

Review

The determination of plastic material and the optimal irrigation characteristics for an agricultural surface - model description

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Abstract: Water management and soil pollution are hot issues in modern agriculture. While more production of food is required, this quantity has to be obtained using the minimum level of resources and the maximum amortization of assets. Moreover, studies show that in Europe, 30% of water consumption is for agriculture, which has a strong influence not only on the amount of water consumed, but also on its quality due to pollution caused by chemical fertilizers, pesticides and other pollutants used in this sector. Therefore, a major concern is related to the use of water, its efficient consumption, which requires optimal irrigation systems both in terms of water transport and distribution. In this context, but also in the context of a turbid environmental debate, the most important facts in agriculture are the protection of the environment on a long range of time. In order to obtain good results for an irrigation system, in this paper we will present a model for calculating the best suited material for a given geographical area and the optimal water content for irrigation.

Keywords: optimality, irrigation, drip, plastic, agriculture

1. Introduction

Drip irrigation is a method that can achieve efficient management of water resources and can also contribute to the protection of the environment, an aspect that is increasingly sensitive today [4, 13]. Irrigation is the most important factor contributing to the increase of agricultural production, hence its importance for agriculture [1]. To the same extent, however, account must be taken of the materials used, which are mostly plastics, whose influence on the environment must be treated responsibly, given that plastics are indispensable materials in all sectors of the economy, but their use must be controlled given the impact they can have on the environment [5, 14]. There is a growing concern of all decision-makers regarding environmental issues resulting from their production and use, and this is demonstrated by documents developed and accepted at European and global level [15, 20]. One of the sectors in which different plastics are used is the agricultural sector [9, 10]. In agriculture, the use of plastic materials, in addition to the use of chemical fertilizers, pesticides, etc. of practicing intensive and semi-intensive systems have made negative contributions on the environment [2, 16].

Strategies to reduce the impact that the use of plastics has on the environment is correct and necessary, and finding solutions and promoting them does nothing but increase performance [12], but at the same time ensure food security by achieving larger and more stable productions [6, 8].

This paper takes into consideration the development of a drip-irrigation system with materials choice based on external data related to soil and climate. Further, we will determine the water necessary for the soil. Previous research has been made on determining the optimal water necessary in the literature [5, 10, 11] and by the authors and we will present the model in the next sections. We

will extend it then by adding useful facts regarding the material used to create the drip irrigation system pipes based on environmental factors. Finally, we will make some simulations in order to validate the closeness to reality of the model.

2. Materials and Methods

Firstly, we will present the irrigation model. The model is based on the literature [7, 18] calculations. Thus, the amount of the soil water is calculated accordingly to equation (1):

$$SWC_T = SWC_Y + EP + I - ETP - ID \quad (1)$$

where:

- SWC_T is the soil water content from today;
- SWC_Y is the soil water content from yesterday;
- EP is the effective precipitation from yesterday;
- I is the irrigation level from yesterday;
- ETP is the evapotranspiration;
- DP is the internal drain.

The model has the next definitions:

- $SWC : \{1,2,\dots,n\} \rightarrow R$, SWC_i = the soil water content from area i ;
- $MIN : \{1,2,\dots,n\} \rightarrow R$, MIN_i = the minimum limit of soil water in area i , or the maximum allowable deficit;
- $MAX : \{1,2,\dots,n\} \rightarrow R$, MAX_i = the maximum limit of soil water in area i , which varies depending on the soil type from 83 mm for sandy soils to 200 mm for clay;
- $DEP : \{1,2,\dots,n\} \rightarrow R$, DEP_i = the depth of the roots.

3. Results

Next, we will present data related to the main plastic used for pipes used in a drip irrigation system. These can be seen in Table 1 (calculated by [3] and [19]).

Table 1. Proprieties for the usual materials used in agriculture as pipes for drip irrigation system.

Material	Operating temperature		UV resistance	Water absorption	Impact strength	Food compatibility
	Min	Max				
	C	C				
EVA	0	55	Very good / 3	0	26.54	Yes
LDPE	0	80	Moderate / 2	0.10	9.65	Yes
PP	-10	130	Very good / 3	slight	37.23	Yes
PVC	0	50	Moderate / 2	0.15 - 0.30	7.500	Yes
HDPE	-50	80	Poor / 1	0.10	51.71	Yes
LLDPE	0	65	Very good / 3	0.10	7.93 – 45.51	Yes
Bioplastic	0	110	-	-	-	Yes

After the determination of the possible usage materials for pipes, we will describe the model that helps at the optimization of the drip irrigation system based on the used material. In this matter, the relation that characterizes the choice of the most suitable material for a drip irrigation system is shown at equation (2).

$$I_M = (T_{Amin} - T_{Mmin}) + (T_{Mmax} - T_{Amax}) + UV_C + 1 / W_A \quad (2)$$

T_A stands for the temperatures of the area. The determination of the best material can be made using an optimization technique, such a genetic algorithm. The algorithm components are:

- The genes, formed of four genes which consist in each characteristic of the material: the first gene is the minimum operating temperature, the second gene is the maximum operating temperature, the third gene is the classification based on UV resistance and the fourth one is the water absorption coefficient;
- The chromosome consists in the material used within the irrigation system;
- The fitness value consists in the application of the equation (2) for each chromosome. The fitness value will be a maximum one, which means the chromosome with the maximum fitness function will be selected.

Finally, after the appliance of the genetic algorithm, the resulted chromosome with the highest fitness value will be selected and this chromosome will be the material with the best suited genes for the given conditions (minimum and maximum temperature of the area and UV radiation level, classified in three classes: low, medium and high). The implementation results will be shown in a further study.

In an integrated vision, the model and the development of the future application would consist in the form presented in Figure 1.

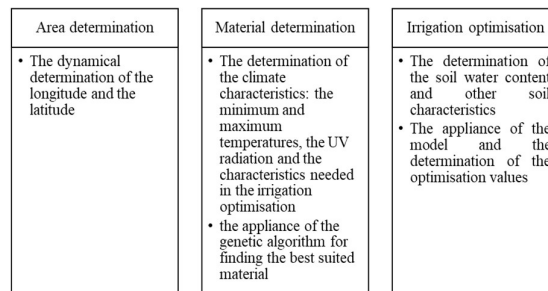


Figure 1. Model description for the given issue.

For a given SWC_i , MIN_i and MAX_i , $i = 1, 2, \dots, n$, the model verifies the next relation:

- $MIN_i \times DEP_i \leq SWC_i \leq MAX_i \times DEP_i$, which means that soil water content is lower or equal than the minimum limit of soil water, $i = 1, 2, \dots, n$;
- the algorithm outputs the difference between $MAX_i \times DEP_i$ and SWC_i ($MAX_i - SWC_i$) and alerts the start of irrigation when $SWC_i \leq MIN_i \times DEP_i$.

4. Discussion

We have created a System Dynamic based model for the integrated environment described above.

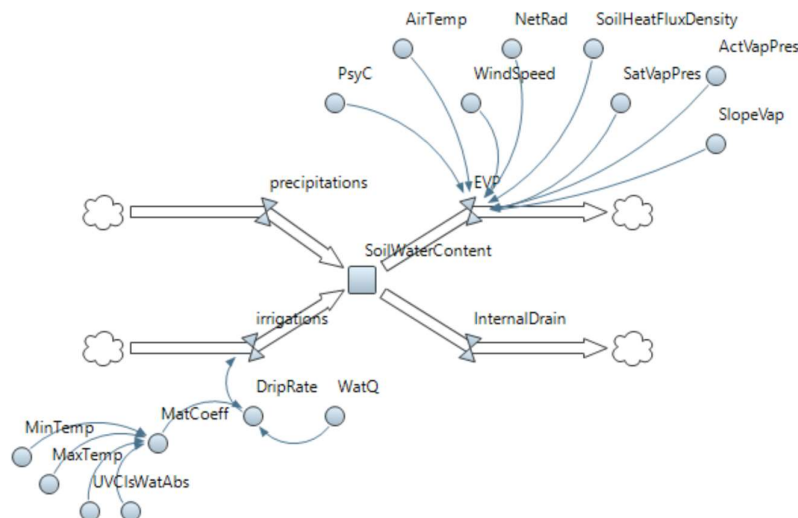


Figure 2. SD model for the optimized drip irrigation system.

We can observe that the level variable $SoilWaterContent$ is positively influenced by the precipitation

and irrigation levels, while the negative influence comes from the evapotranspiration and the internal drain within the soil. The irrigation is influenced by the index formed from the fitness value of the best chromosome obtained in the genetic algorithm and the evapotranspiration is calculated according to Penman-Monteith relation [17], presented in equation 3.

$$EVP_0 = [0.408 \times \Delta \times (R_n - G) + \gamma \times 900 / (T + 273) \times u_2 \times (e_s - e_0)] / [\Delta + \gamma + (1 + 0.34 \times u_2)] \quad (3)$$

where:

- Δ is the slope vapor pressure curve
- R_n is the net radiation
- G is the soil heat flux density
- T is the air temperature
- e_s is the saturation vapor pressure
- e_0 is the actual vapor pressure
- u_2 is the wind speed
- γ is the psychrometric content

The results for the irrigation surface can be observed in Figure 3.

The screenshot shows a software window titled 'Irrigation' with two main panels: 'Practical determination' and 'Theoretical determination'.

Practical determination:

- Choose soil type: Sand, Loam, Clay
- Introduce rooting depth (m): [Input field]
- Introduce number of hectares: [Input field]
- Find soil water content! [Button]

Theoretical determination:

- Soil Water Content from Yesterday (mm): [Input field]
- Effective Precipitation (mm): [Input field]
- Irrigation (mm): [Input field]
- Evapotranspiration (mm): [Input field]
- Find! [Button]

Results:

The soil water content for tap 1 is now 60.0 mm.
The necessary water for irrigation is 23.0 mm/square meter.
The total quantity of water needed is 76.0 cubic meters.

The soil water content for tap 2 is now 70.0 mm.
The necessary water for irrigation is 13.0 mm/square meter.
The total quantity of water needed is 43.0 cubic meters.

The soil water content for tap 3 is now 20.0 mm.
The necessary water for irrigation is 63.0 mm/square meter.
The total quantity of water needed is 209.0 cubic meters.
Irrigation must begin at this moment.

Figure 3. Implementation of the optimization of water consumption issue within the model.

As we can observe, the implementation shows the necessary amount of water, and the level of soil water content needed for an optimal irrigation based on the soil type. Also, the level is checked by the theoretical determination shown in equation (1).

5. Conclusions

The study conducted on the determination of plastic material and the optimal irrigation characteristics for an agricultural surface - model description highlights that the optimal resources can be dynamically allocated in agriculture based on key parameters related to the materials used and the climate of the area. The next steps would consist in the implementation of the genetic algorithm in a user-friendly manner and further study in order to stabilize the model from a scientific point of view⁶. Patents

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