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Effect of Variation of Water-Use Efficiency (WUE) on: Water Management in Agriculture; Crop Production Management; Risk Management in Agriculture; and Labor Management in Agriculture

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Abstract: The Nile in Egypt is that the primary provider of water; it's used for strategically important water uses like drinking, fishing, industrial use, livestock, and irrigation. Water from the Nile is sent to users through a huge network of channels.Wastewater and agricultural wastewater is collected from these uses by drains and is usually returned to the river as internal flows.Any disruption or impairment to the Nile River from natural or anthropogenic threats will probably have far-away-reaching economic and social implications. About ninety-nine percent of Egypt's population (the total population is about 85.783 million people) lives in the Nile Valley and Delta, which amounts to four percent of Egypt's total area. The Nile River Delta itself covers an area of twenty-five thousand square kilometers and includes about thirty-five million people. Reducing water consumption in agriculture has become of great importance as a result of the construction of the Grand Ethiopian Renaissance Dam (GERD) on the Blue Nile in the absence of negotiations or agreements with others. To study the effect of variation in water use efficiency on water management in agriculture, crop production management, risk management in agriculture, and labor management in agriculture water use efficiency (WUE) must be applied. The Water Use Efficiency (WUE) is an analytical tool for applying the water use system in the old lands of Lower Egypt in the agriculture sector in light of water scarcity in Egypt. Whereas, yields can be increased by increasing water inputs or improving water consumption in agricultural systems.

Keywords: Water-Use Efficiency (WUE),water management in agriculture, crop production management, agricultural risk management and labor management in agriculture

Introduction

The Nile River has been the cornerstone of Egyptian regional foreign policy. Egypt constantly declares its historical right to benefit from the water of the Nile, which dates back to 5500 years. Other riparian countries have alternative sources of water supply, while Egypt depends almost entirely on the Nile for water supply and irrigation. Hence, Egypt is very sensitive with regard to diverting water inside the upstream areas of the river. However, the question that is increasingly being asked is whether Egypt can continue to use massive amounts of water for agriculture and other purposes once the requirements of other countries grow within the upstream areas. Ethiopia is currently planning to harness the waters of the Blue Nile, and Kenya and the Republic of Uganda want to develop the water resources of Lake Victoria. Since the late 1980s, the issue has remained tense between the three major countries of the Nile River: Egypt, Sudan, and Ethiopia, where Egypt usually threatens to use its military forces to protect its share of the waters of the Nile (**Dawoud, 2001**).

However, the main significant threat to Egypt's water supply came from Ethiopia in the mid-1990s. With rapid population growth and increasing demand for food, Ethiopia needed lots of water for private use. Not bound by any water-sharing agreement with Egypt or Sudan, it has developed unilateral plans to divert Nile water to its own irrigation projects. Despite the objections of Egypt and Sudan, Ethiopia maintained its sovereign right to develop water resources within its borders. Economic and technological underdevelopment and political problems have led to the suspension of Ethiopian plans to develop the waters of the Nile River for a long time. In the mid-1990s, Ethiopia emerged from a long period of war and famine to a period of accelerated economic growth and development, as well as a significant increase in financial aid from Western countries. This provided confidence in Addis Ababa to successfully address Egyptian and Sudanese objections to its exploitation at the diplomatic level. Since the mid-1990s, the Ethiopian government has built a large and diverse group of small dams, and many additional dams are planned to enhance the country's irrigation and hydropower capacity. Ethiopia's current water development program plans require a portion of the Nile water compared to potential demand between the near future. Ethiopia intends to develop its hydroelectric potential and thus meet the increasing energy needs. However, the real threat to water supply downstream is not from hydroelectric production, and this does not divert water from the watercourse system, as does irrigation. There is an estimated 2.2 x 106 hectares of irrigated land in Ethiopia and its rapid population growth and economic mitigation require the development of a large portion of this land for agricultural purposes, which could seriously threaten the waters of the lower Nile countries (**Swain, 2011**).

Reducing water consumption in agriculture has become a notably important part as a result of building the Grand Ethiopian Renaissance Dam (**GERD**) on the Blue Nile without negotiating or agreeing with others. Consequently, to verify the impact of the variation in water use efficiency on water management in agriculture, crop production management, risk management in agriculture and labor management in agriculture, water use efficiency (**WUE**) should be applied. The Water-Use Efficiency (**WUE**) was developed as a related analytical tool for the use of the water use system in the old lands of Lower Egypt in the agriculture sector in light of water scarcity in Egypt. Whereas, yield can be increased by increasing water inputs or optimizing water consumption in agricultural systems.

Methodology

The study area was the old lands of Lower Egypt with an area of 1385052.9 hectares and located in the Nile River Delta (**MALR, 2019**), which contains 13 governorates (Alexandria, Gharbia, Menoufia, Ismailia, Kafr El Sheikh, Qaliubiya, Dakahlia, Port Said, Sharqia, Damietta, Suez , El-Behaira, and Cairo) (**Figure 1**). The study area has a typical southern Mediterranean climate, the average annual catchment rainfall is low, which occurs mainly in winter and the summer temperatures are almost elevated.The old land in the Nile Valley is the main area that grows in Egypt and is characterized by a pattern of growing crops for a complex year, where crops are cultivated over three consecutive cropping seasons; winter, summer, and nili. The Nile River is the main source of renewable and fresh surface water in Egypt.

Water-Use Efficiency (WUE) is a model formulated as an analytical tool for applying the water use system in the old lands of Lower Egypt in the agriculture sector in light of water scarcity in Egypt (**Figure 2**). To assess the sustainability of agriculture, it is necessary to consider the water use efficiency of the farming system, water use efficiency can often be increased by reducing water use from inputs or by increasing outputs such as crop production. In addition, the model had the flexibility to introduce many types of water use as a prerequisite for efficiency and equity in the agricultural sector in light of financial change and global climate change, which reduces the cost to be able to compete within the global market and reduce the social cost of pollutants on agricultural crops. The economic and financial analysis and risks were also studied, as well as the internal annual rate of return for crop production. To fill in the model, field data reported by farmers was used. The necessary data were collected through a comprehensive energy survey and other inputs for crop fields on a seasonal basis, and a comprehensive data set was attached to the agricultural establishment and its associated socio-economic conditions. Crop area, yield, and cost data were obtained from the Egyptian Ministry of Agriculture and Land Reclamation (**MALR, 2019**), while water consumption data were collected from the Egyptian Ministry of Water Resources and Irrigation (**MWRI, 2019**). The necessary data related to the input of the cropping pattern of the different production systems were collected from primary sources and converted into appropriate cropping pattern values. Greenhouse gas emissions were calculated and represent per unit of energy input. The data provided during this study represented typical and / or average data recorded over the three consecutive years (2013 / 2014-2015 / 2016).

Water-Use Efficiency **(WUE)can be written as:**

Minimize

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{e=1}^{E} A_{\text{WaterUse Efficiency}} B_{\text{WaterUse Efficiency}} \quad (1)$$

Subject to

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{e=1}^{E} \mathbf{A}_{\text{WaterUse Efficiency}} \mathbf{MAX\_\ A_{z}\_}\ \textbf{for}\text{ the crop }\mathbf{W} \quad (2)$$

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{e=1}^{E} \mathbf{B}_{\text{WaterUse Efficiency}} \mathbf{MIN\_B_{z}\ \_}\ \textbf{for}\text{ the crop }\mathbf{W} \quad (3)$$

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{e=1}^{E} \mathbf{C}_{\text{WaterUse Efficiency}} \mathbf{MAX\_C_{z}\_}\ \textbf{for}\text{ the crop }\mathbf{W} \quad (4)$$

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{e=1}^{E} \mathbf{D}_{\text{WaterUse Efficiency}} \mathbf{MAX\_D_{z}\_}\ \textbf{for}\text{ the crop }\mathbf{W} \quad (5)$$

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{e=1}^{E} \mathbf{E}_{\text{WaterUse Efficiency}} \mathbf{MAX\_E_{z}\_}\ \textbf{for}\text{ the crop }\mathbf{W} \quad (6)$$

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{e=1}^{E} \mathbf{F}_{\text{WaterUse Efficiency}} \mathbf{MAX\ \_F_{z}\_}\ \textbf{for}\text{ the crop }\mathbf{W} \quad (7)$$

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{e=1}^{E} \mathbf{G}_{\text{WaterUse Efficiency}} \mathbf{MIN\_G_{z}\_}\ \textbf{for}\text{ the crop }\mathbf{W} \quad (8)$$

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{e=1}^{E} \mathbf{H}_{\text{WaterUse Efficiency}} \mathbf{MIN\_H_{z}\_}\ \textbf{for}\text{ the crop }\mathbf{W} \quad (9)$$

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{e=1}^{E} \mathbf{I}_{\text{WaterUse Efficiency}} \mathbf{MAX\_I_{z}\_}\ \textbf{for}\text{ the crop }\mathbf{W} \quad (10)$$

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{e=1}^{E} \mathbf{J}_{\text{WaterUse Efficiency}} \mathbf{MAX\_J_{z}\_}\ \textbf{for}\text{ the crop }\mathbf{W} \quad (11)$$

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{e=1}^{E} \mathbf{K}_{\text{WaterUse Efficiency}} \mathbf{MAX\_K_{z}\_}\textbf{for}\text{the crop }\mathbf{W} \quad (12)$$

$$\sum_{w=1}^{W}\sum_{u=1}^{U}\sum_{e=1}^{E} \mathbf{L}_{\text{WaterUse Efficiency}} \mathbf{MIN\_L_{z}\_}\ \textbf{for}\text{ the crop }\mathbf{W} \quad (13)$$

Where Variables (A) is:

$\mathbf{A}_{\text{Water use efficiency}}$ Estimated land area allocatedin sub-zone (Old land of Lower Egypt) $\mathbf{B}_{\text{Water use efficiency}}$ Estimated crop water consumption in sub-zone (Old land of Lower Egypt)

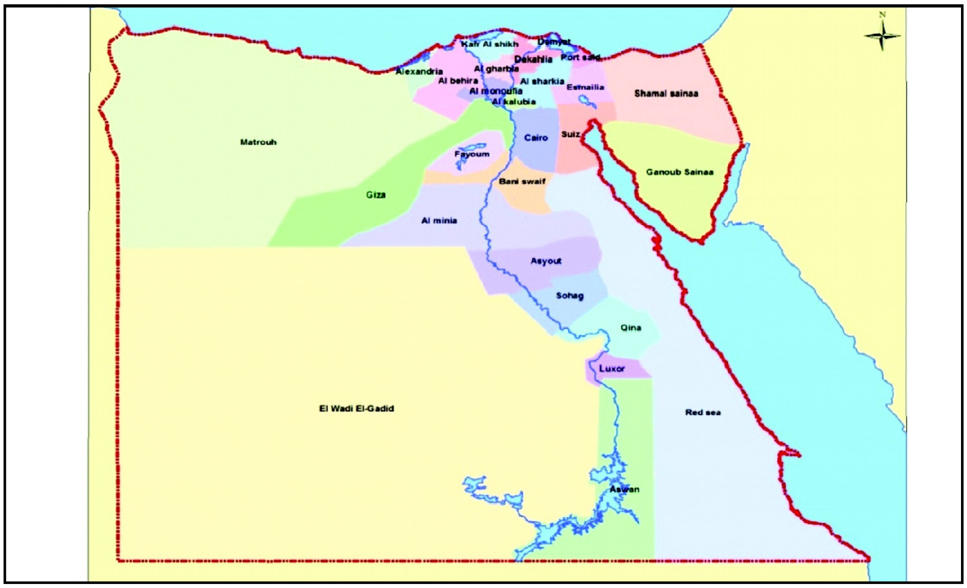
C$_{w}$_ Main crop yieldof the crop **w**
D$_{w}$_ Secondarycrop yieldof the crop **w**
E$_{w}$_ Main crop price of the crop **w**
F$_{w}$_ Secondarycrop price of the crop **w**
G$_{w}$_ Total crop production cost of the crop **w**
H$_{w}$_ Energy consumption in cultivationof the crop **w**
I$_{w}$_ Labor Wagesin cultivationof the crop **w**
J$_{w}$_ Revenue of the crop **w**
K$_{w}$ _Profitof the crop **w**
L$_{w}$ _ Emission in cultivationof the crop **w**

And Variables (B) is:
A$_{z}$_ Last land area of the crop **w**
B$_{z}$_ Last water consumptionin cultivationof the crop **w**
C$_{z}$_ Last main crop yieldof the crop **w**
D$_{z}$_ Last secondarycrop yieldof the crop **w**
E$_{z}$_ Last main crop price of the crop **w**
F$_{z}$_ Last secondarycrop price of the crop **w**
G$_{z}$_ Last total crop production cost of the crop **w**
H$_{z}$_ Last energy consumption in cultivationof the crop **w**
I$_{z}$_ Last labor Wagesin cultivationof the crop **w**
J$_{z}$_ Last revenue of the crop **w**
K$_{z}$ _ Last profitof the crop **w**
L$_{z}$_ Last emission in cultivationof the crop **w**

Solution and Recommendations

Model Results and Discussion

Water Use Efficiency (WUE) in Lower Egypt is a model that was formulated as an analytical tool for applying the water use system in the old lands of Lower Egypt in the agriculture sector in light of water scarcity in Egypt (Figures 1 and 2). To assess the sustainability of agriculture, it is necessary to consider the water use efficiency of the cropping system. Water use efficiency is often increased by reducing water use from inputs or by increasing outputs such as crop production. In addition, the model has the flexibility to introduce many types of water use as a precondition for achieving efficiency and equity in the agricultural sector in light of financial and global climate change, which reduces the cost to become able to compete within global markets and reduce the social



Lower Egypt		*Middle Egypt*	*Upper Egypt*	*Outside the Valley*
Alexandria	Port Said	Giza	Assuit	New Valley
Gharbia	Sharkia	Beni Suef	Sohag	Matruh
Menoufia	Damietta	Fayum	Qena	South Sinai
Ismailia	Suez	Mania	Luxor	North Sinai
Kafr-El Sheikh	Behera		Aswan	Noubaria
Qalyoubia	Cairo			
Dakahlia				

Source: (Agrotechnol 2016)

Figure 1: Map of Egypt's Governorates

Data source: WUE model (2019)

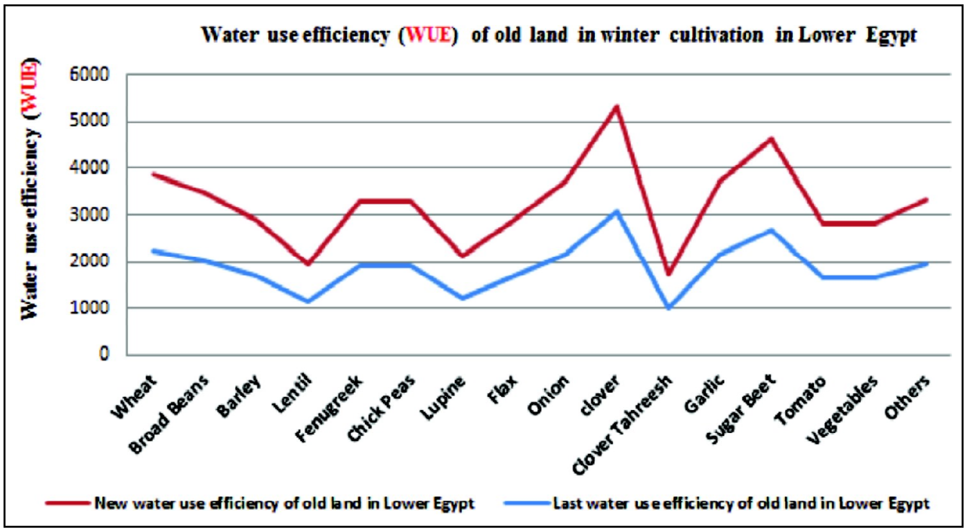
Figure 2: Structure of the Water Use Efficiency Model **(WUE)**

cost of pollutants on agricultural crops. Financial and economic analysis, risks and the internal annual rate of crop yield have also been investigated.

Several steps were followed to implement the WUE model: The first step was the optimal cropping pattern for growing crops in winter in the old lands of Lower Egypt.

The second step was to simulate the optimal cropping pattern for the region (Lower Egypt).The third step was to simulate the optimal cropping pattern in the region with the current cropping pattern (2013 / 2014-2015 / 2016) to reallocate crop acreage according to production and technical risk management.To fill in the model, field data reported by farmers was used. The data were collected through a comprehensive production survey and also system management and alternative inputs to crop fields on a seasonal basis, and comprehensive data set were enclosed to the farm enterprise and associated socio-economic conditions. Crop area, yield, and cost data were obtained from **MALR (2019)**. Information on water consumption was collected from **MWRI (2019)**. The necessary data related to the cropping pattern input of the different production systems were collected from primary sources and converted into appropriate cropping pattern values. Greenhouse gas emissions were calculated and expressed per unit of the energy input. The data presented in this research represented typical and/or average data recorded over the successive years of 2013-2014-2015 / 2016. Current cultivation and its economic evaluation in Lower Egypt presented in the region and the season in old lands are presented in **Tables 1** and **2.** The remaining base year data is available from the sources in **Tables 1** and **2** places of crops in a larger view, which clarifies the place crops and their area as well as cultivation from their source **(ECAPMS, 2019)**.

Water Use Efficiency (WUE)may be a model that should be used. To use production and technical risk management it can be reallocated to increase farm income; the model was adjusted regardless of the change in the land to accompany changes in soil and water type after laser leveling of the land in the old lands of Lower Egypt. The model structure for optimum cultivation based on the appropriate soil type and water in Lower Egypt is shown in **Figure 2**. Moreover, **Table 3** shows the economic assessments of optimal cultivation based on Water Use Efficiency **(WUE)** and laser leveling of land in the old lands of Lower Egypt and was compared with the current situation in Lower Egypt. **Figure 3** illustrates changes in water efficiency in cultivation within the region and season from average 2013-2014-2015 / 2016 to **WUE** in the old lands of Lower Egypt. The results showed that the total water consumption for optimum cultivation decreased by 40.388% in the old lands of Lower Egypt and that the total area of crops would be 2922,487 hectares planted in the old lands of Lower Egypt, as well as the expected model provides a higher net benefit than the current model. The total net profit of the heterogeneous case was 226132.714 million EP higher than the total of the



Data source: (1) MALR (2019) (2) WUE model (2019)

Figure 3: Water Use Efficiency (**WUE**) for the winter season in the old lands of Lower Egypt.

homogeneous case (139919.854 million EP) after applying the model as well as the total cost of crops in heterogeneous case 26607.350 million EP that did not reach the total homogeneous case (23410.930 million EP). This result may indicate that the difference between the heterogeneous case had a significant impact on the optimal solution. For this reason, the **WUE** model of the heterogeneous character of the land area is applicable to cultivation based on production and managing technical risks after laser land leveling in the old lands of Lower Egypt.

A classification of agro-climatic adaptation (per crop) must be established within a suitable type to match crops with climate and soil resources and the cost of crop production specified for each soil and geographical area, convenient to assess whether yields exceed costs or not. According to monetary and economic analyzes, the internal annual rate of return **(IRR)** became higher than the current model of the region and increased by 51.572% in the old lands of Lower Egypt. The absolute risk of optimal cultivation decreased by -17.462% **(Table 3)**. The proposed model provided less greenhouse gas emissions than the current model for all agricultural operations. Pollutants cause harm to the ecosystem, structures, and people's health. The social cost per ton of greenhouse gas emissions and air pollutants was calculated to obtain data on the optimum use of water in old lands in Egypt in **Table 4**. Finally, farmers must level the land by laser because it is the best solution to the Egyptian question, as it is low-cost (261.904 hectares) per hectare in northern Egypt.

Conclusion

Water Use Efficiency (WUE) may be a model ought to be used. In order to implement production and manage technical risks that could be reallocated to increase farm income; the model adjusted whatever changes in lands that were required to accompany changes in soil and water type after laser leveling of land in the old lands of Lower Egypt. The model structure of the optimum cultivation relied on soil type and water in Lower Egypt. The results indicate that the application of Water Use Efficiency **(WUE)** will not change the total irrigated area of crops within the area chosen for old lands in Lower Egypt, but it may be a shift from one crop to another. In order to suit the type of soil and water that can be reallocated to increase farm income, the model adjusted any land change that was required to accompany changes in soil and water type after laser leveling in the old lands of the Nile Valley in Lower Egypt.

As a result of optimal cropping patterns, farm income will increase by 63.553%, decrease in water use by 41.785%, carbon dioxide emissions by 17.490%, and decrease in energy by 14.674%. The Internal Rate of Return **(IRR)** will increase by 51.572% and reduce the risk by -17.462%. In general, the **WUE** model aims to study achieving efficiency and equity in cropping patterns in northern Egypt by focusing on the strategic plan for water shortage preparedness, presentation methodologies, and specific measures to combat drought within overall water planning.

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