
set(gca,'yticklabel',num2str(Ytix,'%.5f'));
view(0, 90);

handles.key  = 2;
handles.data1 = data1;

handles.plotname = 'Shallow';
guidata(hObject, handles);

function filtermin_DeleteFcn(hObject, eventdata, handles)
function FilterButton_DeleteFcn(hObject, eventdata, handles)
```

50. SELECTION (GET DATA)

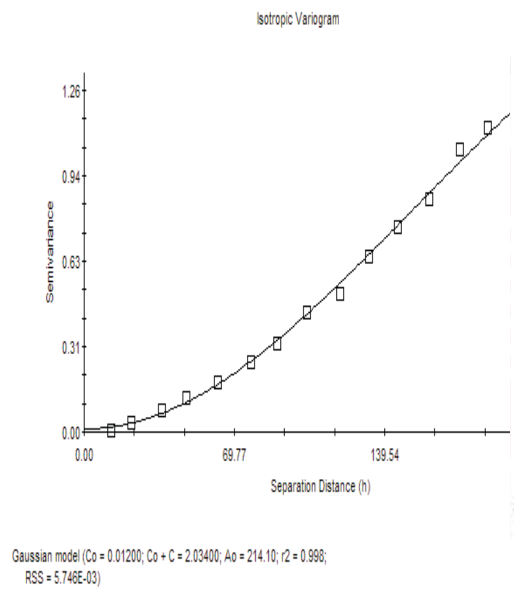
```
function GetData_Callback(hObject, eventdata, handles)
% hObject    handle to GetData (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

dcm_obj = datacursormode;
set(dcm_obj,'UpdateFcn',@viewdata)

% --- Executes on button press in savePost.
function savePost_Callback(hObject, eventdata, handles)
% hObject    handle to savePost (see GCBO)
% eventdata  reserved - to be defined in a future version of MATLAB
% handles    structure with handles and user data (see GUIDATA)

warning('off', 'MATLAB:xlswrite:AddSheet');
        [filename, pathname] = uiputfile(...
            {'*.xls','Excel formats'},...
            'Save as');

        if pathname == 0
            return
        end

     key = handles.key;

   if key == 1
      file  = [pathname, filename];
      data  = handles.data';
      data  = cell2mat(data);
         data1 = data(:,2);
         data2 = data(:,1);
         data3 = data(:,3);
         data4 = data(:,4);

         xlswrite(file, data2, 'P-Data', 'A1' );
         xlswrite(file, data1, 'P-Data', 'B1' );
         xlswrite(file, data3, 'P-Data', 'C1' );
         xlswrite(file, data4, 'P-Data', 'D1' );
   else
         file  = [pathname, filename];
         data1  = handles.data1';
         data1  = cell2mat(data1);
         data11 = data1(:,2);
         data22 = data1(:,1);
         data33 = data1(:,3);
         data44 = data1(:,4);
         xlswrite(file, data22, 'Mg-Data', 'A1' );
```

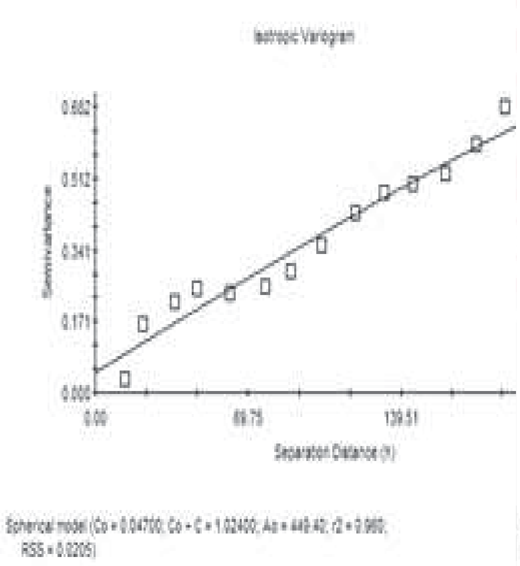
```
    xlswrite(file, data11, 'Mg-Data', 'B1' );
    xlswrite(file, data33, 'Mg-Data', 'C1' );
    xlswrite(file, data44, 'Mg-Data', 'D1' );
end
```

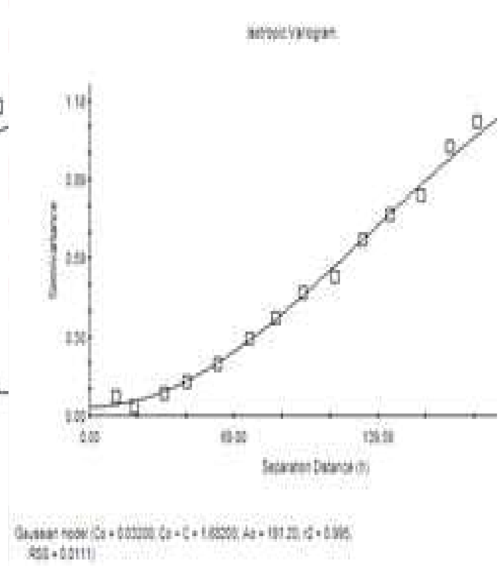
APPENDIX B

The result of GS+ Analyses for Jenderata Estate was listed as follow:

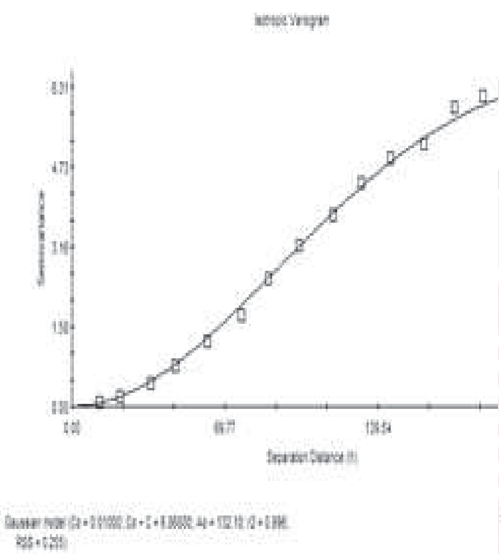
Carbon



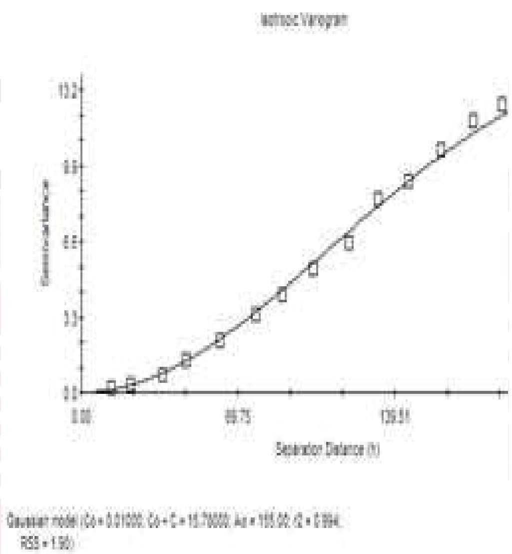




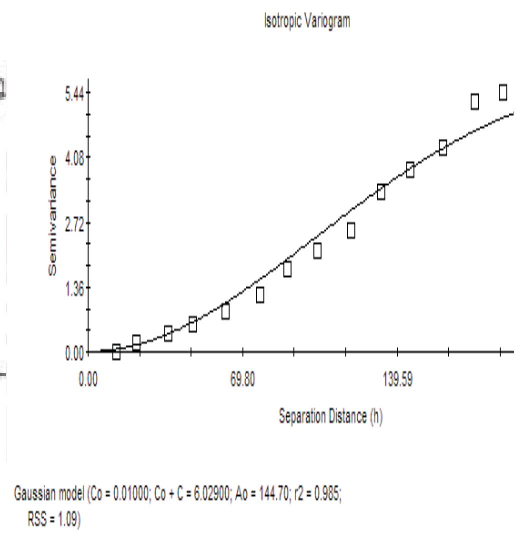
Calcium



Isotropic Variogram
Semivariance
Separation Distance (h)

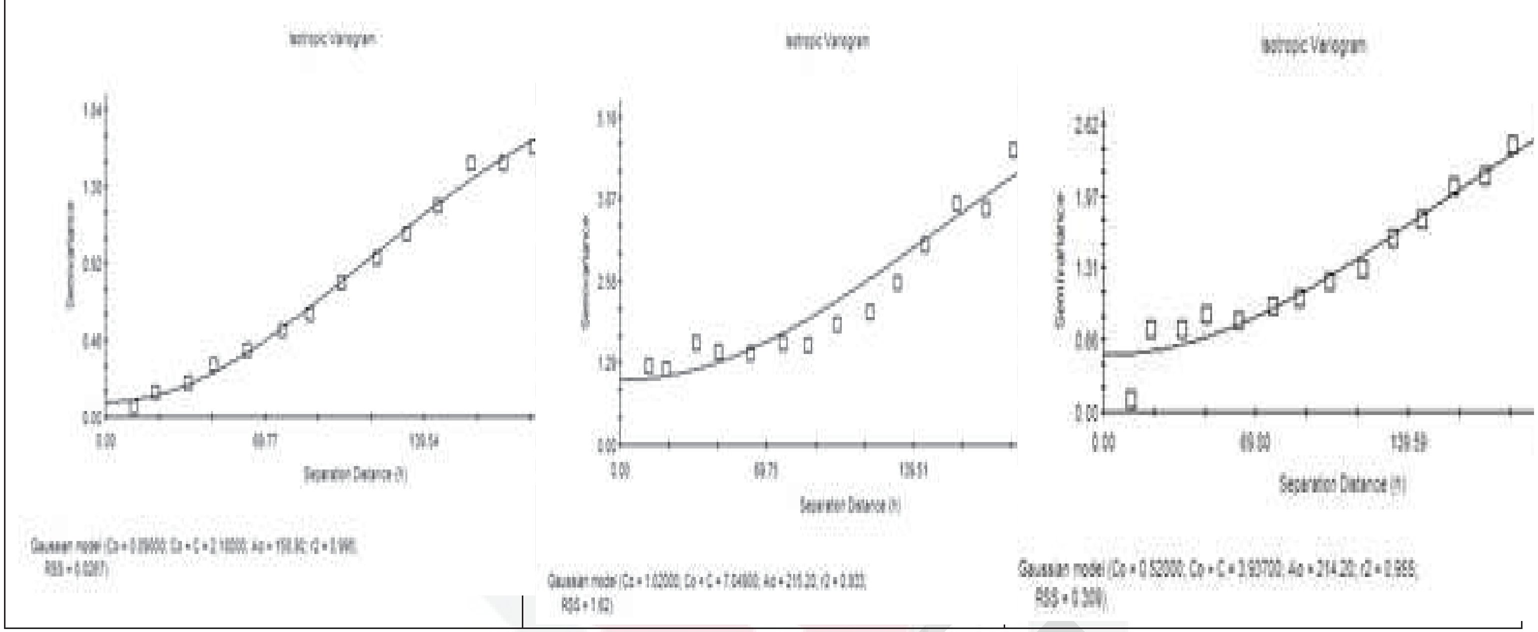


Isotropic Variogram
Semivariance
Separation Distance (h)

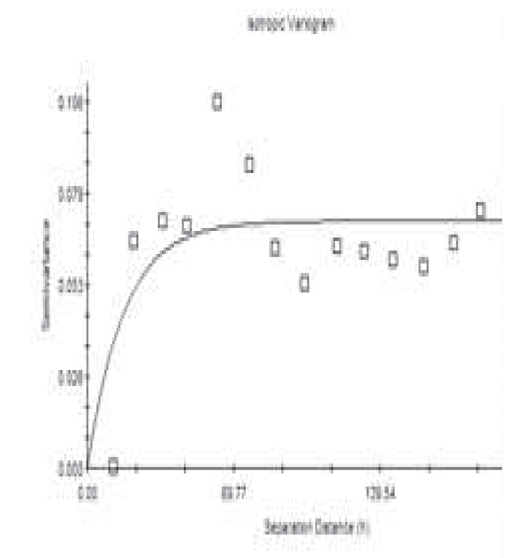


Isotropic Variogram
Semivariance
5.44
4.08
2.72
1.36
0.00
0.00
69.80
139.59
Separation Distance (h)
Gaussian model (Co = 0.01000; Co + C = 6.02900; Ao = 144.70; r2 = 0.985;
RSS = 1.09)

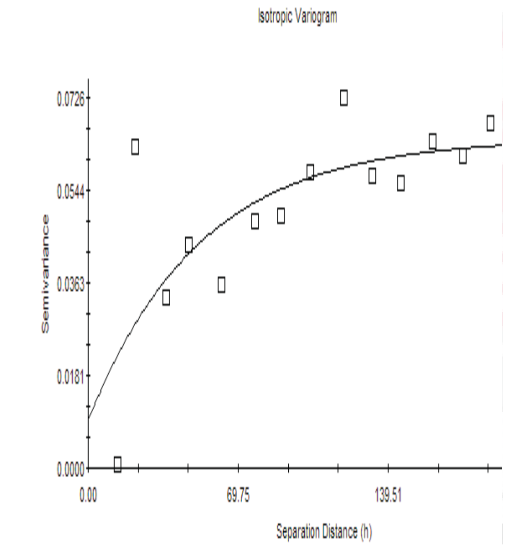
Cation Exchange Capacity



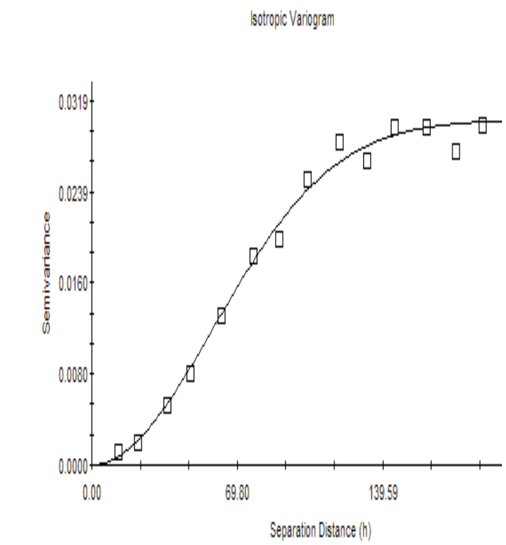
Cone Index



Exponential model (Co = 0.00010; Co + C = 0.07120; Ao = 17.60; r2 = 0.452;
RSS = 4.110E-03)

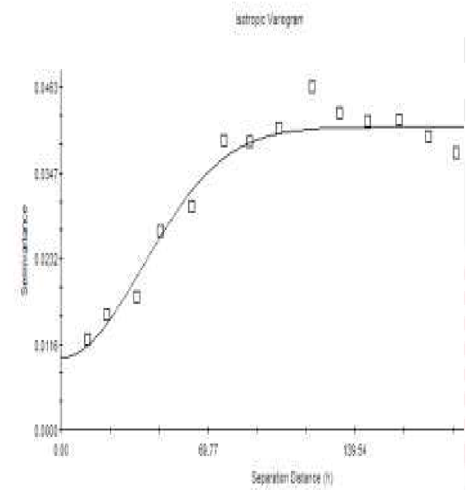


Exponential model (Co = 0.00950; Co + C = 0.06470; Ao = 52.60; r2 = 0.537;
RSS = 2.102E-03)

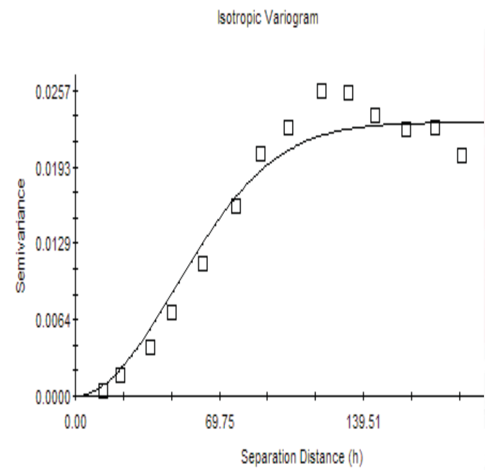


Gaussian model (Co = 0.00001; Co + C = 0.03022; Ao = 82.00; r2 = 0.989;
RSS = 1.846E-05)

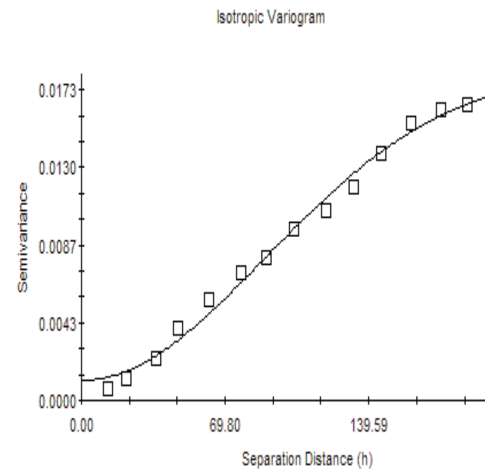
Potassium



Gaussian model (Co = 0.00978; Co + C = 0.04096; Ao = 54.70; r2 = 0.935;
RSS = 1.068E-04)

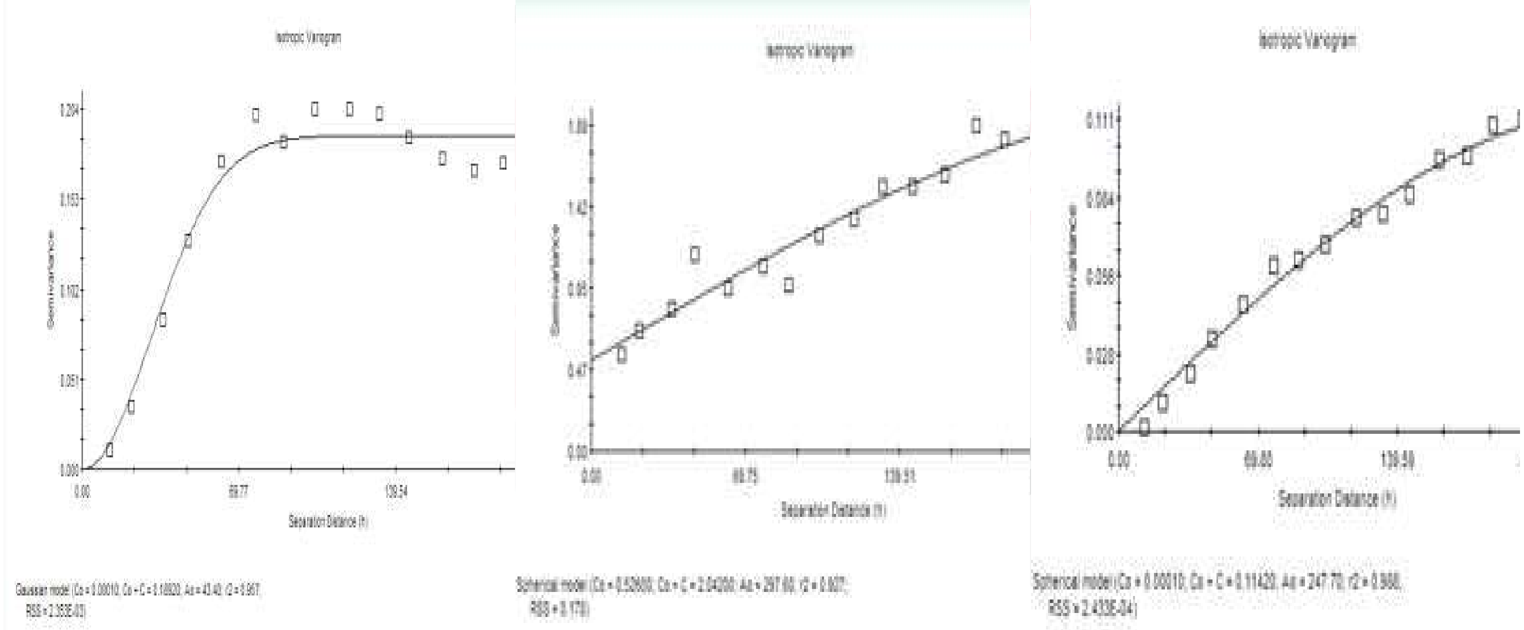


Gaussian model (Co = 0.00001; Co + C = 0.02302; Ao = 68.20; r2 = 0.944;
RSS = 6.521E-05)

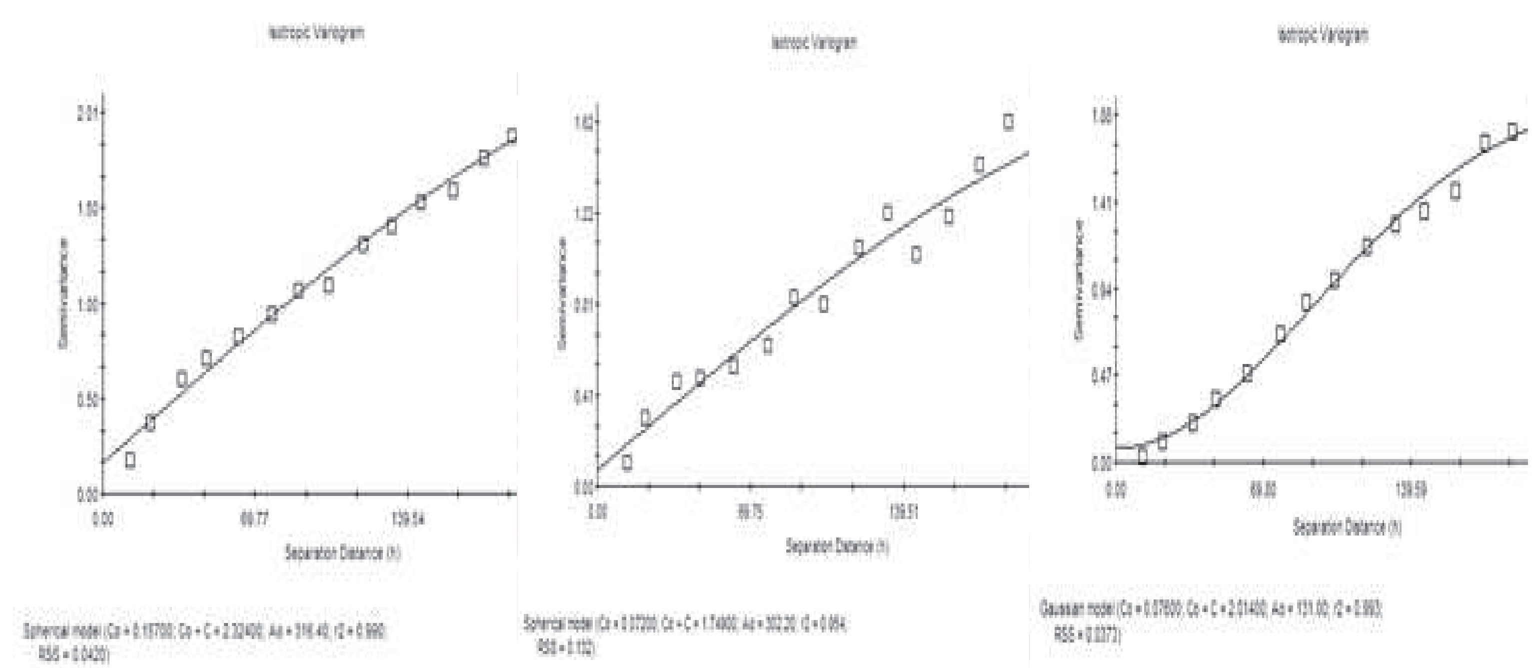


Gaussian model (Co = 0.00112; Co + C = 0.01844; Ao = 126.10; r2 = 0.993;
RSS = 3.303E-06)

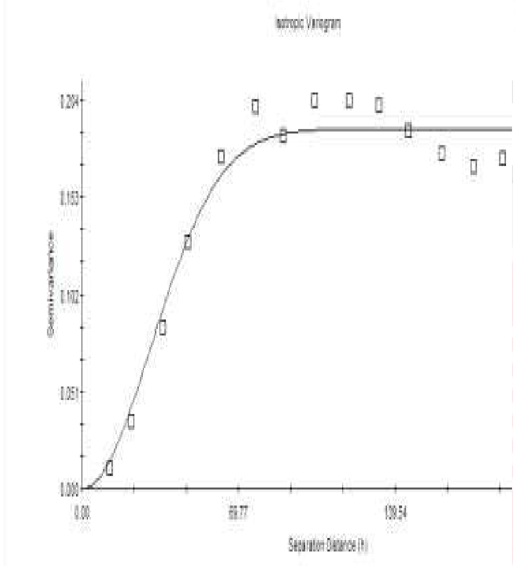
Magnesium

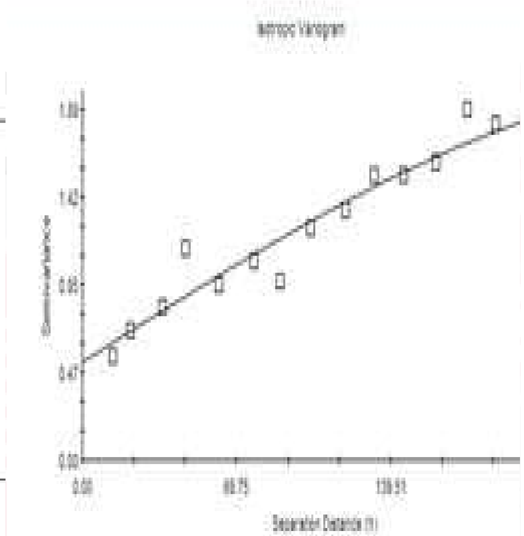

Isotropic Variogram
Semivariance
Separation Distance (h)
Gaussian model (Co = 0.00010; Co + C = 0.18920; Ao = 43.40; r2 = 0.967;
RSS = 2.353E-03)
Isotropic Variogram
Semivariance
Separation Distance (h)
Spherical model (Co = 0.52600; Co + C = 2.04200; Ao = 297.60; r2 = 0.927;
RSS = 0.179)
Isotropic Variogram
Semivariance
Separation Distance (h)
Spherical model (Co = 0.00010; Co + C = 0.11420; Ao = 247.70; r2 = 0.968;
RSS = 2.433E-04)

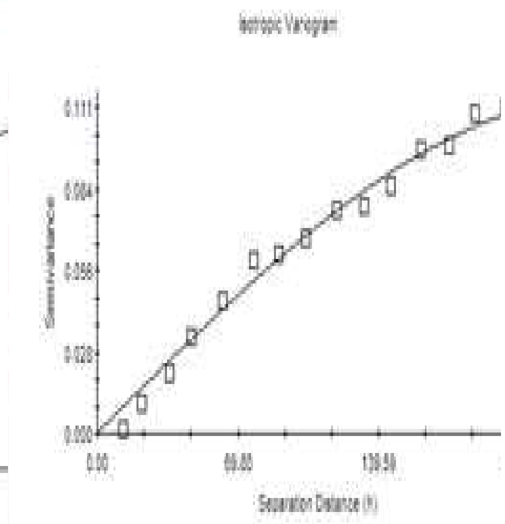
Nitrogen


Isotropic Variogram
Semivariance
Separation Distance (h)
2.01
1.50
1.00
0.50
0.00
69.77
139.54
Spherical model (Co = 0.15700; Co + C = 2.32400; Ao = 316.40; r2 = 0.990; RSS = 0.0420)
Isotropic Variogram
Semivariance
Separation Distance (h)
1.62
1.22
0.81
0.41
0.00
69.75
139.51
Spherical model (Co = 0.07200; Co + C = 1.74900; Ao = 302.20; r2 = 0.964; RSS = 0.132)
Isotropic Variogram
Semivariance
Separation Distance (h)
1.88
1.41
0.94
0.47
0.00
69.80
139.59
Gaussian model (Co = 0.07600; Co + C = 2.01400; Ao = 131.00; r2 = 0.993; RSS = 0.0373)

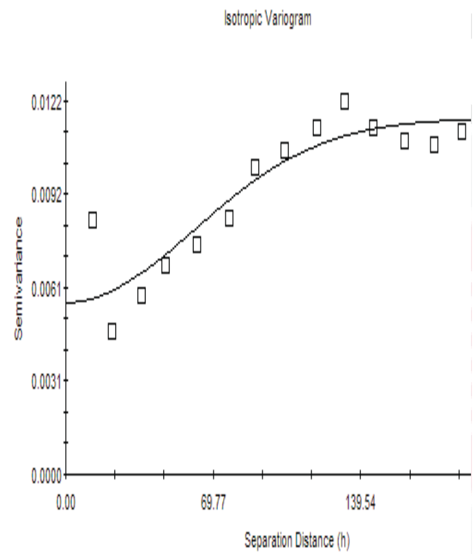
Phosphorus


Isotropic Variogram
Semivariance
0.204
0.153
0.102
0.051
0.000
0.00
69.77
139.54
Separation Distance (h)

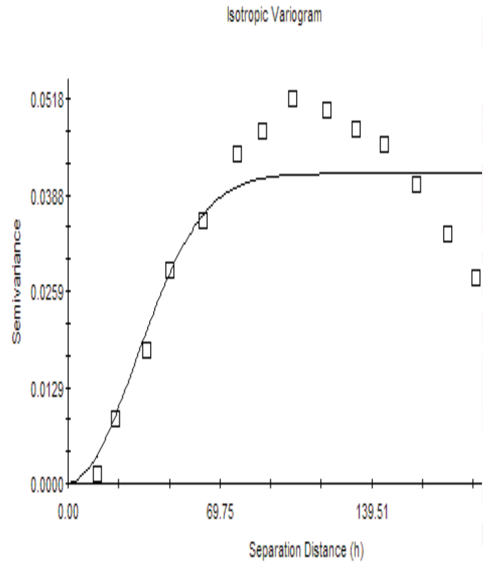

Isotropic Variogram
Semivariance
1.89
1.42
0.95
0.47
0.00
0.00
69.75
139.51
Separation Distance (h)


Isotropic Variogram
Semivariance
0.111
0.084
0.056
0.028
0.000
0.00
69.80
139.59
Separation Distance (h)
Spherical model (Co = 0.00010; Co + C = 0.11420; Ao = 247.70; r2 = 0.988;
RSS = 2.433E-04)

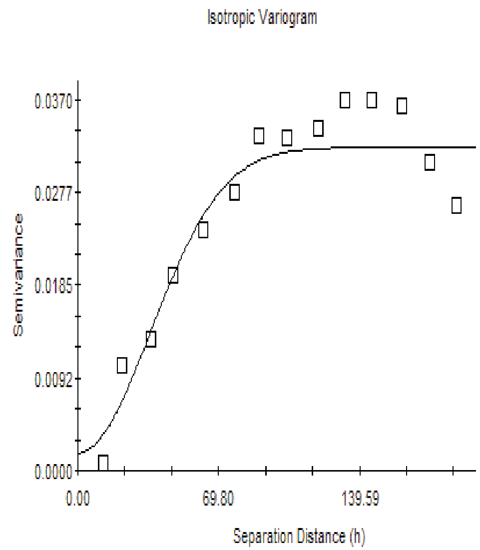
pH



Gaussian model (Co = 0.00564; Co + C = 0.01168; Ao = 86.00; r2 = 0.838; RSS = 1.256E-05)

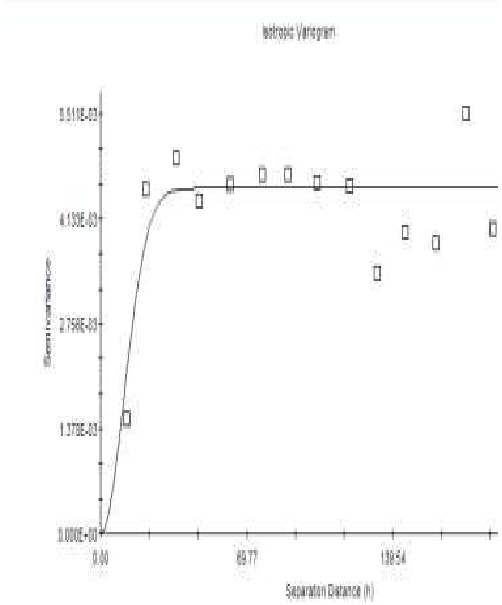


Gaussian model (Co = 0.00010; Co + C = 0.04170; Ao = 43.80; r2 = 0.775; RSS = 7.551E-04)

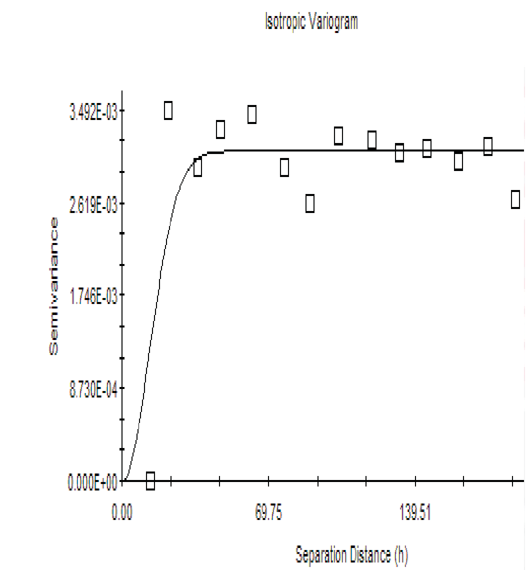


Gaussian model (Co = 0.00177; Co + C = 0.03224; Ao = 50.80; r2 = 0.852; RSS = 2.441E-04)

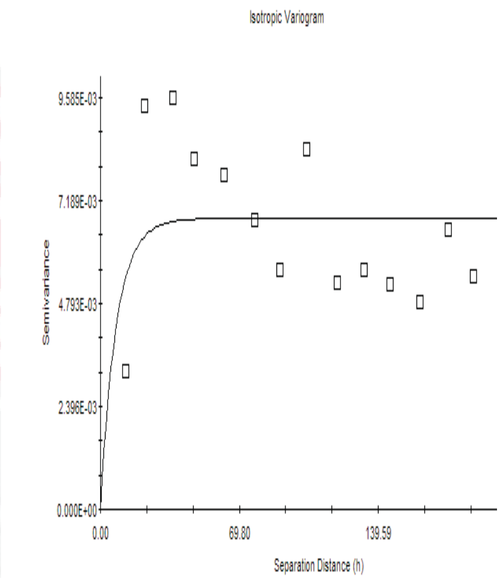
Sulphur



Gaussian model (Co = 0.00001; Co + C = 0.00453; Ao = 15.80; r2 = 0.606;
RSS = 5.228E-06)



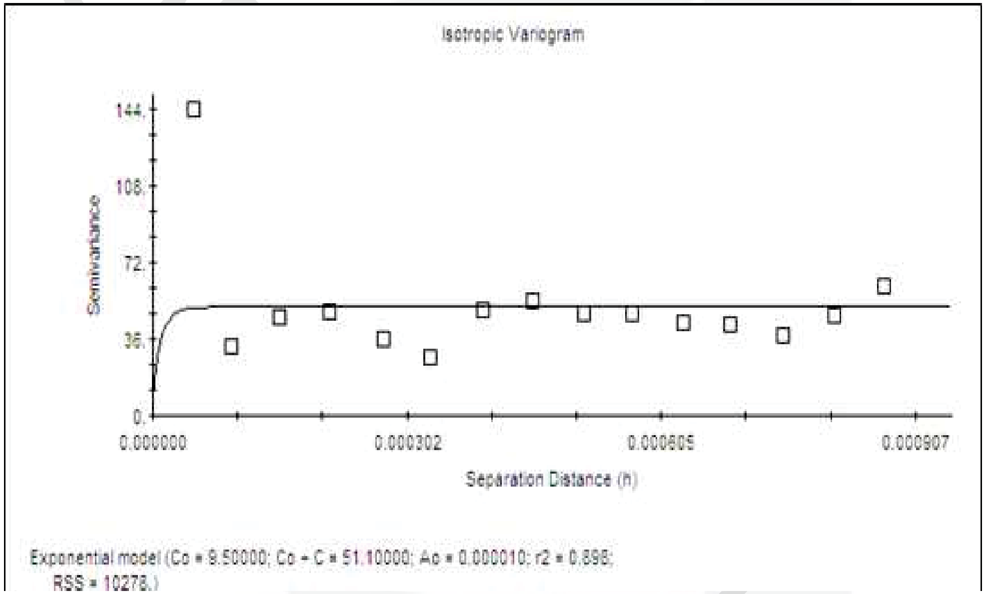
Gaussian model (Co = 0.00000; Co + C = 0.00310; Ao = 18.60; r2 = 0.676;
RSS = 3.708E-06)



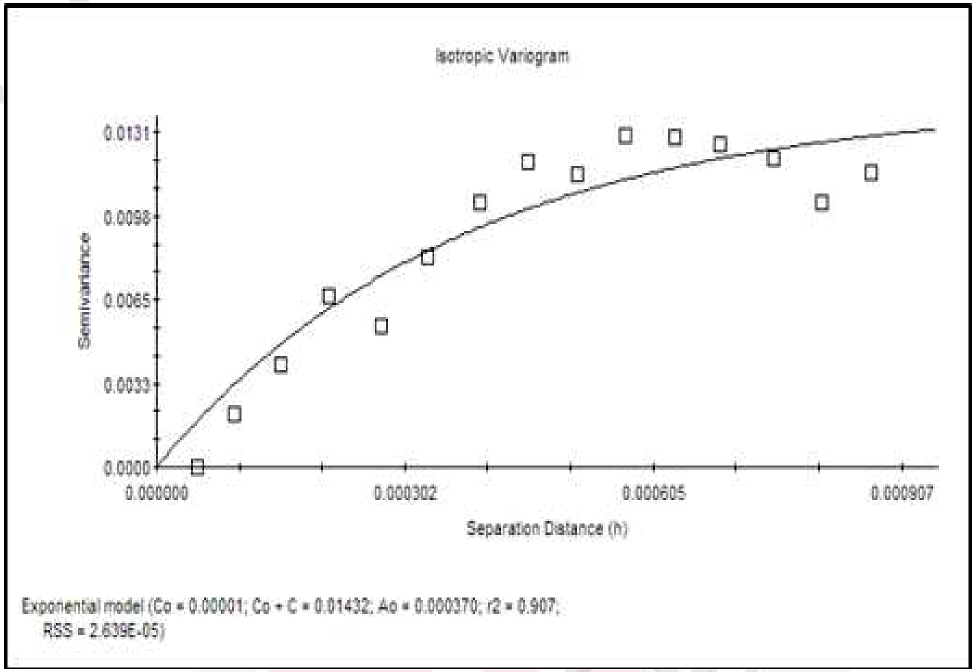
Exponential model (Co = 0.00001; Co + C = 0.00677; Ao = 8.00; r2 = 0.124;
RSS = 4.189E-05)

APPENDIX C

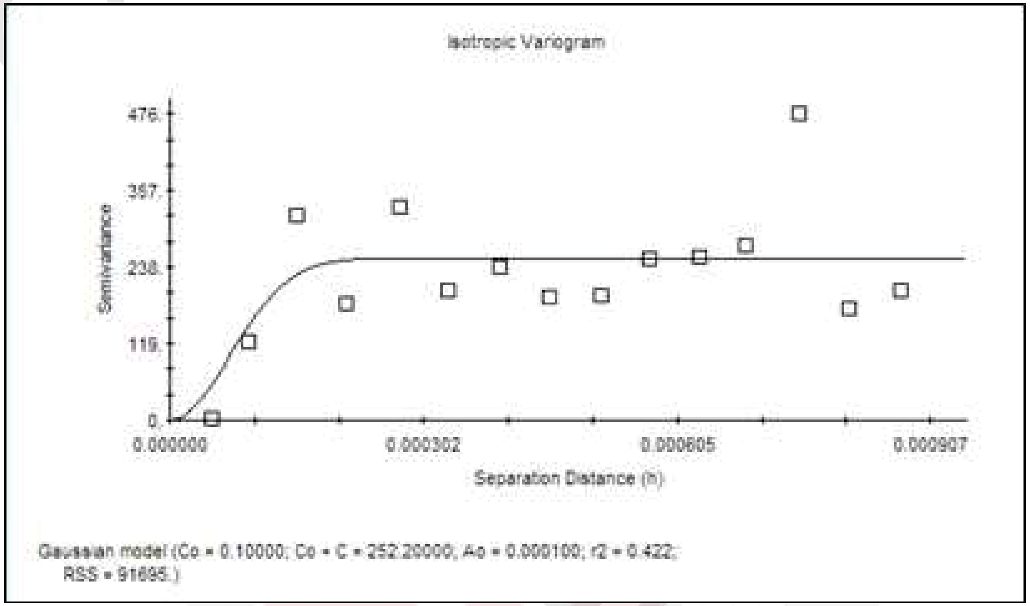
The result of GS+ Analyses for Seberang Perak was listed as follow:

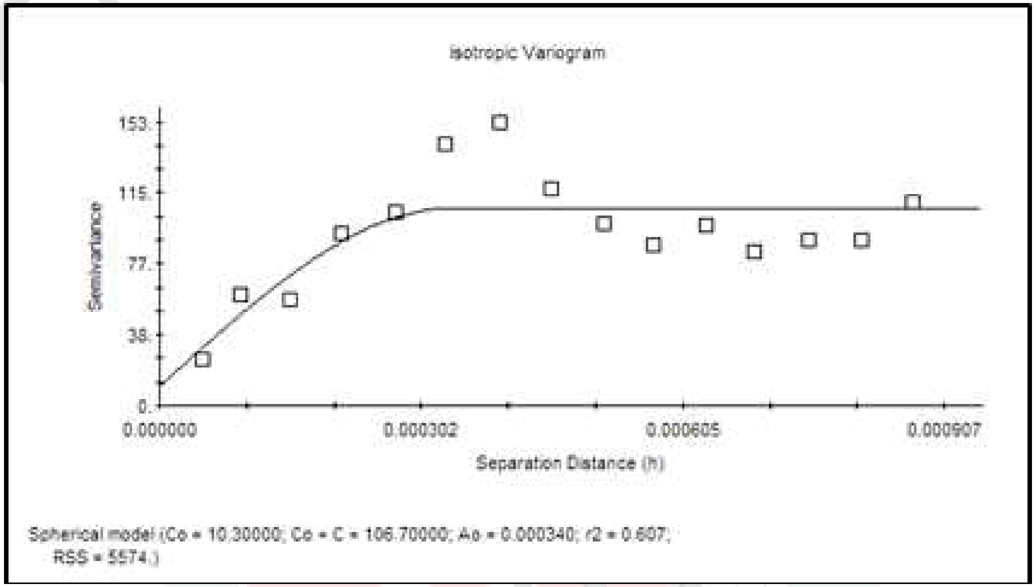


Moisture Content

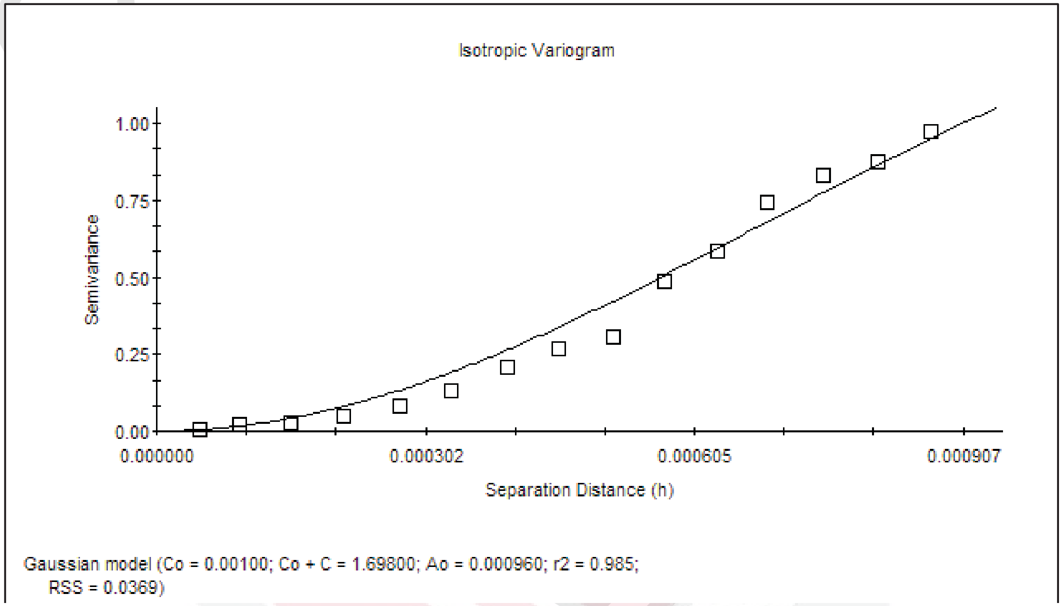

Isotropic Variogram
Semivariance
0.0131
0.0098
0.0065
0.0033
0.0000
0.000000
0.000302
0.000605
0.000907
Separation Distance (h)
Exponential model (Co = 0.00001; Co + C = 0.01432; Ao = 0.000370; r2 = 0.907;
RSS = 2.639E-05)

Carbon

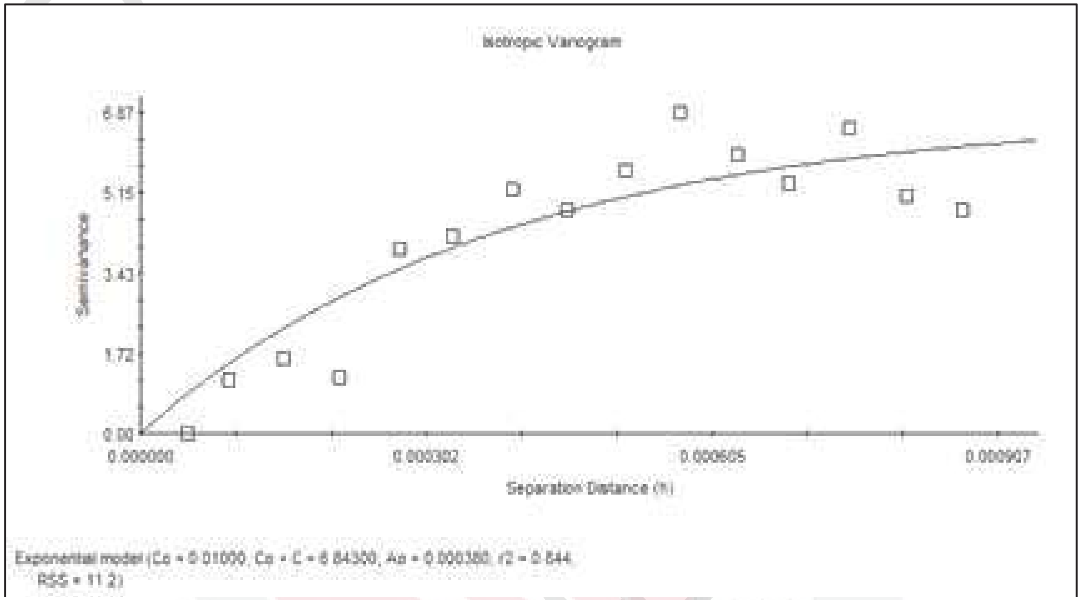

Isotropic Variogram
476.
357.
238.
119.
0.
Semivariance
0.000000
0.000302
0.000605
0.000907
Separation Distance (h)
Gaussian model (Co = 0.10000; Co + C = 252.20000; Ao = 0.000100; r2 = 0.422;
RSS = 91695.)
Shallow ECa


Isotropic Variogram
Semivariance
153.
115.
77.
38.
0.
0.000000
0.000302
0.000605
0.000907
Separation Distance (h)
Spherical model (Co = 10.30000; Co + C = 106.70000; Ao = 0.000340; r2 = 0.607;
RSS = 5574.)

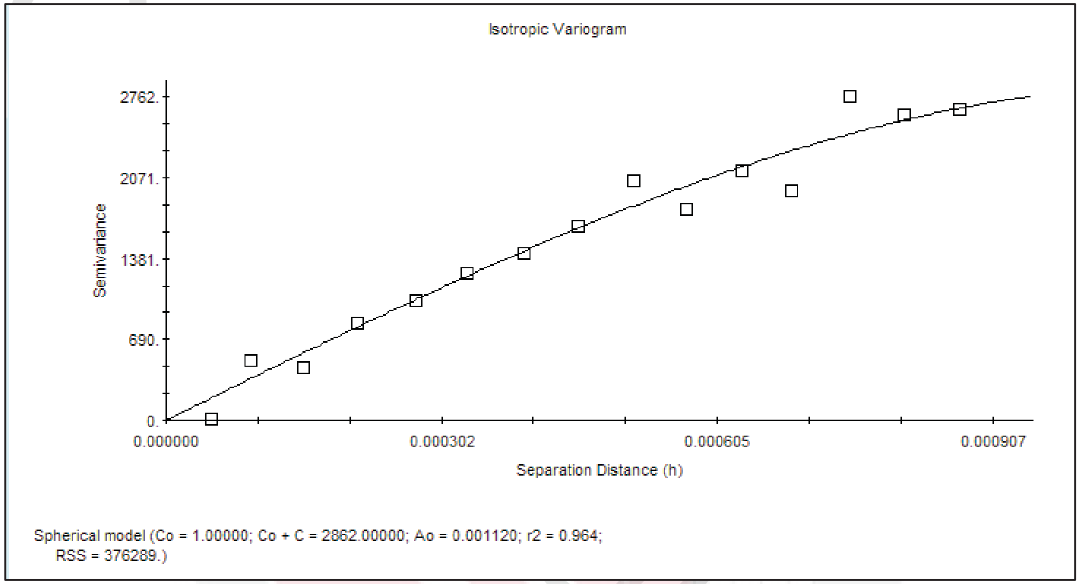
Deep ECa



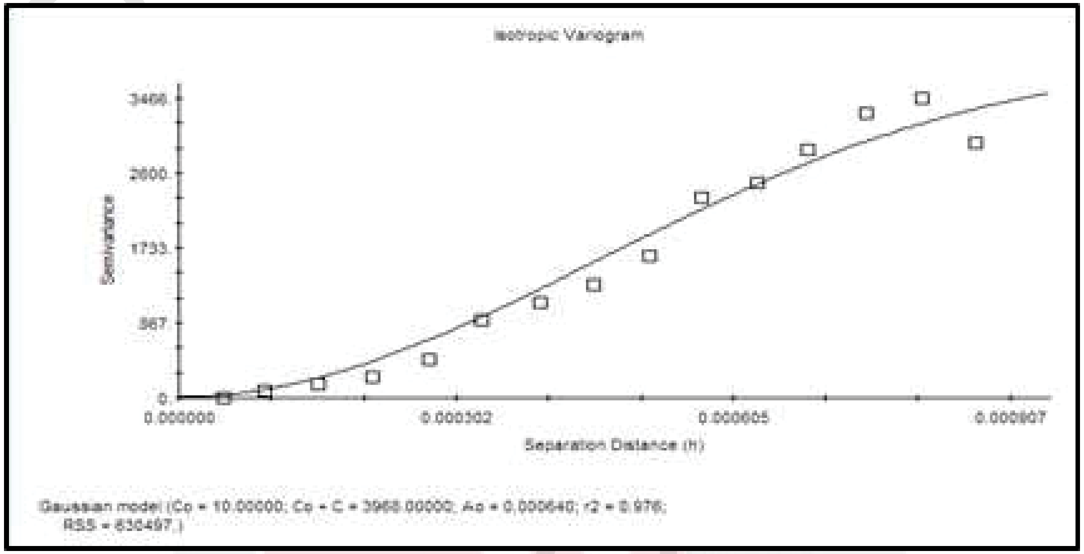
Cation Exchange Capacity


Isotropic Variogram
Semivariance
6.87
5.15
3.43
1.72
0.00
0.000000
0.000302
0.000605
0.000907
Separation Distance (h)
Exponential model (Co = 0.01000; Co + C = 6.84300; Ao = 0.000380; r2 = 0.844;
RSS = 11.2)

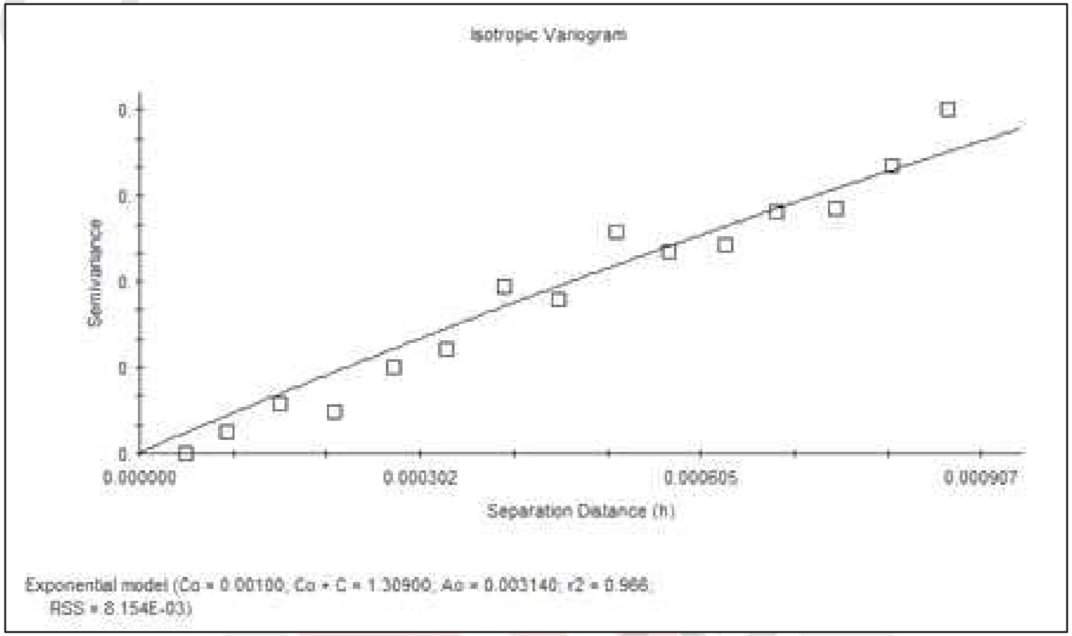
Copper


Isotropic Variogram
Semivariance
2762.
2071.
1381.
690.
0.
0.000000
0.000302
0.000605
0.000907
Separation Distance (h)
Spherical model (Co = 1.00000; Co + C = 2862.00000; Ao = 0.001120; r2 = 0.964;
RSS = 376289.)

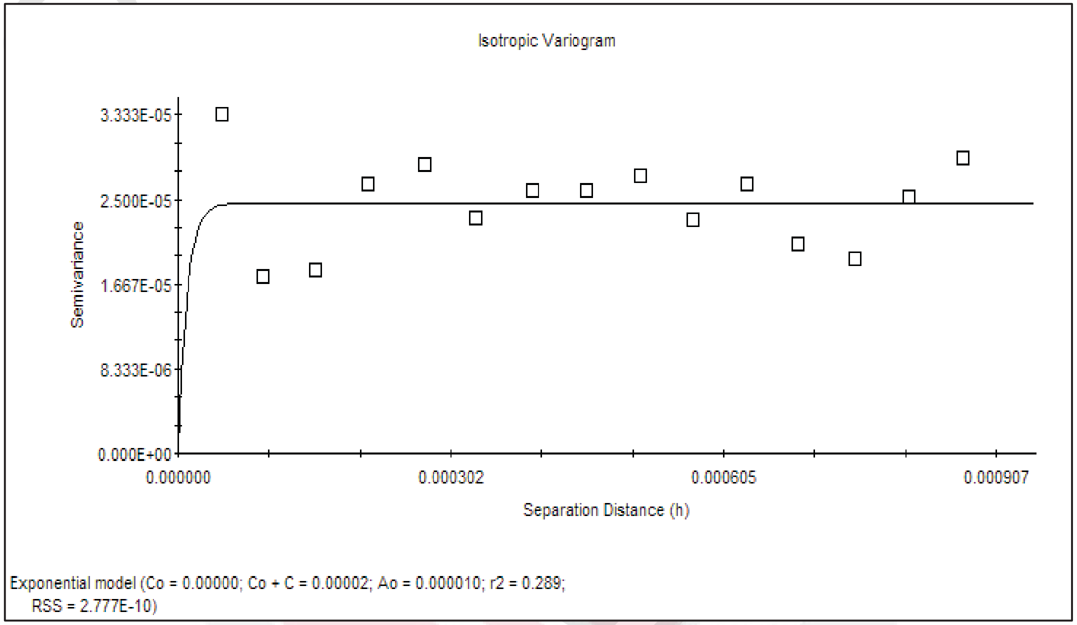
Potassium


Isotropic Variogram
Semivariance
3466.
2600.
1733.
867.
0.
0.000000
0.000302
0.000605
0.000907
Separation Distance (h)
Gaussian model (Co = 10.00000; Co + C = 3968.00000; Ao = 0.000640; r2 = 0.976;
RSS = 630497.)

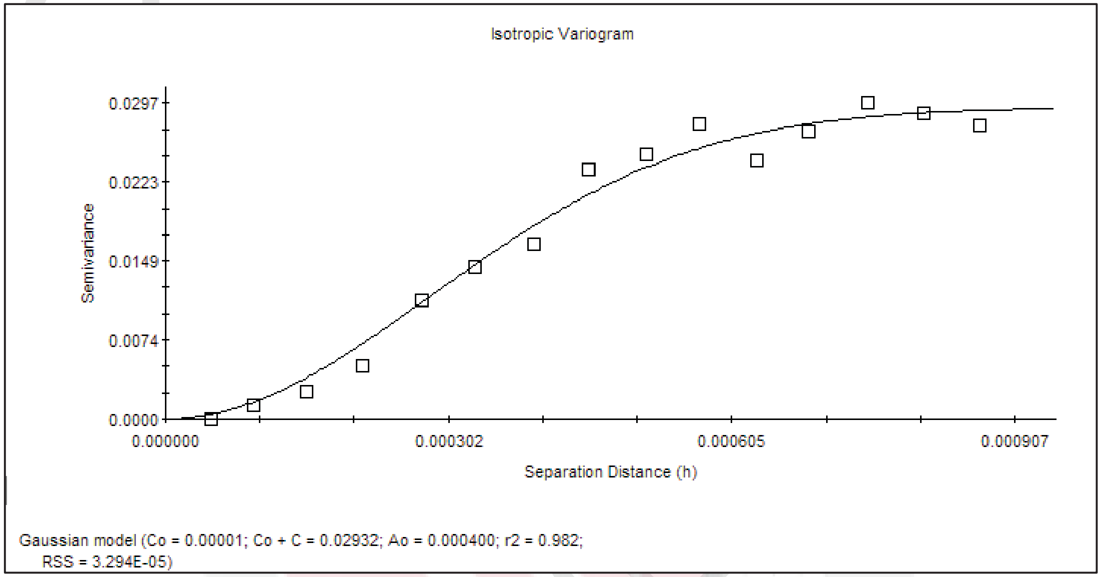
Magnesium


Isotropic Variogram
Semivariance
0.
0.
0.
0
0.
0.000000
0.000302
0.000605
0.000907
Separation Distance (h)
Exponential model (Co = 0.00100; Co + C = 1.30900; Ao = 0.003140; r2 = 0.966;
RSS = 8.154E-03)

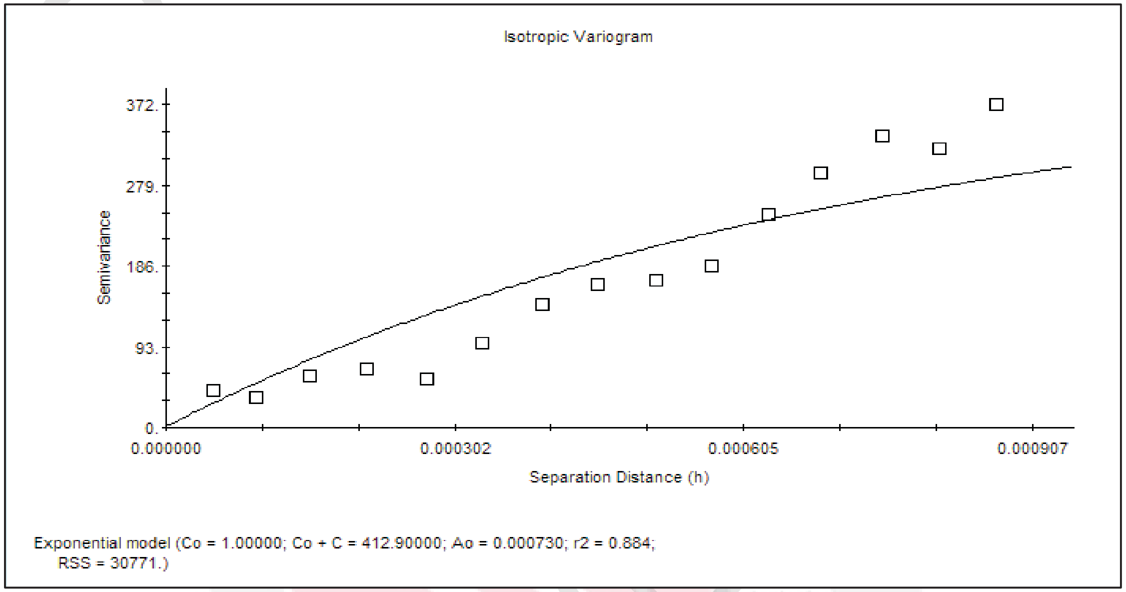
Zinc


Isotropic Variogram
3.333E-05
2.500E-05
1.667E-05
8.333E-06
0.000E+00
Semivariance
0.000000
0.000302
0.000605
0.000907
Separation Distance (h)
Exponential model (Co = 0.00000; Co + C = 0.00002; Ao = 0.000010; r2 = 0.289;
RSS = 2.777E-10)

Sulphur

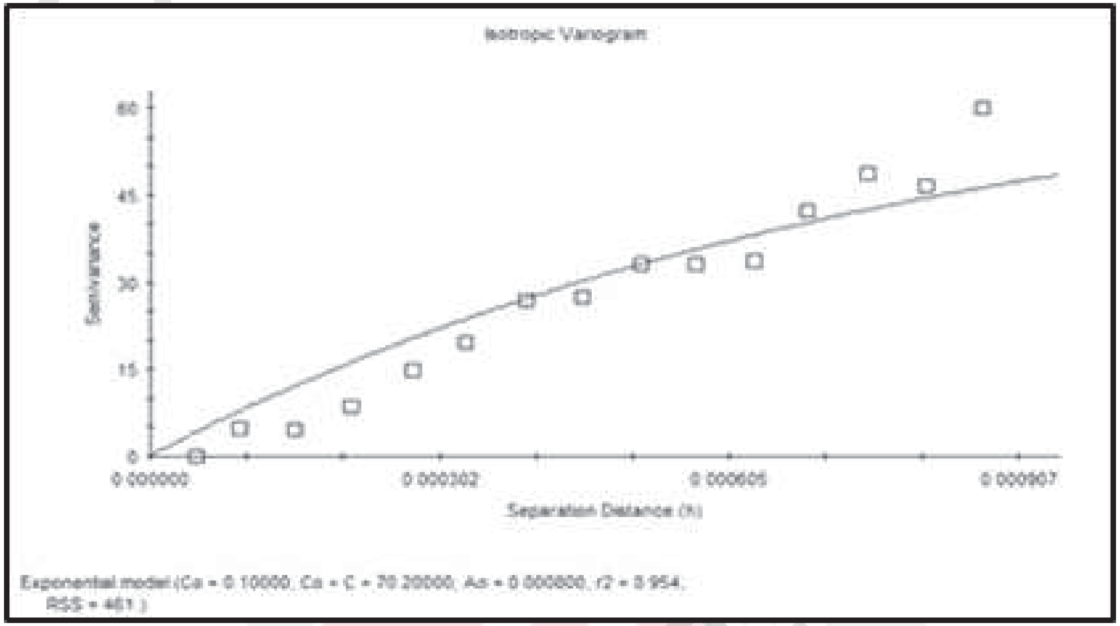

Isotropic Variogram
Semivariance
0.0297
0.0223
0.0149
0.0074
0.0000
0.000000
0.000302
0.000605
0.000907
Separation Distance (h)
Gaussian model (Co = 0.00001; Co + C = 0.02932; Ao = 0.000400; r2 = 0.982;
RSS = 3.294E-05)

pH

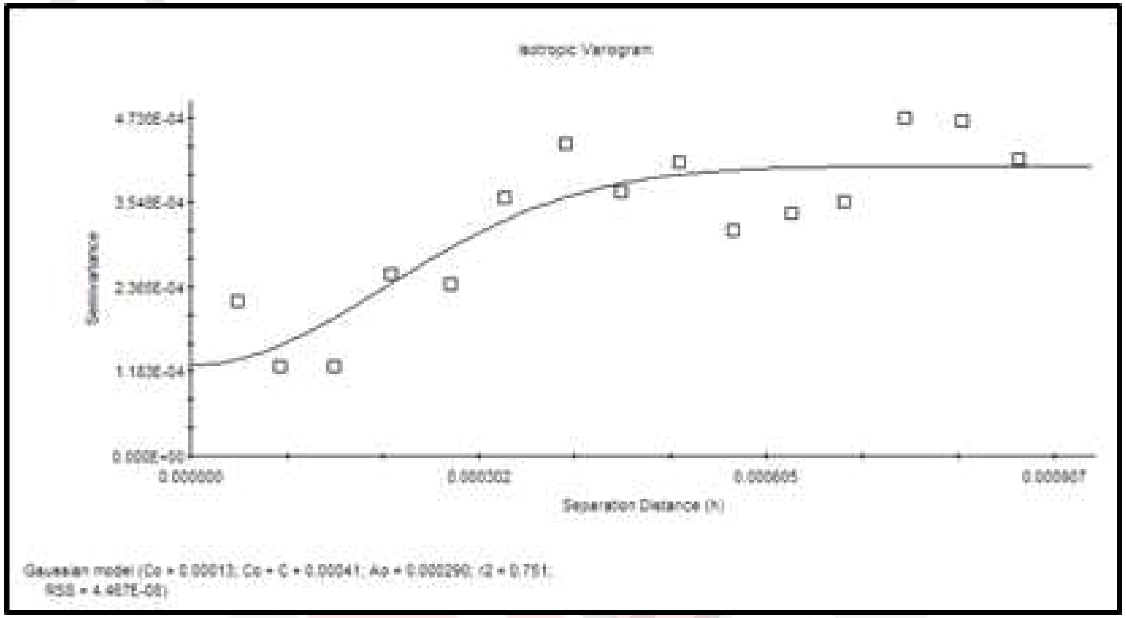


Isotropic Variogram
372.
279.
186.
93.
0.
Semivariance
0.000000
0.000302
0.000605
0.000907
Separation Distance (h)
Exponential model (Co = 1.00000; Co + C = 412.90000; Ao = 0.000730; r2 = 0.884;
RSS = 30771.)

Cone Index


Isotropic Variogram
Semivariance
0
15
30
45
60
0.000000
0.000302
0.000605
0.000907
Separation Distance (h)
Exponential model (Co = 0.10000; Co + C = 70.20000; Ao = 0.000800; r2 = 0.954;
RSS = 461.)

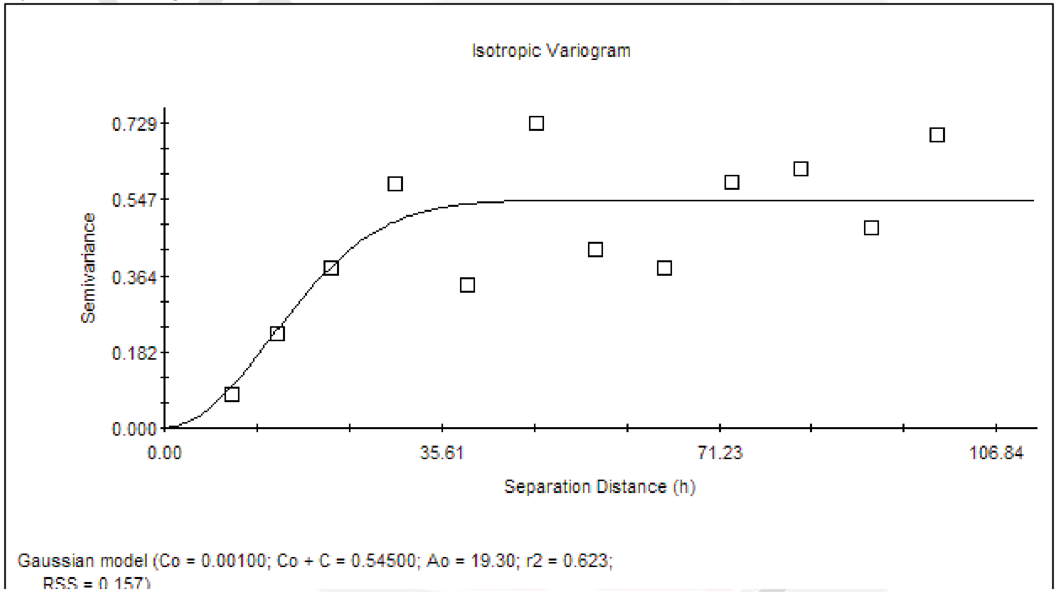
Phosphorus


Isotropic Variogram
Semivariance
4.730E-04
3.548E-04
2.365E-04
1.183E-04
0.000E+00
0.000000
0.000302
0.000605
0.000907
Separation Distance (h)
Gaussian model (Co = 0.00013; Co + C = 0.00041; Ao = 0.000290; r2 = 0.751;
RSS = 4.467E-08)

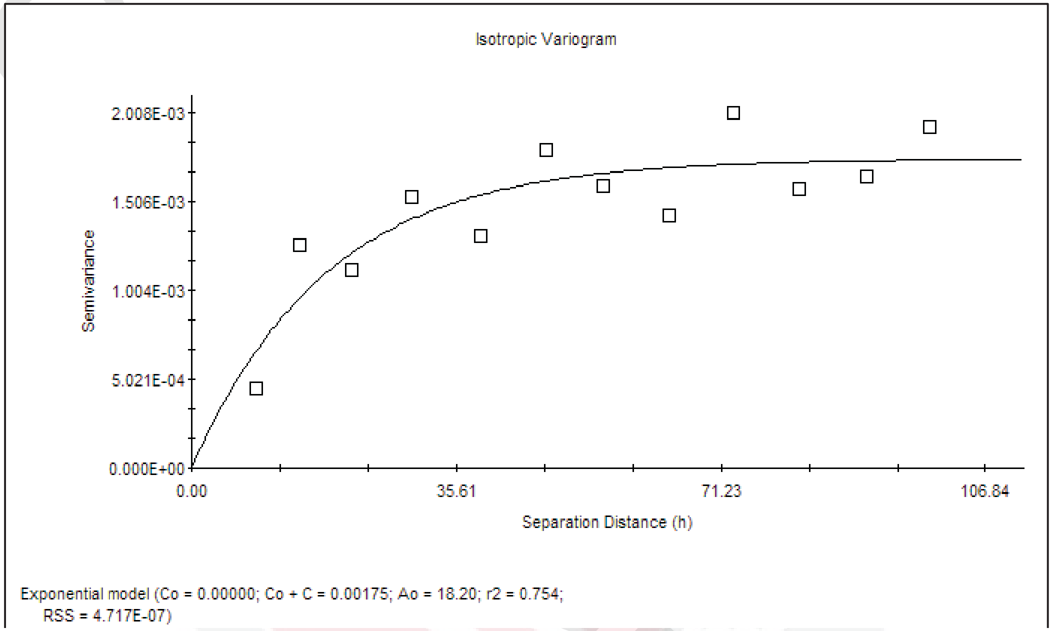
Nitrogen

APPENDIX D

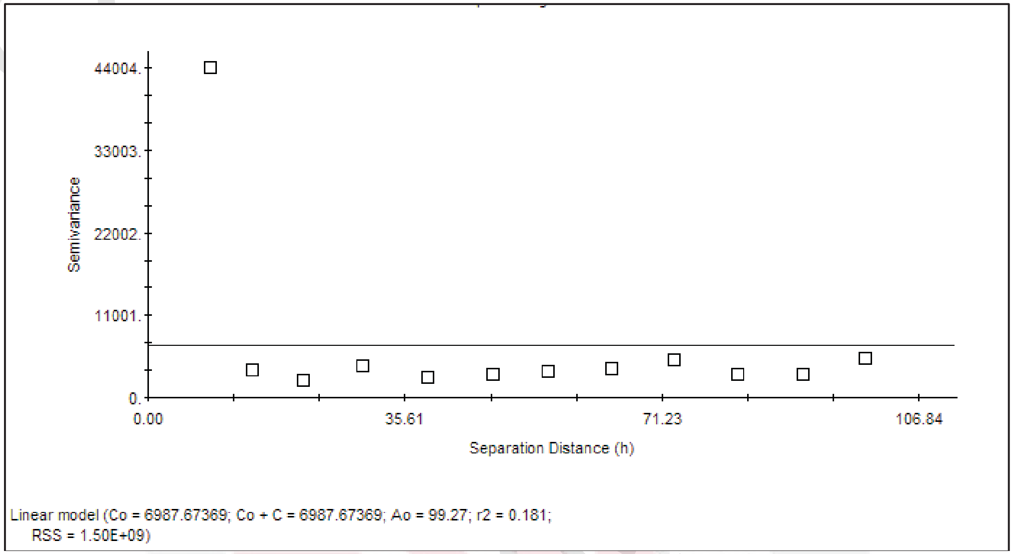
The result of GS+ Analyses for Kluang was listed as follow:



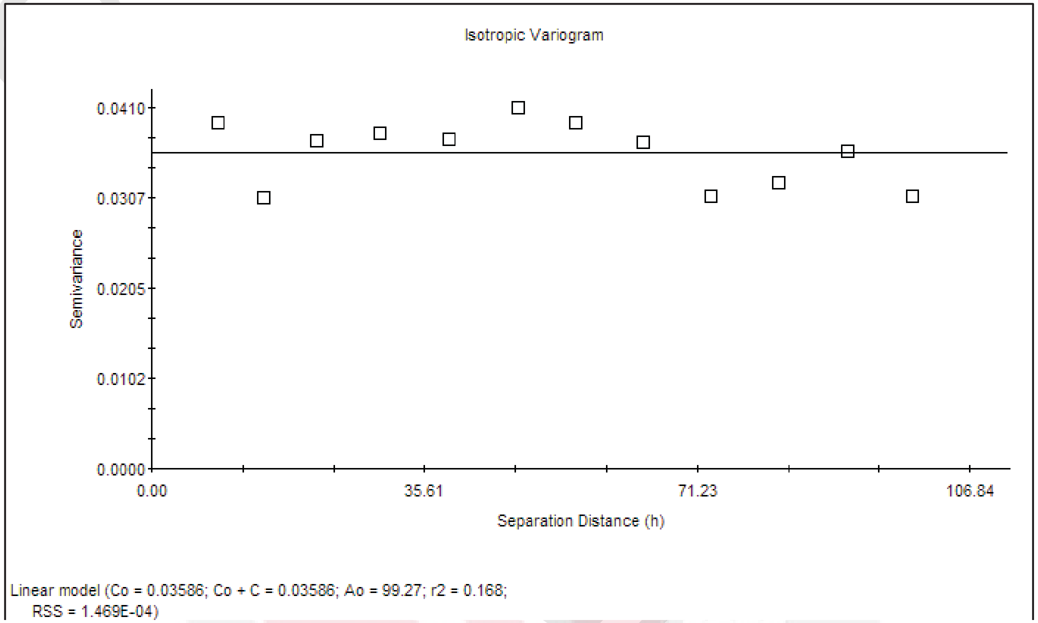
Calcium


Isotropic Variogram
Semivariance
2.008E-03
1.506E-03
1.004E-03
5.021E-04
0.000E+00
0.00
35.61
71.23
106.84
Separation Distance (h)
Exponential model (Co = 0.00000; Co + C = 0.00175; Ao = 18.20; r2 = 0.754;
RSS = 4.717E-07)

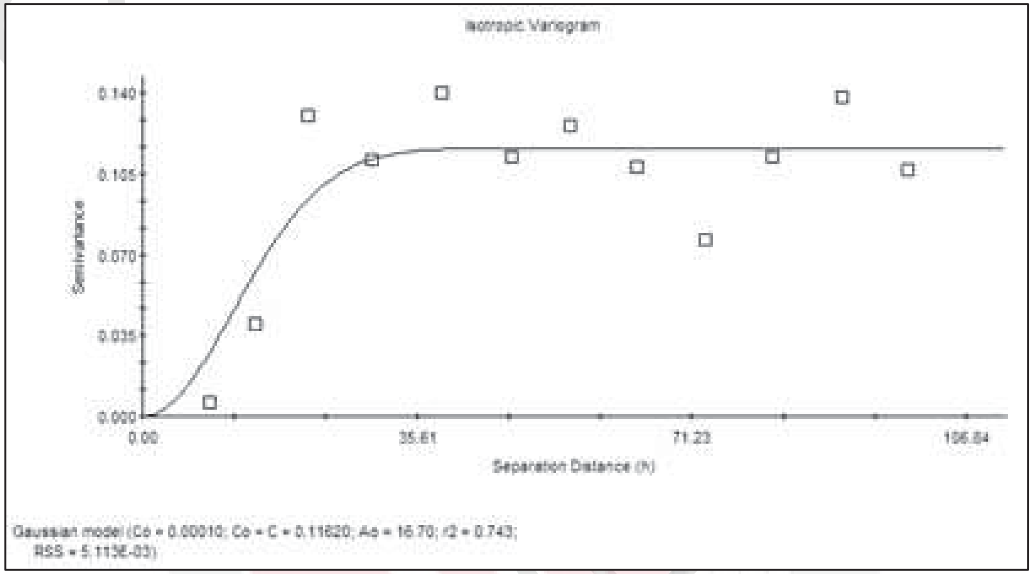
Nitrogen


44004.
33003.
22002.
11001.
0.
Semivariance
0.00
35.61
71.23
106.84
Separation Distance (h)
Linear model (Co = 6987.67369; Co + C = 6987.67369; Ao = 99.27; r2 = 0.181;
RSS = 1.50E+09)

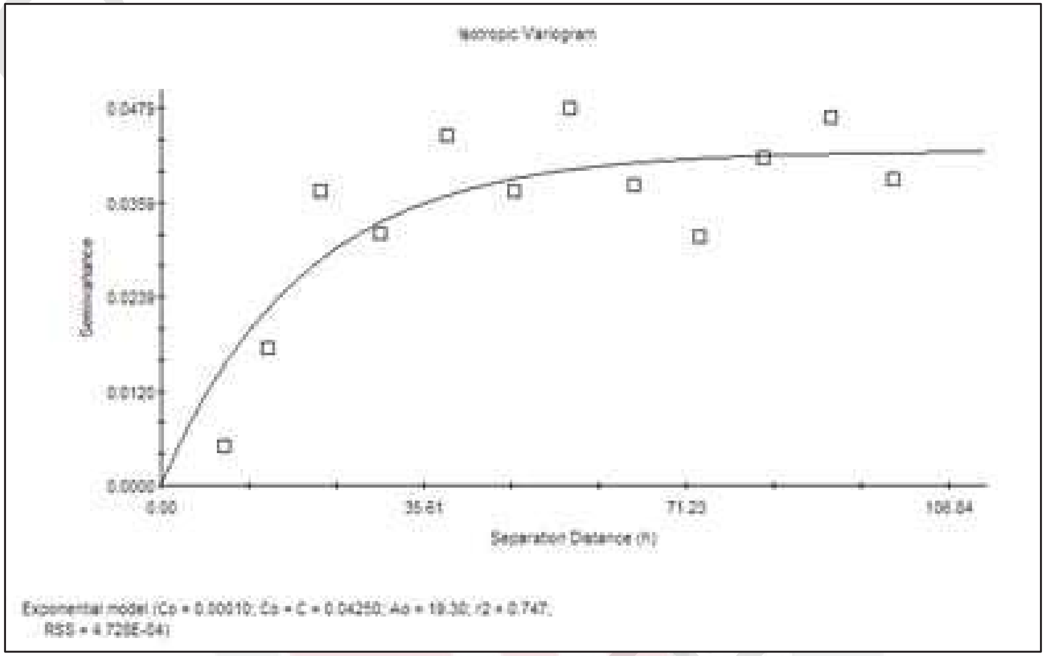
Phosphorus


Isotropic Variogram
Semivariance
0.0410
0.0307
0.0205
0.0102
0.0000
0.00
35.61
71.23
106.84
Separation Distance (h)
Linear model (Co = 0.03586; Co + C = 0.03586; Ao = 99.27; r2 = 0.168;
RSS = 1.469E-04)

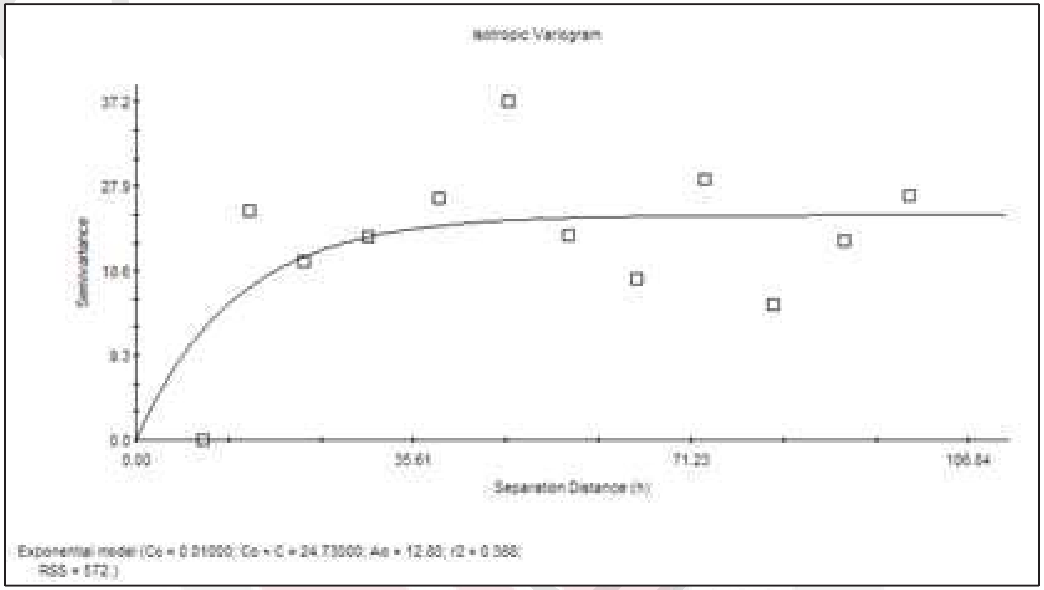
Potassium


Isotropic Variogram
Semivariance
0.140
0.105
0.070
0.035
0.000
0.00
35.61
71.23
106.84
Separation Distance (h)
Gaussian model (Co = 0.00010; Co + C = 0.11620; Ao = 16.70; r2 = 0.743;
RSS = 5.113E-03)

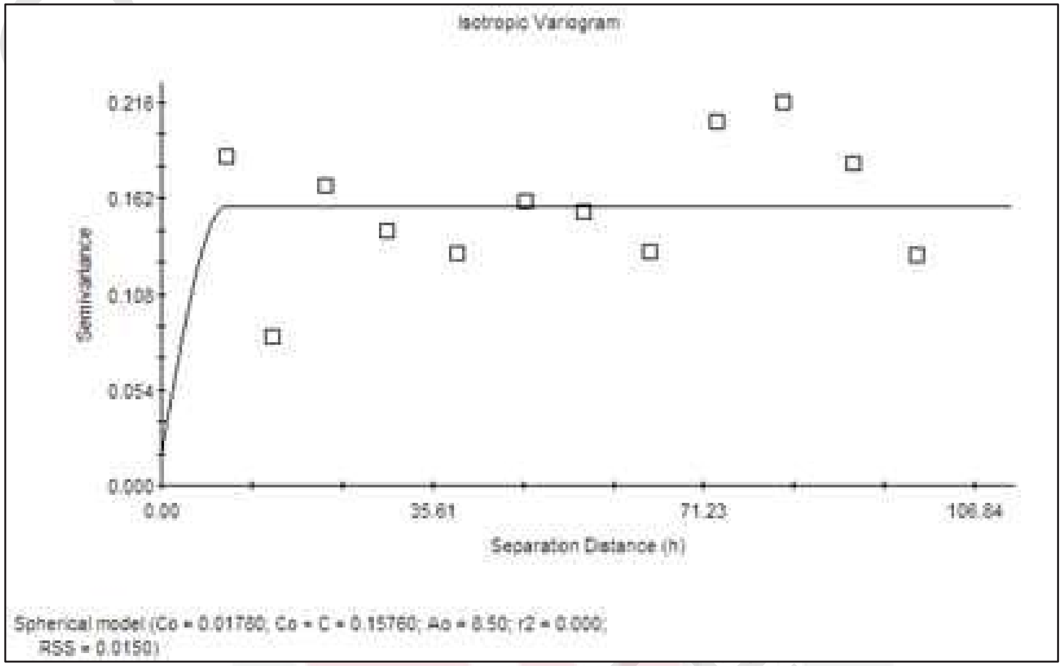
Calcium


Isotropic Variogram
Semivariance
0.0479
0.0359
0.0239
0.0120
0.0000
0.00
35.61
71.23
106.84
Separation Distance (h)
Exponential model (Co = 0.00010; Co + C = 0.04250; Ao = 19.30; r2 = 0.747;
RSS = 4.728E-04)

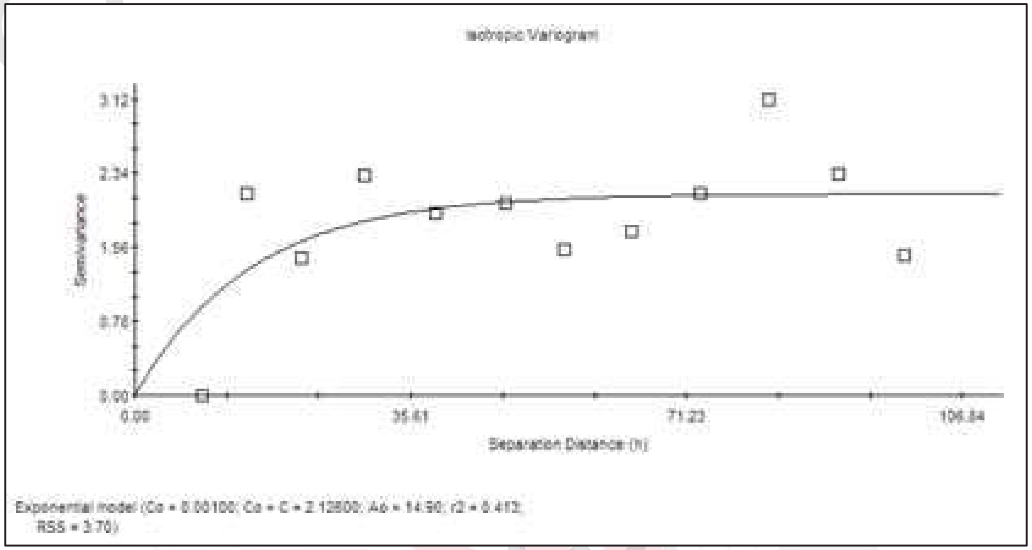
Magnesium



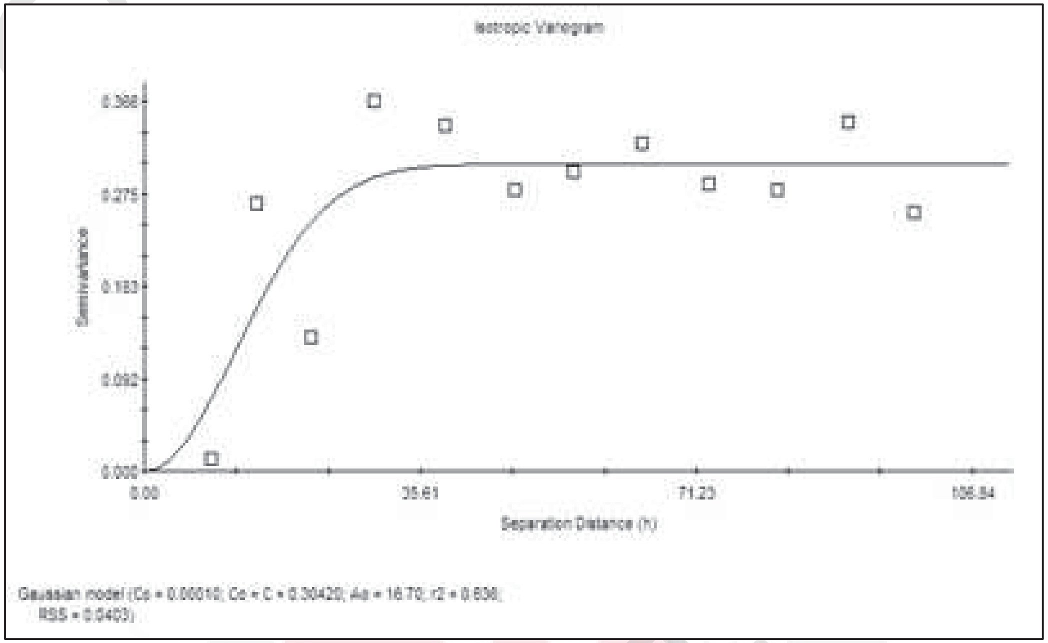
Cation Exchange Capacity


Isotropic Variogram
Semivariance
0.216
0.162
0.108
0.054
0.000
0.00
35.61
71.23
106.84
Separation Distance (h)
Spherical model (Co = 0.01780; Co + C = 0.15760; Ao = 8.50; r2 = 0.000;
RSS = 0.0150)

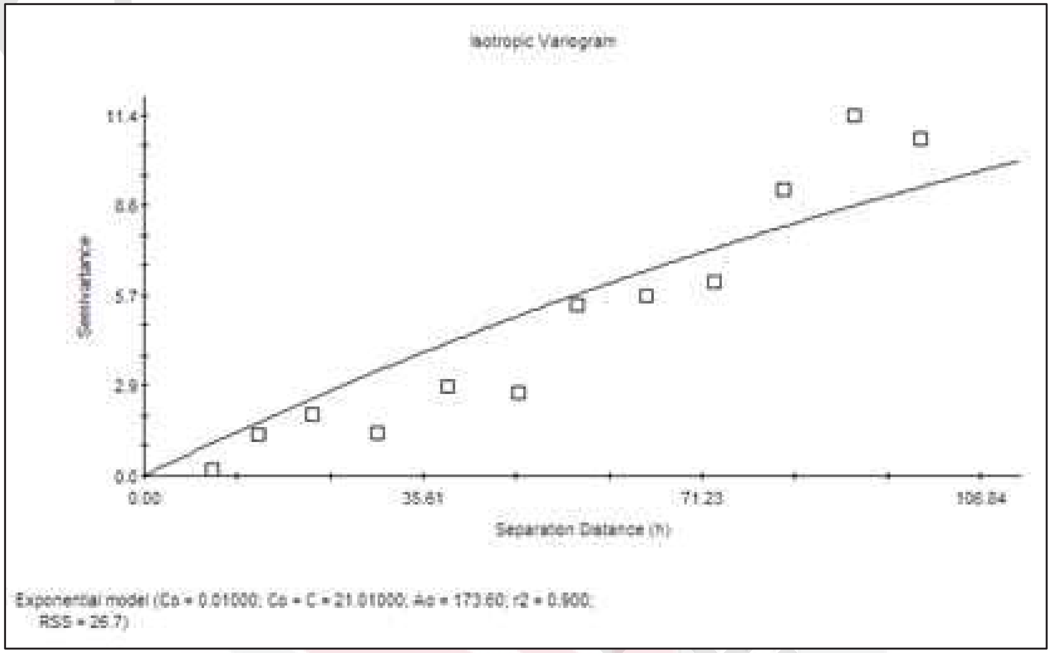
pH


Isotropic Variogram
Semivariance
3.12
2.34
1.56
0.78
0.00
0.00
35.61
71.23
106.84
Separation Distance (h)
Exponential model (Co = 0.00100; Co + C = 2.12600; Ao = 14.90; r2 = 0.413;
RSS = 3.70)

Shallow ECa


Isotropic Variogram
Semivariance
0.368
0.276
0.183
0.092
0.000
0.00
35.61
71.23
106.84
Separation Distance (h)
Gaussian model (Co = 0.00010; Co + C = 0.30420; Ao = 16.70; r2 = 0.636;
RSS = 0.0403)

Deep ECa


Isotropic Variogram
Semivariance
11.4
8.6
5.7
2.9
0.0
0.00
35.61
71.23
106.84
Separation Distance (h)
Exponential model (Co = 0.01000; Co + C = 21.01000; Ao = 173.60; r2 = 0.900;
RSS = 26.7)

Elevation

BIODATA OF STUDENT

Ezrin bin Mohd Husin was born on 4th August 1978 in Kuala Lumpur. He is the youngest child of four of Allahyarham Dr. Hj. Mohd Hussin bin Baharuddin and Allayarhamah Hajjah Rogayah bt Yassin. He received his primary school education in Sekolah Rendah Kebangsaan Bandar Baru Bangi and received his secondary school in Sekolah Menengah Kebangsaan Agama Maahad Hamidiah, Kajang, Selangor, and Maktab Rendah Sains MARA, Muar, Johor. Then he further for his Diploma in Mechanical Engineering in Universiti Teknologi Malaysia, Kuala Lumpur from 1996 until 1999. In 1999, he continued his bachelor's study at Universiti Putra Malaysia and graduated with a Bachelor of Biological and Agricultural Engineering in the year 2002. After he graduated from his bachelor's study, he had work experiences with Universiti Putra Malaysia as a Science Officer. Whilst he was working, he furthers his master's study in the year 2005 at Universiti Putra Malaysia and graduated in the year 2010 with a Master of Science in Smart Farming Technology. Later he enrolled in his Ph.D. in Soil and Water Engineering in 2013 under the supervision of Dr. Aimrun Wayayok in the Faculty of Engineering, UPM. The title of his research was ‘Prospect for Basal Stem Rot Infections Based on Soil Appearance Electrical Conductivity in Oil Palm Plantation’.

LIST OF PUBLICATIONS

Journal

Ezrin Mohd Husin, Mohd Amin Mohd Soom, Aimrun Wayayok and Siti Khairuniza Bejo, 2013. Development of On-The-Go Soil Nitrogen Mapping System for Site Specific Management. Journal of the Institution Of Engineers, Malaysia. Vol. 74(1), pp. 14-20.

M. H. Ezrin, I. Nur Aini and W. Aimrun, 2014. Relationship between Soil Apparent Electrical Conductivity and pH Value of Jawa Series in Oil Palm Plantation. Agriculture and Agricultural Science Procedia 2 (2014), pp. 199 -2016.

M.H. Ezrin, W. Aimrun, M.S.M. Amin and S. Khairunniza Bejo (2016). Development of Real Time Soil Mapping System in Paddy Field. Jurnal Teknologi. Vol. 78, No 1-2. ISSN: 2180-3722: pp. 14-20. (Quartile 3)

Proceeding

I. Nur Aini, Aimrun W, MSM Amin, M.H Ezrin and HZ Shafri (2014). Auto Guided Oil Palm Planter by using multi-GNSS. 7th IGRSM International Remote Sensing & GIS Conference and Exhibition. IOP Conference Series: Earth and Environmental Science 20 (2014) 012013. Doi: 10.1088/1755-1315/20/1/012013. (Participant)

M.H. Ezrin, W. Aimrun, I. Nur Aini. and M.S.M Amin 2014. Relationship of Soil Apparent Electrical Conductivity and Total Nitrogen of Jawa Series Soil in Oil Palm Plantation. Proceeding of National Conference on Agricultural and Food Mechanization 2014 (NCAFM 2014). 20 -22 May 2014, Kota Kinabalu, Sabah. (Presenter)

Mohd Husin, Ezrin and Wayayok, Aimrun and Bejo, Siti Khairunniza and Mahadi @ Othman, Muhammad Razif (2015) Relationship between soil apparent electrical conductivity and soil nutrient of Jawa series in oil palm plantation. In: 7th International Conference on Sustainable Agriculture for Food, Energy and Industry in Regional and Global Context (ICSAFEI 2015), 25-27 Aug. 2015, Faculty of Engineering, Universiti Putra Malaysia. (pp. 1-6).

M.H. Ezrin, W. Aimrun, A.F. Abdullah and S. Khairunniza Bejo (2016). Rapid Nutrient Mapping System for Oil Palm Plantation. The 9th Thai Society of Agricultural Engineering International Conference. 8-10 September 2016.

Ezrin, M.H., Aimrun, W., Bejo, S.K., Abdullah, A.F. (2018). Relationship between Soil Apparent Electrical Conductivity with Nitrogen and CEC in Oil Palm Plantation. The 4th International Conference on Agricultural and food Engineering. 7 – 9 November 2018.