SIMULATION MODEL FOR CENTER PIVOT IRRIGATION SYSTEM MANAGEMENT

By

YOUSRIA ATEF ABDELHAMEED AHMED

B.Sc., Agricultural Engineering, Ain Shams University, 2008

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This thesis for M.Sc. degree has been approved by:

Dr. Gamal Hassan El-Sayed ……………………

Emeritus Chief Researcher, Agricultural Engineering Research Institute, Agriculture Research Centre

Dr. Ahmed Abou El-Hassan Abdel-Aziz ……………………

Prof. of Agricultural Engineering, Faculty of Agriculture, Ain Shams University

Dr. Abdel-Ghany Mohamed El-Gindy ……………………

Prof. Emeritus of Agricultural Engineering, Faculty of Agriculture, Ain Shams University

Date of Examination: 14 / 8 / 2014

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B.Sc., Agricultural Engineering, Ain Shams University, 2008

Under the supervision of:

Dr. Abdel-Ghany Mohamed El-Gindy

Prof. Emeritus of Agric. Eng., Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University (Principal Supervisor)

Dr. Yasser E. Arafa

Associate Professor of Agric. Eng., Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University

Dr. Essam El-Din Wasif

Chief Researcher, Agricultural Engineering Research Institute, Agriculture Research Centre

ABSTRACT

Yousria Atef Abdelhameed Ahmed: Simulation Model for Center Pivot Irrigation System Management. Unpublished M. Sc. Thesis, Department of Agricultural Engineering, Faculty of Agriculture, Ain Shams University, 2014.

Center-pivot sprinkler irrigation became very popular in Egypt. The center pivot irrigation management model (CPIM) has been developed with the objective of design new system or changes in system in operation. The CPIM model is based on crop type, weather data, and soil characteristics. The software consists of a simulation package developed in C# and data base in Microsoft Excel 2010. The model comprises five sub-models for: (a) main sub-model; (b) data entry sub-model; (c) weather sub-model; (d) irrigation sub-model; and (e) results sub-model. The most important simulation outputs of the CPIM model include nozzle flow rate (m^3/h), application rate (mm/h), and throw diameter (m). These outputs (outputs of 9 scenarios) were compared with observed/manufactured data for the calibration and validation of the model.

Results of this comparison show that differences in model accuracy owing to different variables affecting design and management of the center pivot were not significant. The relationships between the observed/manufactured and simulated results have a good correlation with high value of coefficient of determination and the best models are as follows:

1. Nozzle flow rate, m^3/h: is in scenario 5 with R^2 = 0.967 and explained by an exponential model: $Q_{SIM} = 0.1067e^{4.1131\,(Q_{Obs})}$.

Where:

Q_{SIM} : Simulated nozzle flow rate

Q_{Obs} : Observed nozzle flow rate

2. Application rate, m^m/h: is in all scenarios with a very high R^2 and explained by a linear model.

3. Throw diameter, m: is in scenario 1 with $R^2 = 0.942$ and explained by a power model: $Dw_{SIM} = 3.9064 (Dw_{MFD})^{0.4361}$.

Where:

Dw_{SIM} : Simulated throw diameter

Dw_{MFD} : Manufactured throw diameter

The CPIM simulation model accuracy was very high and perfectly mimic the real world for nozzle flow rate and application rate, whereas, the accuracy of the model was good for the throw diameter. Therefore, results of model evaluation confirm the accuracy and robustness of CPIM for simulation of center pivot variables under real field conditions. Finally, it is recommended that using the model as a kernel and useful tool for center pivot irrigation management and design that should be subjected for further development to provide a good tool for center pivot design and management.

Key Words: Simulation; Model; Validation; Verification; Center pivot; Application rate; Nozzle flow rate; Throw diameter.

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LIST OF ABBREVIATIONS

Abbreviation	Definition
A	Total irrigated area
ASAE	American Society of Agricultural Engineers
C	Roughness coefficient
CUC	Christiansen uniformity coefficient
CUD	Christiansen uniformity distribution
D	Root zone depth
D	Pipe inside diameter
d_{sp}	Nozzle size
D_w	Sprinkler throw diameter
Dw_{MFD}	Manufactured throw diameter
Dw_{SIM}	Simulated throw diameter
E_a	Efficiency of the irrigation system
ET_c	Crop evapotranspiration
ET_o	Reference evapotranspiration
f	Outlet friction coefficient
FC	Field capacity
H_e	Pressure head required in the end of the sprinkler line
H_f	Friction head losses
H_r	Height of Sprinkler
H_{rg}	Head losses in pressure regulator
H_{sp}	Sprinklers operating pressure head
H_v	Operating pressure head in the pivot point
H_z	Height difference between pivot and the end of lateral
I_a	Irrigation requirement
I_a	Available solar energy
I_n	Net irrigation depth
K	Conversion factor
K_c	Crop coefficient
K_{cb}	Basal crop coefficient

K_e	Soil evaporation coefficient
PWP	Permanent wilting point
Q_{obs}	Observed nozzle flow rate
Q_{SIM}	Simulated nozzle flow rate
Q_s	Center pivot System capacity
Q_{sp}	Nozzle discharge
R	Pipe length
R^2	Determination coefficient
R_a	Sprinkler application rate
Ra_{MFD}	Manufactured application rate
Ra_{SIM}	Simulated application rate
r_{sp}	Radius at sprinkler
S.E	Standard error
SD	Soil depletion
SG	Specific Gravity
S_s	Distance between sprinklers
T	Operating time
T_i	Irrigation intervals

I. INTRODUCTION

Over the past decade, many countries around the world have witnessed a growing scarcity and competition for water among different users (domestic, municipal, industrial, and agricultural purposes). Therefore, the increasing of water demands can be met either through the development of new water resources or by using the existing resources more efficiently. In Egypt, the development of new water resources is not economically viable and faces political problems and strict environmental resistance. In addition to the presence of a close connection with energy that is also a valuable resource.

Agriculture is a major user of freshwater on a global basis and contributes to water pollution from excess nutrients, pesticides and other pollutants. The estimated average of the fresh water withdrawn from rivers and groundwater is 80% for producing food and other agricultural activities. Conjointly, an undetermined amount of water required for irrigation and mal water management are putting stress on groundwater reservoirs. For the previous mentioned reasons, the situation is worrisome and calls for greater efforts in sustainable management of water in agriculture and application of new technologies in irrigation which, in turn, will add more value to agricultural production, environmental preservation, and social benefits of water systems.

Centre pivot irrigation system, as a promising modern and precision irrigation system, can help in increasing the efficiency of existing water resources and reducing the water pumping energy consumption. Additionally, center pivot is not dependent on the surface topography in a field to distribute water; unlike previous forms of gravitational irrigation systems which require a minimum slope and are dependent on the slope of the land. Due to these features that distinguish the center pivot irrigation system and the lack of research on its water management are leading to make further research on it.

Generally, a model intended for a simulation study is a mathematical model developed with the help of simulation software.

INTRODUCTION

Several simulation models have been developed to study the flow processes involved during an irrigation event in sprinkler irrigation to improve the design and operation of these systems. On the contrary, there is a lack of information about the center pivot simulation models.

Therefore, the general objective of this research is to develop a simulation-decision-support model for center pivot irrigation system aimed at increasing the usability of this technology to improve decision-making capabilities. Specifically, the research objectives are:

1. Develop a robust, reliable simulation model for center pivot irrigation management for a decision support system under optimization and systematic response evaluation of different engineering factors affecting the center pivot irrigation management.
2. Develop a computer simulation program for center pivot management as a scalable platform in the future to combine the components developed in the simulation model with database facilities and a graphical user interface.
3. Investigate the capability of the simulation program to mimic the real world, and therefore, obtaining reliable and trustable results for decision support.