



Ain Shams University

Faculty of Engineering

Irrigation and Hydraulics Department

Crop Pattern Assessment in Western Delta Using GIS

By

Eng. Eman Sayed Ahmed Soliman

(B.Sc. Civil Engineering – Cairo University)

Ministry of Water Resources and Irrigation

Thesis Submitted in Partial Fulfillment of

The Requirements for the Degree of

MASTER of Science

In CIVIL ENGINEERING

Supervised by

Prof. Dr. **Sohier M. Mahmoud Kamel**

Professor of Hydraulics

Irrigation and Hydraulics Department

Faculty of Engineering

Ain Shams University

Dr. **Ghada Mahmoud Samy**

Irrigation and Hydraulics Department

Faculty of Engineering

Ain Shams University

Dr. **Hoda Kmal Soussa**

Irrigation and Hydraulics Department

Faculty of Engineering

Ain Shams University

CAIRO, EGYPT

2005

Crop Pattern Assessment in Western Delta Using GIS

By

1. Eng. Eman Sayed Ahmed Soliman

A thesis submitted in the Partial fulfillment of the
Master Degree

Examiners Committee

Name	Signature
Dr. Hussien Ehsan El-Atfy	Head of Sector for Minister's Office Affairs Ministry of Water Resources and Irrigation
Prof. Dr. Nahla M. AbouelAtta	Professor of Irrigation Design Irrigation and Hydraulics Department Faculty of Engineering Ain Shams University
Prof. Dr. Sohier Mohamed Kamel	Professor of Hydraulics Irrigation and Hydraulics Department Faculty of Engineering Ain Shams University

Cairo, Egypt

2005

STATEMENT

This thesis is submitted to Ain Shams University for the degree of Master of Science in Civil Engineering.

The work included in this thesis was carried out by the author in the Department of Irrigation and Hydraulics, Ain Shams University and the Planning Sector of the Ministry of Public Works and Water Resources from August r, 2003 to June 2005.

No part of this thesis has been submitted for a degree or qualification at any other University or Institution.

Date : / /2005

Name : Eman Sayed Ahmed Soliman

Signature :

ACKNOWLEDGMENTS

The author is greatly indebted to her supervisor Prof. Dr. Sohier M. Mahmoud Kamel, Professor of Irrigation Design, Irrigation and Hydraulics Department, Faculty of Engineering, Ain Shams University, for her invaluable support and encouragement.

My particular thanks is due to my supervisor Dr. Ghada Mahmoud Samy, Irrigation and Hydraulics Department, for the useful information I have gained from her experience. Moreover, I would like to express my sincere gratitude for her great help, her concern, and useful revision of the thesis. I would like to thank her for valuable advice and encouragement during the development of the thesis.

I am also grateful to Dr. Hoda Kamal Soussa, Irrigation and Hydraulics Department, for her guidance and advice throughout the development of this thesis.

I would also like to thank my manager in the GIS Unit Eng. Tarek Elsayed, and Eng. Marwa Abd-Elrhman.

Great thanks are due to my family - specially my husband - who patiently supported me during the years of research, which would not have possible without them.

Crop Pattern Assessment in Western Delta Using GIS

Supervised by:

Prof. Dr. Sohier M. Mahmoud Kamel

Dr. Ghada Mahmoud Samy

Dr. Hoda Kmal Soussa

Name : Eman Sayed Ahmed Soliman

Degree : Master degree

Department : Irrigation & Hydraulics

Faculty : Engineering

University : Ain Shams

Graduation year : 1995

ABSTRACT

Changing the policy reform from a centralized economy to market economy has led to the liberalization of the cropping pattern (CP). Since then the area cultivated with rice has doubled from the 700,000 fed. to some 1,500,000 fed. Rice considered as low profitable crop and, in the same time, it is one of the highest water consuming crops. Which requires well control on the irrigation efficiency, as well as design of an indicative cropping pattern for each region in the country based on climatologically conditions, soil characteristics, and water resources availability in terms of quantity and quality.

The study is conducting on a pilot area level (Abou-Hummus irrigation district in western delta). The study main objectives are to; Maximize the benefits from the water resources through selecting the most suitable CP to maximum production considering either the economic or the environmental aspects besides the quantity and the quality of water used, in addition developing a GIS tool to help in selecting the most suitable CP. Finally, the study tries to assess the suitability of the current CP for the system.

The Study Outputs are:- 1) Maps and Information about Abou-Hummus irrigation districts land and water resources. An understanding of the Cropping Pattern trends in the area. 2) A decision support system for Cropping Pattern selection. 3) Suggestions of different Cropping Pattern scenarios according to different objectives. 4) Assessment of different CP Scenarios and perform comparison between them, as well as compare the total water needs for different scenarios against the water delivered to the area, and the total income for the different scenarios. 5) Recommendations to apply the suggestions on different areas and link it to the Integrated Water Management District implemented by Ministry of Water Resources and Irrigation.

TABLE OF CONTENTS

ABSTRACT	I
TABLE OF CONTENTS	II
LIST OF FIGURES	V
LIST OF TABLES	VIII
List of Acronyms and Abbreviations.....	IX
1. Introduction.....	1
1.1 Background.....	1
1.2 Problem Definition.....	2
1.3 Study Objective and Approach	3
1.4 Methodology:.....	4
1.5 Study Outputs.....	4
2. Review of Literature	5
2.1 Introduction.....	5
2.2 Water Resources Management.....	6
2.2.1 Main Challenges in Water Resources Management	7
2.2.2 Integrated Water Resources Management.....	7
2.3 Demand Management.....	8
2.3.1 Cropping Pattern Shifts	9
2.4 Demand Management Tools	10
2.4.1 Mathematical Models	10
2.4.2 GIS Entity	14
2.4.2.1 GIS and Environmental Problem-Solving	15
2.4.2.2 GIS in Policy	15
2.4.2.3 Samples of GIS Applications	16
2.5 Environmental Impact Assessment	19
2.5.1 Legislative Frameworks.....	20
2.5.2 History of the EIA system in Egypt.....	20
2.5.3 Conceptual Approach for the Studies.....	21
2.5.4 Samples of EIA Studies	25
2.6 Findings.....	27

3. Factors Affecting Crops Cultivation.....	28
3.1 Introduction.....	28
3.2 Water Duties	29
3.2.1 Evapotranspiration (source FAO, 56)	29
3.2.1.1 Factors Affect in Evapotranspiration.....	30
3.3 Economic Aspects	34
3.3.1 Soil Salinity.....	34
3.3.1.1 Crop Tolerance to Salinity.....	35
3.3.2 Ground Water Table.....	36
3.3.3 Field Drainage.....	37
3.3.4 Labour Force.....	38
3.4 Environmental Aspects	38
3.4.1 Water Quality.....	39
3.4.1.1 Water Quality Problems.....	39
3.4.1.2 Water Quality Guidelines.....	41
3.4.2 Sea Water Intrusion Phenomenon.....	43
3.4.3 Land Topography	45
3.5 Findings.....	46
4. Abou-Hummus, Pilot Area.....	47
4.1 Introduction.....	47
4.2 Data Collection.....	47
4.2.1 Study Area Location.....	47
4.2.2 Drainage System	49
4.2.3 Water supply.....	51
4.2.3.1 Water Distribution System	51
4.2.3.2 Water Quality	54
4.2.4 Cropping Pattern Data.....	58
4.2.4.1 Year 1994	58
4.2.4.2 Year 2002	59
4.2.4.3 Crop Consumption.....	60
4.2.4.4 Crop Economic Values	62
4.2.4.5 Crops Social Value	63
4.2.5 Weather Conditions	64
4.2.5.1 Temperature.....	64
4.2.5.2 Relative Humidity.....	65
4.2.6 Land Topography	66
4.2.7 Soil Characteristics.....	66
4.2.8 Sea Water Intrusion.....	69
4.3 Data Analysis	70
4.3.1 Weather Conations	70
4.3.2 Soil Salinity.....	70
4.3.3 Soil Permeability.....	70
4.3.4 Ground Water Depth	71

4.3.5	Water Quality Data	72
4.3.6	Land Topography	72
4.4	Findings.....	73
5.	Cropping Pattern GIS Model	74
5.1	Introduction.....	74
5.2	Categories of different Criteria	74
5.3	Importance of GIS Modelling	77
5.4	Suitability Modelling	78
5.4.1	Conceptual Model.....	78
5.4.2	Model Description.....	80
5.4.2.1	Individual priorities.....	84
5.4.2.2	Weighting System.....	84
5.4.2.3	Cropping Pattern Scenarios.....	89
5.4.2.4	Scenario A.....	89
5.4.2.5	Scenario B.....	91
5.4.2.6	Comparison.....	92
5.4.2.7	Intermediate scenario	95
6.	Crop pattern Assessment	97
6.1	Introduction.....	97
6.2	Assessment	97
6.3	Mitigation Measures	101
6.4	Environmental Management Plan.....	103
7.	Conclusions and Recommendations.....	104
7.1	Conclusion.....	104
7.2	Recommendations	107
	References	108
	Annex A.....	111
	Annex B.....	114
	Annex C.....	115

LIST OF FIGURES

<i>Figure 1.1: projected water demand in the agriculture sector till year 2020, (NAWQAM, 2002)</i>	<i>2</i>
<i>Figure 2.1: Algorithm of ASME Model.....</i>	<i>12</i>
<i>Figure 2.2: ET chart, OPDM output.....</i>	<i>13</i>
<i>Figure 2.3: Flowchart for Sustainable land development modelling using RS & GIS.....</i>	<i>16</i>
<i>Figure 2.4: Priorities for rice cultivation in delta zone, Egypt.....</i>	<i>17</i>
<i>Figure 2.5: Crop pattern classification, integrated NOAA and Landsat output ..</i>	<i>18</i>
<i>Figure 2.6: Structure of the SDSS for the Nagwan test watershed.....</i>	<i>19</i>
<i>Figure 2.7 : Existing vs. LP-model proposed land-use plan for the Nagwan watershed.....</i>	<i>19</i>
<i>Figure 2.8:: EEAA system for EIA, Guidelines for Egyptian EIA.....</i>	<i>21</i>
<i>Figure 2.9 : 10-activity model steps for EIA studies.....</i>	<i>22</i>
<i>Figure 3.1: Factors affecting crop cultivation</i>	<i>29</i>
<i>Figure 3.2: Effect of wind speed on ET in different weather conditions.</i>	<i>31</i>
<i>Figure 3.3: Reference (ET_o), crop ET under standard (ET_c) and non-standard conditions (ET_{cadj})</i>	<i>33</i>
<i>Figure 3.4: Divisions for relative salt tolerance ratings of agricultural crops, FAO 29</i>	<i>36</i>
<i>Figure 3.5: The Relation between ground water level and crops production, EIA of Rice Cultivation - WMRI & IRRI – 1995</i>	<i>37</i>
<i>Figure 3.6: Divisions for relative salt tolerance ratings of agricultural crops, FAO 29</i>	<i>38</i>
<i>Figure 3.7: Hypothetical cross section showing the zone of dispersion and flow patterns in a coastal aquifer.....</i>	<i>44</i>
<i>Figure 3.8: Saline water intrusion mechanism in costal zone, (After WMRI et al, 1996).....</i>	<i>45</i>
<i>Figure 4.1: study Area Location.....</i>	<i>48</i>
<i>Figure 4.2: Overlap of Abou Hummus Irrigation District command area with MALR boundary</i>	<i>49</i>
<i>Figure 4.3: Drainage catchment areas overlapped with Abou-Hummus irrigation district</i>	<i>50</i>
<i>Figure 4.4: Drainage network of Abou-Hummus district.....</i>	<i>50</i>
<i>Figure 4.5: Irrigation network of Abou Hummus district.</i>	<i>51</i>
<i>Figure 4.6: Location of Water measurements at Abou-Hummus District.....</i>	<i>52</i>

<i>Figure 4.7: Crop water needs and water delivered to Abou Hummus District, APRP, 2002.</i>	54
<i>Figure 4.8: Water quality monitoring locations along El- Mahmoudia canal.....</i>	55
<i>Figure 4.9: Variation No3 values from Aug.2001 to Jun 2004.....</i>	56
<i>Figure 4.10: Variation of, PH values from Aug.2001 to Jun 2004.....</i>	56
<i>Figure 4.11: Variation of Electrical conductivity values from Aug., 2001 to Jun., 2004.....</i>	57
<i>Figure 4.12: Variation of Boron values from Aug., 2001 to Jun., 2004.</i>	57
<i>Figure 4.13: Variation of SAR values from Aug., 2001 to Jun., 2004.</i>	57
<i>Figure 4.14: Variation of TDS values from Aug., 2001 to Jun., 2004.....</i>	58
<i>Figure 4.15: Summer crop pattern for year 1994</i>	59
<i>Figure 4.16: Summer crop pattern for year 2000.....</i>	60
<i>Figure 4.17: ETo distribution within the study area, WRI, 2004.....</i>	61
<i>Figure 4.18: water requirement for the major crops in year 2003 - 2004, WRI.2004.....</i>	61
<i>Figure 4.19: Economic values of different crops, CAMPS, 2003.</i>	62
<i>Figure 4.20: Locations of metrological station.....</i>	64
<i>Figure 4.21: Average temperature distribution over the study area, in summer season.....</i>	65
<i>Figure 4.22: Relative humidity distribution over the study area, in summer season.....</i>	65
<i>Figure 4.23: Digital elevation model for the study area</i>	66
<i>Figure 4.24: Soil salinity distribution in ds/m</i>	67
<i>Figure 4.25: Distribution of soil permeability in m/day.....</i>	68
<i>Figure 4.26: Depth to groundwater in the Quaternary Aquifer, (RIGW, 2002) ..</i>	68
<i>Figure 4.27: Distribution of ground water depth in cm</i>	69
<i>Figure 4.28: Zones of upward and downward flow in western delta.</i>	70
<i>Figure 4.29: Soil salinity distribution Chart</i>	71
<i>Figure 4.30: Soil permeability distribution chart.....</i>	71
<i>Figure 4.31: Ground water table depth distribution chart.....</i>	72
<i>Figure 4.32: % land slope for the study area.....</i>	73
<i>Figure 5.1 Conceptual steps for creating the CPDSS.....</i>	80
<i>Figure 5.2: Layout of CPDSS.....</i>	82
<i>Figure 5.3: location of the CPDSS in ArcCatalog.....</i>	83
<i>Figure 5.4: Window of CPDSS.....</i>	83
<i>Figure 5.5: individual re-classification for different inputs</i>	85

<i>Figure 5.6: Suitability map for different crops according to salinity.</i>	<i>85</i>
<i>Figure 5.7 Suitability map for different crops according to GWD.....</i>	<i>86</i>
<i>Figure 5.8: Suitability map for different crops according to ground water percolation zones.....</i>	<i>86</i>
<i>Figure 5.9: Suitability map for different crops according to Land Slope.</i>	<i>86</i>
<i>Figure 5.10: Suitability map for different crops according to DEM.....</i>	<i>87</i>
<i>Figure 5.11: Suitability map for different crops according to soil permeability... </i>	<i>87</i>
<i>Figure 5.12: Intermediate weighting system for production's category.</i>	<i>88</i>
<i>Figure 5.13: Overall weighting system for all categories.</i>	<i>88</i>
<i>Figure 5.14: Cropping pattern generated from CPDSS for scenario A.....</i>	<i>90</i>
<i>Figure 5.15: cropping pattern generated from CPDSS for scenario B</i>	<i>92</i>
<i>Figure 5.16: Crop water requirement vs. water delivered for varies scenarios. .</i>	<i>93</i>
<i>Figure 5.17: Net income for the different scenarios.....</i>	<i>94</i>
<i>Figure 5.18: Crops net income per unit water for the different scenarios</i>	<i>95</i>
<i>Figure 5.19: cropping pattern generated from intermediate scenario.....</i>	<i>96</i>
<i>Figure 6.1: Suitability scores for different scenarios</i>	<i>101</i>

LIST OF TABLES

<i>Table 3.1: Estimated deep percolation as fraction as related to water application efficiency</i>	33
<i>Table 3.2: Variation of K-Values by Soil Texture</i>	34
<i>Table 3.3: Cotton & Maize % Yield reduction against water table Depth.</i>	37
<i>Table 3.4: Guidelines for Interpretations of Water Quality for Irrigation, FAO 29</i>	41
<i>Table 4.1: Overlap of Abou Hummus Irrigation District with MALR boundary....</i>	48
<i>Table 4.2: Main Canals feeding the study area.</i>	52
<i>Table 4.3: Statistical analysis for WQ parameters.</i>	56
<i>Table 4.4: Summer crop pattern data for year 1994.....</i>	58
<i>Table 4.5 : Crop pattern data for year 2002.....</i>	59
<i>Table 4.6: Total crop WR (m³/fed.), WMRI, 2004.....</i>	62
<i>Table 4.7: Analysis of farmers' preference of rice cultivation in Egypt.....</i>	63
<i>Table 5.1: Accepted values of different parameters relate to cropping pattern selection</i>	76
<i>Table 5.2: Conditions for the selection of cropping pattern in scenario A</i>	90
<i>Table 5.3: Cultivated areas with different crops for scenario A.....</i>	90
<i>Table 5.4: Condition for selection cropping pattern in scenario B</i>	91
<i>Table 5.5: Cultivated areas with different crops for scenario B.....</i>	91
<i>Table 5.6: Comparison between different scenarios cropped areas in fed.</i>	93
<i>Table 5.7: comparison between crop water requirements in Mm³/season.....</i>	94
<i>Table 5.8: Cultivated areas with different crops for intermediate scenario.....</i>	95
<i>Table 6.1: Meaning of Assessment Parameters.....</i>	98
<i>Table 6.2: Assessment matrix for the different scenarios.....</i>	100
<i>Table 6.3: Mitigation measures for "As Usual Scenario" and "scenario A"</i>	102
<i>Table 6.4: different mitigation measures to "Scenario B"</i>	102
<i>Table 6.5: Detailed items of EMP for the different issues.....</i>	103

List of Acronyms and Abbreviations

APRP	Water Policy Reform Activity
ASME	The Agriculture Sector Model of Egypt
B	Boron
CALAG	California Agricultural Model
CLEQM	Central Laboratory for Environment Quality
CAPMAS	Agency for Public Mobilization and Statistics
Cl	Chloride
CPDSS	Cropping pattern decision support system
DAE	Description of The Affected Environment
DEM	Digital Elevation Model
ds/m	deciSiemens per meter
DSS	Decision Support System
EC	Electrical Conductivity
Ecw	Irrigated Water Salinity
EEAA	Egyptian Environmental Affairs Agency
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan And Monitoring
EPADP	Egyptian Public Authority for Drainage Projects
ET	Evapo-Transpiration
Etc	ET Under Standard Conditions
ETo	Reference Crop Evapotranspiration
FAO	Food And Agricultural Organization of The United Nation
Fed.	Feedden
G	Soil Heat Flux
GAMS	General Algebraic Modelling System
GIS	Geographic Information System
GLI	Guidelines for Interpretations of Water Quality for Irrigation
GWD	Groundwater Depth Measured from The Land Surface
IA(PP)	Impact Assessment (Planning Program)
H.C	Hydraulic Conductivity
IIIP	Integrated Irrigating Improvement Project
IIP	Irrigating Improvement Project
IM	Impact Mitigation
IP	Impact Prediction
IPI	Identification of Potential Impacts
IWRMS	Integrated water resources management system
K (m/d)	Soil Permeability
K _c	Crop Coefficient
LP	Linear Programming
Mm ³	Million Cubic meter
MWRI	Ministry of Water Resources and Irrigation
NAWQAM	National Water Quality and Availability Management Project
NILECON	The Nile Economic Model

NO ₃	Nitrogen
NWRC	National Water Research Centre
NWRP	National Water Resource Plane
MALR	Ministry of Agriculture and Land Reclamation
OPDM	The Operational Planning Distribution Model
PDN	Project Description And Needs
PII	Pertinent Institutional Information (Scoping)
PS	Planning Sector
P.S.	Pump Station
PSM	Planning Studies and Models
PWD	Preparing the Writing Documentation
R.H	Relative Humidity
RIGWA	Research Institute Of Ground Water
S	Salinity
SAR	Sodium Adsorption Ratio
Sc	Scoping
SDSS	Spatial Decision Support System
SEA	Strategic Environmental Assessment
SL	Land Slope
SPA	Selecting Proposed Action
T	Air Temperature
TDS	Total dissolved solids (mg/l).
WQ	Water Quality
WR	Water Requirements
WMRI	Water Management Resources Institute
WOGL	Water quality guidelines for irrigation

2. Introduction

2.1 Background

A major challenge facing the Ministry of Water Resources and Irrigation of Egypt is to close the rapidly increasing gap between the limited water resources and the sustainable exploitation of the water resources system in support of production of economic goods and services that are required to meet national and regional development objectives.

The water requirements of the agricultural sector represent the largest component of the total water demand in Egypt. Agriculture consumes more than 80% of Egypt's share of Nile water annually. Municipal and industrial water requirements represent a small portion of Egypt's total requirements. Other usage is livestock, fish farming, and non-withdrawals for navigation and hydropower generation. It is expected that the future demands definitely increase for all uses due to the rapid increase in population and the land reclamation and industrialization policies. The rate of increase will vary from one sector to another according to the government national policy and, thus, reallocation of the available water resources will be needed to meet these future demands. Figure (1.1) shows the demand in the agriculture sector, as it will consume about 75,000 mm³ by the year 2020 (NAWQAM, 2002), which is considered a large number. And requires a broader vision to reduce the agriculture demand and control the cropping pattern as well as reduce the area cultivated with high water consumer crops.

Demand-oriented approach looks at the real demand for water and tries to urge the users to make better use of this valuable resource. This can be achieved by creating awareness among the users that the resource is precious for example by letting them pay for it, or pay the costs to treat and deliver it. Over the agricultural, institutional measures include public awareness programs for water