DEPIVOT – A SOFTWARE PACKAGE TO DESIGN AND EVALUATE CENTER-PIVOT SYSTEMS

M. I. Valín[1,2], M. R. Cameira[1], C. Pedras[1,3], P. R. Teodoro[1], J. M. Gonçalves[1,4] and L. S. Pereira[1]
[1]Biossystems Engineering Research Center, Institute of Agronomy, Technical University of Lisbon
Tapada da Ajuda, 1349-017, Lisbon, Portugal
[2]Agricultural College, Viana do Castelo Polytechnic Institute
Refóios do Lima, 4990-706, Ponte de Lima, Portugal
[3]University of Algarve, Campus de Gambelas, 8005-139, Faro, Portugal
[4]Agricultural College, Coimbra Polytechnic Institute, 3040-316, Coimbra, Portugal

Keywords: Hydraulics design, Sprinkler chart, Database, Performance indicators.

Abstract: This paper presents a simulation model aimed at center-pivot design and support assessing the performance of systems under operation: DEPIVOT (Design and Evaluation of center PIVOT). The software code was developed in Visual Basic and includes an Access database. DEPIVOT allows considering performance criteria for design and to iteratively search better system solutions. The model has two main components: A. the design of new systems and B. the evaluation of operating systems. The first component starts with the agronomic design aiming the calculation of the system flow rate; this is followed by the hydraulic design: (a) computes friction head losses along the lateral; (b) the creation of the sprinkler chart; and (c) the validation of the sprinkler chart. The second component requires field data to calculate performance indicators, such as distribution uniformity (DU) and the coefficient of uniformity (CU).

1 INTRODUCTION

Irrigation modelling allows the simulation of the water distribution by an irrigation system under real working conditions. Models have been developed in order to avoid laborious field tests and to design and improve irrigation systems. Montero et al. (2001) consider that using a simulation model enables to reduce water and energy consumption and increases the efficiency of utilization of these resources.

Center-pivot systems have experienced a wide diffusion because of its advantages relative to other irrigation systems such as: 1) high potential for uniform and efficient water applications, (Qassim et al., 2008); 2) high degree of automation, (Al-Kufaishi et al., 2006); and 3) ability to economically and environmentally apply water and nutrients over a wide range of soil, crop and topographic conditions. Center pivot design models have been reported in the literature for the last fifty years. Heermann and Heid (1968) developed a model based on Bittinger and Longenbaugh (1962), which computed depth, rate, and uniformity of application along the lateral, when the discharge and wetted diameter at each sprinkler are specified. James (1982) investigated the effects of topography on water distribution and Allen (1989) developed a program, USUPIVOT, where the user can input infiltration rate parameters (surface storage, infiltration pattern, and seal factor), crop parameters (Etc), irrigation system parameters (working hours and lateral radius), and the sprinkler pattern (triangular and elliptic). Heermman et al., (1990) simulated water distribution along the system introducing new profiles with a donut design for low pressure sprinklers. Bremod and Molle (1995) have considered the pivot discontinuous motion, determined sprinkler distribution pattern in laboratory and calculated the water depth received in each point. Other models have introduced the calculus of runoff and soil loss in different soils watered by the same system (Silva, 2006).

This paper presents a software package (DEPIVOT) to use for the design of center-pivot systems and for the assessment of the performance of systems under operation or being designed. DEPIVOT simulates different sprinkler charts for the same system configuration and estimates runoff

Valín M., Cameira M., Pedras C., Teodoro P., Gonçalves J. and Pereira L..
DEPIVOT – A SOFTWARE PACKAGE TO DESIGN AND EVALUATE CENTER-PIVOT SYSTEMS.
DOI: 10.5220/0003610402980301
In *Proceedings of the 6th International Conference on Software and Database Technologies* (ICSOFT-2011), pages 298-301
ISBN: 978-989-8425-77-5

for each of them. This option allows to compare the different sprinkler charts based on water conservation criteria.

2 MODELING APPROACH

Fig. 1 shows the conceptual structure of the DEPIVOT software. The software code was developed in Visual Basic 6.0 and includes a database in Access. The model has two main components: A. design of new systems and B. evaluation of operating systems. The first component starts with the agronomic design aiming the calculation of the system flow rate; being followed by the hydraulic design; and the validation of the sprinklers chart. The second component uses field data to calculate the performance indicators, Distribution Uniformity (DU) and Uniformity Coefficient (UC) (Pereira and Trout, 1999).

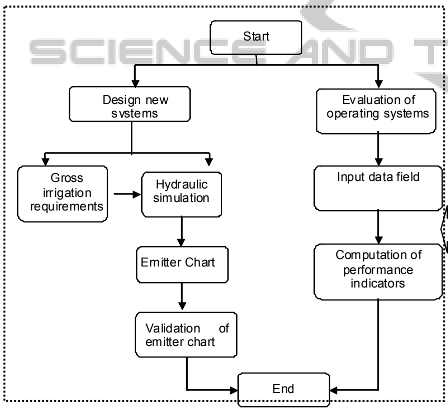

Figure 1: Conceptual structure of the DEPIVOT software.

In the hydraulic design the user makes a first selection of the span diameter, length and outlet spacing. Considering the span with a continuous flow rate (Keller and Bliesner, 1990; Scaloppi and Allen, 1993) the friction head losses along the lateral are determined in order to select the adequate diameter, length and outlet spacing for all the spans.

The most important step of a center pivot design is the creation of the sprinkler chart. To choose the most suitable sprinkler for each outlet is necessary to calculate the type, working pressure and the flow rate at that point (sprinkler chart). To achieve this the friction head loss is computed by the stepwise method**,** which calculates friction losses in each pipe length between two consecutive outlets.

The input data required for the calculation of the required discharge (qi) and pressure (pi) for each output are the same as those used for span selection, plus the distance between outlets. The q_i is the one that produces the best uniformity along the lateral and also the ideal pressure (p_i).

Starting form q_i, the sprinklers charts can be obtained directly by the user, manual chart, or by the model through an optimized automatic approach. With the first option, the model runs a query to the database and shows all sprinklers. The user chooses the sprinkler and the model calculates and shows the actual discharge as a function of the pressure in that point. If the optimized sprinkler chart option is selected, the model, starting at the first outlet, chooses the sprinkler whose discharge is the nearest to the required discharge (q_i, L s^{-1}). Afterwards, it calculates the friction head losses section-by-section ($h_{f\ i,i+1}$), thus obtaining the actual pressure (p_{ai+1}) at each outlet as the result of the pressure in the previous output minus the friction head losses and the difference in elevation between consecutive outlets (Figure 2). The flow rate is then calculated (q_{ai+1}) by the discharge-pressure function. The model runs a new query to the database, being the cycle repeated for every outlet. The model allows the storage of several possible sprinkler charts for the lateral.

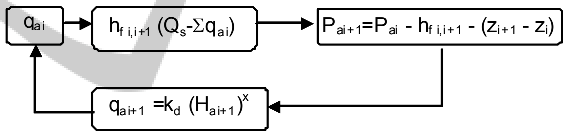

Figure 2: Iterative computation of pressure (P_{ai}, kPa) and discharge (q_{ai}, ls^{-1}) for each outlet i.

Each sprinklers chart can be validated using two criteria: i) performance indicators; and ii) runoff calculations. At the sprinkler level, two performance indicators, the Distribution Uniformity (DU) and the Uniformity Coefficient (UC) are calculated. For the second validation the model calculates the potential runoff (P_R, mm) for each sprinkler chart selected previously by comparing the application (P) and infiltration rate curves (i) as function of time (t).

The DEPIVOT database was developed with Microsoft Access and can be updated whenever required. It stores the equipment (sprinklers and spans) available in the market and the results (information relating to projects created or evaluated). For each nozzle inserted in the database, it is necessary to enter the pairs of maximum and minimum values of pressure and flow recommended by the manufacturer. This allows: i) limiting the operating range of the sprinkler; and ii) calculating the coefficients k_d and x to be stored and used to calculate the flow rate associated to the pressure supplied.

3 RESULTS

The model initiates with two options: design of a new system or evaluation of an operating system.

After choosing the option *Design a new system* DEPIVOT allows the user to introduce the system flow rate as an input or to request the model to use an algorithm to calculate it by the soil water balance. This algorithm is feed manually or by importing WinISAREG model output file to calculate the crop irrigation requirements.

Once the system flow rate is defined, the user begins the hydraulic simulation. The user introduces the system characteristics and selects diameter (D, mm) and length (L, m) of the span from the database, including the spacing between outlets (Se, mm). Selection of all spans is made trough database consulting, where the equipment characteristics were previously introduce. The model allows the installation of a gun in the distal end. If the total friction losses, is higher than 15% of the working pressure, a message is displayed indicating the need to select a different span. The program simulates a static position for the system, therefore the user must decide previously which is the most representative position in terms of the field slope.

Once the spans are sized, the sprinklers chart is defined. The sprinklers' characteristics are acceded in a specific database. The sprinklers chart (Figure 3) includes for each outlet: the radial distance (ri); the required discharges (qi) and actual discharges (qa); the required pressure (Pi) and actual pressure (Pa); and the identification of sprinklers (manufacture, model, description and nozzle). Sprinkler's selection can be carried out for a given manufacturer or within the entire database. The selection may be optimized by the model by searching, for each outlet i, located at the radial distance ri from the pivot, the sprinklers that produce a discharge qai that is the closest to the required one qi if the available outlet pressure is Pi. In alternative, the selection may be done by the user, option Manual. This option allows i) to choose one of the charts created and individually change each sprinkler (within a range of 10% of the discharge) and ii) create a new sprinkler chart that allows to choose any sprinkler existing in the database. Once this selection is completed, the sprinkler pressure and discharge are computed by the iterative process (Fig. 3).

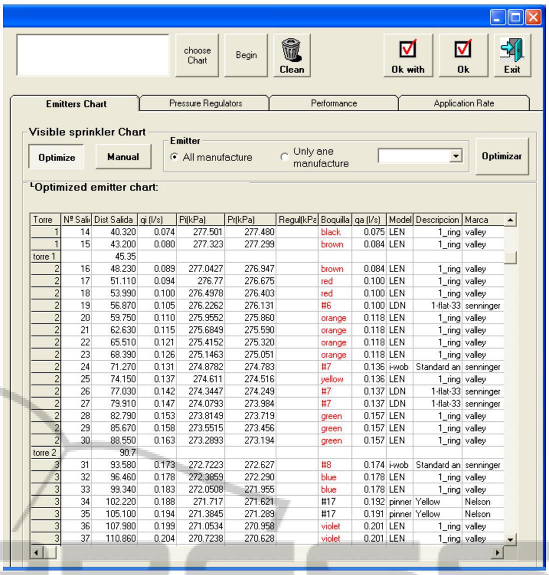

Figure 3: Window for design the sprinklers chart at each lateral.

The model allows the association of several sprinkler charts to each system, to modify them and store it with different names. Figure 3 shows in red ink the nozzles that work above the pressure defined by the manufacturer in the database. If the user chooses to install pressure regulators its selection is supported by an additional window where the user decides in which span should the regulators be installed and which is the regulating pressure (PRmax). The model updates the pressure values and allocates them in column Regul (kPa) in the sprinklers chart as the pressure used for calculating the flow rate.

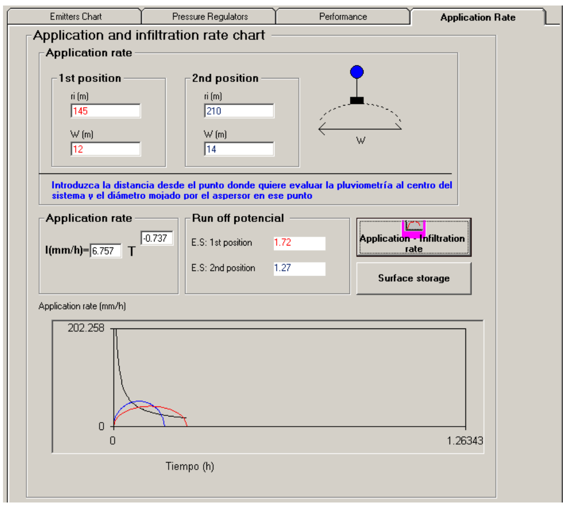

Figure 4: Window for estimating potential runoff and surface storage.

The potential runoff computation is supported by the window shown in Figure 4. Results for potential runoff are shown graphically and numerically for two positions. By pressing the button *Aplication – infiltration rate* the model presents a dialog box to insert the number of hours needed for a complete revolution.

When the model is used to evaluate a system under operation, first the common data to all evaluations are introduced (equipment´s characteristics); second the water depths caught in catch cans placed along two radius are used to compute DU and UC. Results are presented in numerical and graphical formats.

4 CONCLUSIONS

DEPIVOT model is oriented to find solutions for the critical aspects that limit achieving good performances in the farmer irrigation practice. Particular attention has been given to: determining the irrigation water requirements and the corresponding system discharge; sizing of the lateral in order to achieve an adequate variation of pressure; producing the sprinklers charts; determining the functioning conditions for every sprinkler; estimating the runoff potential; and defining the main information for system management in practice. The model is presented in WINDOWS environment, with a structure between windows and with a set of databases that can be consulted and altered from the model itself. Once developed, the model has been tested with results of field evaluations. These results show that the model is able to respond to the objectives that led to its development, which are to assist farmers and technicians in selecting and designing new centre-pivot systems and to identify operational performance problems and respective solutions.

ACKNOWLEDGEMENTS

The support by CEER - Biosystems Engineering (POCTI/U0245/2003) and the research project PTDC/AGR-AAM/105432/2008 funded by Portuguese Foundation for Science and Technology are acknowledged.

REFERENCES

Allen, R. G., 1989. USUPIVOT: Center pivot nozzle selection computer software user´s manual. Department of Agriculture and Irrigation Engineering, *Utah State University*, Logan, Utah, 15.

Al-Kufaishi, S. A.,·Blackmore, B. S., H. Sourell 2006. The feasibility of using variable rate water application under a central pivot irrigation system. *Irrig Drainage Syst* 20:317–327.

Bittenger, M., W., Logenbraugh, R. A., 1962. Theoretical distribution of water from a moving irrigation sprinkler", *Transactions of the ASAE* 5(1): 26-30

Bremond B., Molle, B., 1995. Characterization of rainfall under centre pivot. Influence of measuring procedure. *Journal of Irrigation and Drainage Engineering ASCE* 121 (5): 347 – 353

Heermann, D. F., Hein, P. R., 1968. Performance characteristics of self-proped center-pivot sprinkler irrigation system. *Transactions of the ASAE* 11(1): 11-15

Heermann, D. F., Wallender, W. W., Bos, G. M, 1990. Irrigation eficiency and Uniformity. In: Hoffman, G. J., Howell, T. A., Solomon, K. H. (Eds.), *Management of Farm Irrigation Systems*. ASAE, St. Joseph, MI, 125 -149.

James, L. G., 1982. Modeling the performance of center pivot irrigation systems operating on variable topography. *Transactions of the ASAE* 38(1): 143-149.

Keller, J. y Bliesner, R. D., 1990. Sprinkle and Trickle Irrigation Van Nostrand Reinhold. New York.

Montero, J., Tarjuelo, J. M., Carrión, P. 2001. Nueva versión del modelo de simulación de riego por aspersión SIRIAS. *In: XIX Congreso Nacional de Riegos*, AERYD, Madrid, CD-ROM paper C-18.

Pereira, L. S., Trout T. J., 1999. Irrigation Methods. In: HN van Lier, LS Pereira, FR Steiner (Eds.) *CIGR Handbook of Agricultural Engineering, Vol. I: Land and Water Engineering,* ASAE, St. Joseph, MI, pp. 297-379

Qassim, A., Dunin F., Bethume M. (2008). Water balance of center pivot irrigated pasture in northern Victoria, Australia. Agric. Water Manag. 95, 566-574

Scaloppi E. J., Allen R., 1993. Hydraulics of Center-Pivot laterals. *Journal of Irrigation and Drainage Engineering* ASCE 119 (3): 554-567

Silva, L. S. (2006) The effect of spray head sprinklers with different deflector plates on irrigation uniformity, runoff and sediment yield in a Mediterranean soil. Agric. Water Manag. 85, 243-252