AN OPTIMIZATION MODEL FOR DRAINAGE SYSTEM DESIGN TO REDUCE DAILY WATER LOGGING

MODELE D'OPTIMISATION DE LA CONCEPTION DU SYSTEME DE DRAINAGE POUR REDUIRE L'ENGORGEMENT QUOTIDIEN

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ABSTRACT

In addition to increasing yield, drainage guarantees sustainable agriculture. High cost, huge value of drainage water and poor drainage effluent quality are some of most common problems of drainage projects. Optimization is a scientific tool that could produce best decision in drainage design and management. SEW and WX are the two indexes used to evaluate drainage projects. In this research, an optimized model is presented to minimize SEW and WX. The system parameters such as depth, distance and radius of drain were selected as the design variables. The model was solved by using Genetic algorithm. Data from Kesht and Sanat at the north of Khoramshahr were used for the case study to evaluate drainage design by optimization model. Optimal value of depth, distance and radius of drain were 2m, 30m and 0.18m, respectively, that produced no incidence of waterlogging. But the optimized model preferred was with 1.6m, 32m and 0.3 m as drain depth, drain spacing and drain radius, respectively, which resulted in 4 days of waterlogging with only 1mm SEW value with respect to the crop root zone.

Keywords: *drain depth, drain spacing, optimization model, SEW index, WX index.*

RESUME

En outre l'augmentation du rendement, le drainage assure l'agriculture durable. Le coût élevé, la valeur élevée de l'eau de drainage, la basse qualité des effluents sont quelques-uns des problèmes des projets de drainage. L'optimisation est un outil scientifique qui pourrait produire la meilleure décision dans la conception et la gestion de drainage. SEW et WX sont les deux indices utilisés pour évaluer les projets de drainage. Dans cette recherche,

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un modèle optimisé est présenté pour réduire SEW et WX. Les paramètres du système tels que la profondeur, la distance et le rayon de drain ont été retenus comme les variables de conception. Le modèle a été résolu en utilisant l'algorithme Génétique. Les données de Kesht et de Sanat au nord de Khoramshahr ont été utilisées pour l'étude de cas pour évaluer la conception de drainage par le modèle d'optimisation. La valeur optimale de la profondeur, de l'écartement, et du rayon de drain était de 2m, 30m et 0.18m respectivement, qui n'a produit aucune incidence de l'engorgement. Mais, le modèle optimisé préféré détenait la valeur de 1,6m, 32m et 0,3 m respectivement pour la profondeur de drain, l'écartement de drain et le rayon de drain, qui a donné lieu à 4 jours de l'engorgement avec la valeur SEW de 1mm en ce qui concerne la zone racinaire agricole.

Mots clés: *Profondeur de drain, écartement de drain, modèle d'optimisation, indice de SEW, indice de WX.*

1. INTRODUCTION

Waterlogging and salt accumulation in the root zone depth reduce crop yield. To avoid over-drainage in the water deficit regions for the optimal management of water resource and avoiding frequent irrigation need, a drainage system should be so designed as to maintain the water table near the root zone to allow the roots taking benefit of the upward moisture flux to meet parts of plant water requirement. Depth, spacing and radius of the drain are the design parameters in a subsurface drainage system and an optimum combination of these parameters ensures proper drainage in removing excess water and salts from the crop root zone. Non-optimum values of these parameters may cause harmful waterlogging and salinity in the crop root zone on the one hand or over drainage causing environmental problems and grequent irrigation requirement on the other (Christen and Skehan 2001).

In usual design of drainage systems, depth of drain is estimated by engineering experiments and drainage installation equipment and drain spacing and radius are decided based on the depth to impermeable layer, drainage coefficient and some other considerations such as considering natural drainage effect, evaporation effect, outlet availability, etc. Optimization model is a scientific tool that could use in the best design of a drainage system and its management. Navabian and Liaghat (2006) had presented an optimization model to determine drainage depth and spacing to minimize drain water salinity. The optimal results of drainage depth and spacing had good effects on salinity outgoing from root depth zone. SEW (Sum of Daily Exceedances) and WX (Number of Daily Exceedances) are the two commonly used indexes to evaluate drainage projects (Ayars et al, 1997 and Ayars et al, 2006).

In this research, an Optimization model to design and manage of drainage systems considering SEW and WX is presented

2. MATERIALS AND METHODS

Then objective function of optimization model were minimization of SEW and WX (Eq. 1).

$$Min \quad \text{Number of Daily Exceedances}=N$$
$$Min \quad \text{Sum of Daily Exceedances}=\text{D}_0-(d-h_t) \tag{1}$$

Parameters as depth, spacing and radius of drain were selected as design variables and their optimal values were determined using the optimization model, subject to certain constraints. The constraints were: 1m ≤ depth of drain ≤ 2.5m, 20m ≤ spacing between adjacent drains ≤ 500m and 5cm ≤ radius of drain ≤ 30cm. Mathematically, they could be expressed as:

$$\begin{aligned} &Subject\,to: \\ &1.5 \le d \le 2.5 \quad (m) \\ &20 \le L \le 500 \quad (m) \\ &0.05 \le r \le 0.3 \quad (m) \end{aligned} \tag{2}$$

Unsteady state equation (De zeeuw and Hellinga, 1958) was used in water table simulation.

$$h_t = h_{t-1} \times e^{-\alpha\times\Delta t} + R \times \frac{\left(1-e^{-\alpha\times\Delta t}\right)}{0.8\mu\alpha} \tag{3}$$

$$\alpha = \frac{\pi^2 kd}{\mu L^2} \tag{4}$$

$$R = Irr + \Pr e - stor - et \tag{5}$$

Where h, R, µ, t, ΔK, d, L, Irr, Pre, sto and et are water table, recharge rate, effective porosity, time period, saturated hydraulic conductivity, drainage depth, distance depth, irrigation depth, soil capacity and evapotranspiration, respectively. Optimization model was solved by simple Genetic algorithm (GA). Genetic algorithm is well-suit for nonlinear programming and complex problems. Genetic algorithm was presented by Holand (1970) and advanced by Goldberg (1989). GA parameters were selected 152, 200, 0.05 and 0.95 for initial population, generation number, mutation probability and crossover probability, respectively.

Data of Kesht and Sanat of north of Khoramshahr were used as case study to evaluate drainage design by the described optimization model. Soil profile texture was silty loam and silty clay loam. Shallow water table, heavy soil texture, inadequate natural slope of farms and high salinity of groundwater and soil profile are reason of drainage requirement in area. Saturated hydraulic conductivity, root depth zone, drainable porosity and trench widthe were 0.5 m/d, 1 m, 5 (%) and 50 cm, respectively. Rainfall, irrigation requirement, evapotranspiration and soil storage in growth season (July, August, September and October were 0, 0, 4.1 and 15 mm; 3.5, 3.25, 2.69 and 1.8 mm; 10.83, 10.1, 8.13 and 5.6 mm and 0, 0, 0 and 0 mm, respectively.

3. RESULTS

Optimal value of depth, spacing and radius of drain, respectively, were obtained as 2, 30 and 0.18 m for no waterlogging to occur. The corresponding optimal values when 4 days of waterlogging could be allowed were 1.6, 32 and 0.3 m for drain depth, spacing and radius, which resulted an SEW of 1 mm only. The current project design (Depth= 1.8 m, spacing= 40 m and radius= 125 mm) cause 5 days water logging with 40 cm SEW.

Table 1 shows optimal values of drainage depth, distance and radius in different restricted of decided values according to farm and equipment position. Option 1 is best choice because high distance and low radius of drainage in no restriction of mechanical equipment of drainage installation. Option 2 was suggested when there is drainage depth installation restricted up to 2 m. the option has effective role in reduction of drainage water salinity and environmental pollution. Options 3 and 4 were recommended by plant resistance in water logging stress.

Table 1. Optimal values of design parameters under various constraints

Num.	Constraints	d (m)	L (m)	Radius (cm)	Number of Daily Exceedance (days)
1	$1.5 \le d \le 2.5\ (m)$ $20 \le L \le 500\ (m)$ $0.05 \le r \le 0.3\ (m)$	2.45	48.0	19.0	0
2	$2.0 \le d \le 2.5\ (m)$ $20 \le L \le 500\ (m)$ $0.05 \le r \le 0.3\ (m)$	1.76	22.5	21.0	0
3	$2.0 \le d \le 2.5\ (m)$ $20 \le L \le 500\ (m)$ $0.05 \le r \le 0.3\ (m)$	2.00	29.0	0. 29	4
4	$1.5 \le d \le 2.5\ (m)$ $50 \le L \le 500\ (m)$ $0.05 \le r \le 0.3\ (m)$	2.50	50.0	7.5	4

4. CONCLUSIONS

Results show that combination of optimization model and unsteady state equation with use of suitable indexes for drainage would result in a design that will ensure high performance of drainage systems especially in sensitive plant as drainage design parameters are related with tolerance of plants to waterlogging and salinity.

REFERENCES

Ayars, J.E., M.E., Grismer and J.C. Guitjens. 1997. Water quality as design criterion in drainage water management systems. Journal of Irrigation and Drainage Engineering 123(3): 154– 158.

Ayars J.E., E.W. Christen and J.W. Hornbuckle. 2006. Controlled drainage for improved water management in arid regions irrigated agriculture. Agricultural water management 86: 128 – 139.

Christen, E. and D. Skehan. 2001. Design and management of subsurface horizontal drainage to reduce salt loads. Irri. Drain. Eng. 127 (3): 148-155.

De Zeeuw, J. W., and F. Hellinga. 1958. Neerslage en afvoer. Landbouwkundig Tijdschrift. 70, pp. 405-422.

Goldeberg, D. E. 1989. Genetic algorithm in search, optimization and machine learning. New York. Addison, Wesley.

Holland, J. H. Genetic algorithm and the optimal allocation of trial, 1970, SIAM J. of Computing, Vol. 2(2), PP 88-105.

Navabian, M. and A. Liaghat. 2006. Optimal drainage design in view environment by Genetic algorithm. IRNCID conference. 12-14 Ordibehesht. Ahvaz.