PRECISION AGRICULTURE USING ADVANCED REMOTE SENSING TECHNIQUES IN ARID LANDS

By

MOHAMED MORTADA RAGAB EL SHARKAWY

B.Sc. Agric. Sc. (Natural Resources &Agric. Engineering), Alex. Univ., 2007

PGD Natural Resources Management, ITC, TWENTE Univ., Netherlands 2011

M.Sc. Agric. Sc. (Soil and Water), Damanhour University, 2013

A Thesis Submitted in Partial Fulfillment
Of
The Requirements for The Degree of

DOCTOR OF PHILOSOPHY

in
Agricultural Sciences
(Agriculture in Desert and Salt Affected Areas)

Arid Land Agricultural Graduate

Studies and Research Institute

Faculty of Agriculture

Ain Shams University

2018

Approval sheet

PRECISION AGRICULTURE USING ADVANCED REMOTE SENSING TECHNIQUES IN ARID LANDS

By

MOHAMED MORTADA RAGAB EL SHARKAWY

B.Sc. Agric. Sc. (Natural Resources &Agric. Engineering), Alex. Univ., 2007

PGD Natural Resources Management, ITC, TWENTE Univ., Netherlands 2011

M.Sc. Agric. Sc. (Soil and Water), Damanhour University, 2013

This thesis for PhD degree has been approved by:

Dr. Afify Abbas Afify **…….....**

Chief Research Emeritus, Soil, Water and Environment Research Institute, Agricultural Research Center

Dr. Ayman Farid Abou Hadid **…….…….....**

Prof. Emeritus of Vegetable Crops, Faculty of Agriculture, Ain Shams University

Dr. Usama Ahmed El-Behairy **…….…….....**

Prof. of Vegetable Crops, Faculty of Agriculture, Ain Shams University

Dr. Abd El-Aziz Saad Sheta **…….…….....**

Prof. Emeritus of Soil, Faculty of Agriculture, Ain Shams University

Date of Examination: 15 / 8 /2018

PRECISION AGRICULTURE USING ADVANCED REMOTE SENSING TECHNIQUES IN ARID LANDS

By

MOHAMED MORTADA RAGAB EL SHARKAWY

B.Sc. Agric. Sc. (Natural Resources &Agric. Engineering), Alex. Univ., 2007

PGD Natural Resources Management, ITC, TWENTE Univ., Netherlands 2011

M.Sc. Agric. Sc. (Soil and Water), Damanhour University, 2013

Under the supervision of:

Dr. Abd El-Aziz Saad Sheta

Prof. Emeritus of Soil, Department of Soil Science, Faculty of Agriculture, Ain Shams University (Principal supervisor)

Dr. Osama Ahmed El-Behiery

Prof. of Vegetable Crops, Department of Horticulture, Faculty of Agriculture, Ain Shams University

Dr. Sayed Medany Arafat

Research Prof. Emeritus of Soil, National Authority for Remote Sensing and Space Sciences

ABSTRACT

Mohamed Mortada Ragab El-Sharkawy: Precision Agriculture Using Advanced Remote Sensing Techniques in Arid Lands, Unpublished PhD thesis, Arid Land Agricultural Graduate Studies and Research Institute, Faculty of Agriculture, Ain Shams University, 2018.

One of the most important tools for precision agriculture is remote sensing data and GIS advanced techniques. The main objectives of the current study are to establish a management zones based on various soil and nutrient maps linked to crop productivity. Monitoring plant water consumption and nutrient availability help for increasing the efficient use of water and other inputs. Two sites were selected in El-Salhiya and East of Beni-Suef to represent two regions and different management practices in irrigated desert lands. Soil samples were collected from both study areas. The collected soil samples were analyzed and nutrient availability were measured. Data obtained were used to identify different soil management zones. In order to evaluate the role of remote sensing data, Landsat satellite data (2014-2016) were selected and processed. The advanced resolution merge techniques were used to enhance the spatial resolution from 30 meters in Landsat sensors to 5 meters of Rapideye data which specially designed for precision agriculture service. In this study, image fusion using Principal Component Spectral Sharpening (PCSS) method was applied to integrate NDVI and plant water consumption calculated from Landsat satellite data. Moreover, four hyperspectral vegetation indices were calculated from satellite data.

The obtained results showed that remote sensing data with soil data analyses allowed for the identification of spatial pattern of crop growth variability. Data indicated that peanut yield was mainly affected by soil variability obtained from different spatial maps. Using the soil suitability model and a sufficient number of field observations within each class, an acceptable accuracy and good spatial distribution of the suitability classification was achieved. The empirical regression growth model was able to predict the yield across the field when the correct inputs were used, showing great potential for use in yield map prediction and interpretation in the contest precision agriculture. Results of Tukey's HSD showed that Blue, Red and NIR spectral zones are more sufficient in the monitoring differences between peanut growth stages than green, SWIR-1 and SWIR-2 spectral zones. Also, there are significant correlations between varied classes productivity and spectral similarity measures, indicating that similarity between the samples' spectra decreases as the pigments concentration in the plant leaves increases, which offer as a precision agriculture tool to manage crop variations within fields that can affect crop yield. Moreover, resulting yield predictions showed a high agreement with field data with good significant correlation coefficient. From the obtained results we concluded that remote sensing spectral data with their appropriated derived indices are important source for producing various vegetation-soil models and controlling inputs based on soil and plant requirements in irrigated lands of arid climate.

Key words: Precision agriculture, Peanut, Data fusion, Hyperspectral indices; arid land, SMCE, Remote sensing and GIS.

ACKNOWLEDGEMENT

I would like to thank **Prof. Dr. Abdel-Aziz Saad Nasr Sheta,** Prof. Emeritus of soil in Soil Sciences Department, Faculty of Agriculture, Ain Shams University for his valuable supervision in addition to his scientific supporting and suggestions throughout this work.

In the same Soil Sciences Department, my greatest debt is to **Prof. Mohamed Saif El-Din Abd El-Wahed,** Associate Prof. of soil for his supervision, and continues supporting.

Many thank for staff members in Arid Land Agricultural Graduate Studies and Research Institute for their help; in particular **Prof. Dr. Usama Ahmed El-Behairy**, Professor of vegetables, Horticulture Department, Faculty of Agriculture, Ain Shams University**,** for his supervision, guidance and encouraging to improve this work.

I would like also to acknowledge my colleagues in faculty of Agriculture, Beni-Suef University for their support, in particular **Prof. Dr. Mostafa Mohamed Kotb** and **Prof. Dr. Adel Mohamed Goda** their guidance.

I would like to thank **NARSS** team, in particular my supervisor **Prof. Dr. Sayed Medany Arafat** for data availability, their help and continues support.

I would like to acknowledge special thanks and my gratitude to my family also; I dedicate this thesis to my family: mother, father and all family members for their support, continuous encouragement and patience during the duration of this study.

CONTENTS

	LIST OF TABLES	II
	LIST OF FIGURES	III
	ABBREVIATIONS	V
1	**INTRODUCTION**	1
2	**REVIEW OF LITERATURE**	3
2.1.	Precision Agriculture	3
2.1.1.	Definition	3
2.1.2.	History of Precision agriculture	4
2.1.3.	Precision agriculture driving force “Spatial variability”	7
2.1.4.	Precision agriculture benefits and Sustainability	8
2.2.	Precision agriculture data sources	9
2.2.1.	Soil sampling	9
2.2.2.	Soil evalution using Spatial Multi Criteria Evaluation (SMCE)	10
2.2.3.	Remote sensing applications	12
2.2.4.	Crop yield data collection and Potential yields	20
2.3.	Study sits characteristics and crops description	22
2.3.1.	Peanut Pivot	22
2.3.2.	Peanut crop importance	25
2.3.3.	Peanut growth stages	26
2.3.4.	Olive Farm	28
3	**MATERIALS AND METHODS**	32
3.1.	Study area description	32
3.1.1.	Salhiya site	32
3.1.2.	East of Beni-Suef Area	33
3.2.	Field work	34
3.3.	Soil analyses	35
3.4.	Deriving of soil productivity maps	36
3.5.	Field management practices	39
3.5.1.	Salhiya Site	39

3.5.2.	East of Beni-Suef Site	40
3.6.	Canopy reflectance measurements in Salhiya site	41
3.7.	Satellite data collection and image processing	43
3.8.	Deriving of calculated indices	45
3.9.	Image fusion between actual Evapotranspiration calculated by Surface Energy Balance Algorithm for Land (SEBAL) and NDVI maps to manage field irrigation	47
3.9.1.	CROPWAT model (based on FAO Penman-Monteith approach).	50
3.9.2.	Climatic, crop and soil data for CROPWAT model	50
3.9.3.	Principal Component Spectral Sharpening (PCSS)	51
3.10.	Statistical analyses	52
3.11.	Kriging	54
3.12.	Flowchart of the work steps	56
4	**RESULTS AND DISCUSSION**	55
4.1.	Salhiya area	55
4.1.1.	Soil properties	55
4.1.1.2.	Contents of Available nutrients in the site	66
4.1.1.3.	Management zones based on soil physical and chemical properties and available nutrients levels	73
4.2.	East of Beni-Suef Site	77
4.2.1.	Soil properties of East of Beni-Suef Site	77
4.2.1.1.	Morphological, physical and chemical attributes	77
4.2.1.2.	Amount of available nutrient elements at Beni-Suef site	81
4.3.	Salhiya Soil characteristics at middle growth stage	83
4.4.	Correlation between peanut yield and the values of derived indices	86
4.5.	Correlation between peanut yield and soil characteristics	93
4.6.	Correlation between soil characteristics and derived indices in the middle stage	94
4.7.	Correlation between derived indices and slope at middle stage	99

4.8.	Using vegetation and moisture indices for water stress detection	102
4.9.	Soil productivity assessment	106
4.9.2.	Accuracy assessment of mapping peanut productivity	107
4.10.	ANOVA and Tukey's HSD analyses of derived indices	110
4.11.	Hyper-spectral data of peanut crop using field spectrometer	118
4.11.1.	Correlating reflectance with physiological spectral indices	120
4.12.	Nitrogen management zones	121
4.13.	Estimating daily evapotranspiration:	126
4.13.1.	Calculating ETc using SEBAL, FAO 56-Penman-Monteith (PM) and FAO crop-water model	126
4.13.2.	Variable irrigation rate of water consumption in the pivot area	136
4.13.3.	NDVI and ETc data fusion using PCSS	136
4.14.	Conclusion and Recommendations	141
5	**SUMMARY**	143
6	**REFERENCES**	149
	APPENIX	169
	الملخص العربى	173

LIST OF TABLES

Table (1)	Meteorological data for Salhyia site **Chandler *et al.* (2015)**	22
Table (2)	Growth stage descriptions for peanut (**Boote, 1982**).	26
Table (3)	Days from planting to specific reproductive growth stages for Starr and Florunner peanut cultivars (**Boote, 1982**).	27
Table (4)	Meteorological data for Beni-Suef site **Chandler *et al.* (2015)**	29
Table (5)	Soil and Climate Evaluation Criteria of peanut crop **Saaty** (**1980)**; **Sys *et al.* (1991)** and **Eastman *et al*. (1995)**	37
Table (6)	Soil and Climate Evaluation Criteria for olive crop **Saaty** (**1980)**; **Sys *et al.* (1991)** and **Eastman *et al*. (1995)**	38
Table (7)	Field management practices in Beni-Suef farm 2014 - 2017	39
Table (8)	the ASD FieldSpec 4 Specifications	40
Table (9)	Landsat OLI 8 satellite data specifications	42
Table (10)	criterion weights based on ranking sum eq	51
Table (11)	Soil description of the surface layers in Salhiya site	56
Table (12)	Some of physical properties of the studied soil samples	58
Table (13)	Some soil chemical properties of the studied soil samples	62
Table (14)	Available P, K and micro nutrients (Fe, Mn and Zn) of the soil samples before plantation	67
Table (15)	Area of different units based on soil properties	73
Table (16)	Area of different soil management zones based on soil fertility	74
Table (17)	Soil profile distribution of east Beni-Suef site	78
Table (18)	Some soil physical properties of the studied soil profiles	79
Table (19)	Some soil chemical characteristics of the studied soil profiles	80
Table (20)	Amount of water and nutrient elements in Beni-Suef farm 2014 - 2017	81
Table (21)	Some soil chemical characteristics of the studied soils at middle stage	83

Table (22) Levels of available P, K, Fe, Mn and Zn of the studied soils at middle stage 84
Table (23) Correlation between yield (ton/ha) and derived indices 85
Table (24) Results of the stepwise MLR analysis for soil characteristics and correlation between model parameters and measured yield 86
Table (25) Value of derived vegetation and moisture indices 88
Table (26) Correlation between yield (ton/ha) and derived indice 91
Table (27) Correlation between derived indices and ECe 95
Table (28) Correlation between derived indices and $CaCO_3$ 95
Table (29) Correlation between derived indices and SP 95
Table (30) Correlation between derived indices and pH 95
Table (31) Correlation between derived indices and slope 100
Table (32) Single regression based on NDVI of different growth stages versus NDMI 102
Table (33) Single regression based on EVI of different growth stages versus NDMI 102
Table (34) Confusion matrix of soil productivity output classification 107
Table (35) Producer and user's accuracies of soil productivity output data classification 108
Table (36) Classification accuracy assessment of different classes of peanut soil productivity 109
Table (37) Descriptive statistics for NDVI, SAVI, Albedo, Emissivity and estimated LAI variables of peanut 110
Table (38) Spectral indices of difference peanut growth stages 120
Table (39) Average NDVI, slope and average reflectance at 2180 nm. 122
Table (40) Nitrogen Indices used in the current study 123
Table (41) Results of Nitrogen Indices used in the current study 124
Table (42) Daily actual ET of peanut **Khalifa *et al.* (2011)** 130
Table (43) Total irrigation requirements for peanut 132
Table (44) Peanut irrigation schedule, gross irrigation and net irrigation 133
Table (45) Total area, average seasonal evapotranspiration and total 139

summer season ET for different land use classes, Salhyia 2015
Table (46) Amounts and costs of phosphorus application using VRT 140
Table (47) Amounts and costs of potassium application using VRT 141

LIST OF FIGURES

Figure (1)	Delineated physiographic- soil units of the study area (regionally covered by **Afify *et al.* 2010**)	14
Figure (2)	Salhiya climatic elements as reflected by air temperature, relative humidity, wind speed, solar radiation and average sunshine hours.	24
Figure (3)	Olive growth stages	28
Figure (4)	Beni-Suef climatic elements as reflected by air temperature, relative humidity, wind speed, solar radiation and average sunshine hours	31
Figure (5)	The site (A) and situation (B) of the study area in Salhiya	32
Figure (6)	the site (A) and situation (B) of the study area in Beni-Suef	33
Figure (7)	Location of the elaborated spectra	40
Figure (8)	Whisker box (plot) components as shown in one way ANOVA test results	52
Figure (9)	Kriging **(Geography, 2008)**	53
Figure (10)	Flowchart of methodology applied in the current study	54
Figure (11)	Soil Texture, Saturation Percentage (SP) and $CaCO_3$	59
Figure (12)	Soil classes of Texture, Saturation Percentage (SP) and $CaCO_3$	61
Figure (13)	Soil ECe, pH and ESP of the study soil locations before plantation	64
Figure (14)	Soil classes of ECe, pH and ESP of the study soil locations before plantation	65
Figure (15)	Available phosphorus &potassium of the study soil locations	68
Figure (16)	Available Fe, Mn &Zn of the study soils in Salhiya Site	69
Figure (17)	Available phosphorus (P) and available potassium (K)	71

Figure (18)	Different soil units based on soil factors **(USDA, 2003)**	72
Figure (19)	Different soil units based on some soil characteristics	75
Figure (20)	Total areas of final management zones map based on soil properties and soil fertility management zones	76
Figure (21)	Soil sample locations and digital soil characteristics maps of pivot 22 at middle growth stage, El-Salhiya area, Ismailia governorate	84
Figure (22)	Actual yield by predicted yield response and RMSE	86
Figure (23)	Costume tones mapping for the spatial distribution of derived indices values of peanut crop	89
Figure (24)	Costume tone mapping for the spatial distribution of derived indices values of Beni-Suef olive farm	93
Figure (25)	Validation of ECe verses NDVI, SAVI, LAI, Albedo and Emissivity	96
Figure (26)	Validation of $CaCO_3$ verses NDVI, SAVI, LAI, Albedo and Emissivity	96
Figure (27)	Validation of SP verses NDVI, SAVI, LAI, Albedo and Emissivity	97
Figure (28)	Validation of pH verses NDVI, SAVI, LAI, Albedo and Emissivity	97
Figure (29)	Validation of slope model verses NDVI, SAVI, LAI, Albedo and Emissivity	100
Figure (30)	Validation of NDVI model based on initial growth stage (A), Middle growth stage (B) and late growth stage (C) verses NDMI	103
Figure (31)	Validation of EVI model based on initial growth stage (A), Middle growth stage (B) and late growth stage (C) verses NDMI	104
Figure (32)	Soil productivity of the studied pivot	106
Figure (33)	Results of Statistical analysis ANOVA and grouped quantile plots of NDVI in different growth stage	111

Figure (34) Results of Statistical analysis ANOVA and grouped quantile plots of SAVI in different growth stage 112
Figure (35) Results of Statistical analysis ANOVA and grouped quantile plots of *albedo* in different growth stage 114
Figure (36) Results of Statistical analysis ANOVA and grouped quantile plots of Emissivity in different growth stage 115
Figure (37) Results of Statistical analysis ANOVA and grouped quantile plots of LAI in different growth stage 116
Figure (38) Average spectral reflectance measured at different stages 117
Figure (39) Correlation between NDVI and Reflectance at 2180 nm 121
Figure (40) Peanut NDVI map (17 August 2015) and slope map 121
Figure (41) Validation of NRI calculated from Landsat 8 verses $NDNI_{1510}$ 125
Figure (42) Daily evapotranspiration of Salhyia in 24 July 2015 127
Figure (43) Peanut daily evapotranspiration estimated using SEBAL 128
Figure (44) Daily Actual Evapotranspiration mapping of peanut crop 129
Figure (45) Olive daily evapotranspiration estimated using SEBAL 131
Figure (46) Irrigation water requirements for peanut pivot 134
Figure (47) Result of (C) the resolution merges within (A) ETc and (B) NDVI using PCSS method 137
Figure (48) Daily Actual Evapotranspiration mapping of Olive field 138