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A mobile application to calculate optimum drip irrigation laterals

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ABSTRACT

The parameters to be taken into account when installing a drip irrigation system include the diameters of piping to be used in the irrigation installation. Certain applications developed for PC permit an approximate calculation of these diameters outside the installation environment, which makes on-site optimization of the system difficult. This paper presents a software application developed for Android mobile devices by which the user can immediately evaluate the responsiveness of all of the available optimum commercial diameters to operational changes, such as changing water demands (e.g., cultivation, water needs, and spacing), types of emitters used in the installation, or lateral feeding (from an extreme or from an intermediate point). The input data mainly required by the application are: emitter flow rates, the number of emitters, the space between emitters, the average pressure in the lateral, and the pressure tolerance. As a result, the application indicates if each irrigation lateral is valid or not for the situation provided by the user, and displays some graphics of the pressures in the lateral that indicate the pressures at the system's extremities, which permits identification of the critical points of the irrigation lateral.

1. Introduction

The sustainable use of water represents one of the primary challenges affecting the future of agriculture and makes necessary the adoption of new practices that enhance the efficiency of water use (Costa et al., 2012; Garcia-Orellana et al., 2013). In that sense, drip irrigation systems are widespread due to their numerous advantages (Egea et al., 2009; Phogat et al., 2013; Fernández-Pacheco et al., 2014): evaporation losses are minimal, there is no movement of water droplets through the air, weed growth is limited because no watering of the entire surface is executed, and the foliage of the plants is not watered. Moreover, this type of system permits the irrigation of all the cultivated area without watering outside the edges of said area. However, the main advantage of drip irrigation systems is the water consumption savings obtained by using them because very precise amounts of water can be applied during each watering (Rodriguez-Diaz et al., 2004).

Drip irrigation systems do not require high maintenance costs, and in case a dripper is broken, the repair cost is very low. For this reason, careful system design is required to improve crop growth and obtain greater benefits by reducing the margins of losses, for example, in water and installation materials.

Some of the parameters to be taken into account when installing a drip irrigation system are the commercial diameters of pipe and hose to be used in the irrigation installation. In the market, some applications developed for desktop PCs, such as AquaFlow (Toro, US) or IrrLoc (Irritrol, Italy), permit an approximate calculation of these diameters outside the installation environment, but on-site optimization of a system remains difficult. For this reason, a mobile application capable of performing these calculations would be useful.

Moreover, as the crop grows, it is common to add new emitters to supply the increasing volumes of water required by the crop. If the farmer decides to increase the plant density or to change the crop by maintaining the existing irrigation system, he needs to adapt the system to the new situation. This involves adapting the number and type of emitters in the drip line to the new water requirements. In this case, if the flow and pressure required at the beginning of the drip line are known, it would be very useful to have a quick and precise software application that helps the farmer to determine if the current drip line is amenable to these changes, as well as the actions to be taken.

This paper presents a software application developed for Android mobile devices that enables the user to: (i) calculate the irrigation laterals that obtain the maximum efficiency in the amount of material used, and (ii) in case of extending the real

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crop, evaluate the responsiveness of all the available optimum commercial diameters to changing demands (cultivation, water needs, spacing, etc.), the type of emitters used in the installation, or lateral feeding (from an extremity or from an intermediate point), among others.

The paper is organized as follows. In Section II, the main parameters estimated by the application and the mathematical equations required for their calculation are described. Section III offers a detailed description of the implemented software. Finally, Section IV presents the conclusions.

2. Calculation of the parameters

The theoretical basis of the formulae used in the hydraulic design of drip irrigation assumes that the flow distribution in a drip line is approximated by a continuous distribution. Thus, the head loss gradient in a lateral can be calculated using the Darcy–Weisbach equation (Rettore Neto et al., 2014):

$$J = 10^5 f \frac{V^2}{D_i 2g} \quad (1)$$

where J is the head loss gradient caused by friction in the lateral (given in meters of water column per 100 meters lateral length), f is the friction factor, V is the average speed of water (m s^{-1}), D_i is the inner diameter of the lateral (mm) and g is the acceleration of gravity ($g = 9.80665$ m s^{-2}).

The average speed of water V is defined by the equation (Rodrigo and Cordero, 2002):

$$V = \frac{4000Q}{\pi D_i^2} \quad (2)$$

where Q is the flow through the lateral (l s^{-1}) and can be obtained using this equation:

$$Q = \frac{q_e n_e}{3600} \quad (3)$$

where q_e is the emitter input flow (l s^{-1}) and n_e is the number of emitters.

To determine the friction factor f, the Reynolds number R_e must first be calculated:

$$R_e = 10^3 \frac{D_i V}{\upsilon} \quad (4)$$

where υ is the kinematic viscosity of water (m^2 s^{-1}) and can be obtained from its temperature T (°C) through the following equation:

$$\upsilon = \frac{1.8 \times 10^{-6}}{1 + 0.03620862T + 0.00015909T^2} \quad (5)$$

Due to the kinematic viscosity of water having a value very close to the unity at a water temperature of 20 °C, this value of temperature is commonly used for calculation purposes, obtaining:

$$\upsilon = \frac{9}{8939042} \quad (6)$$

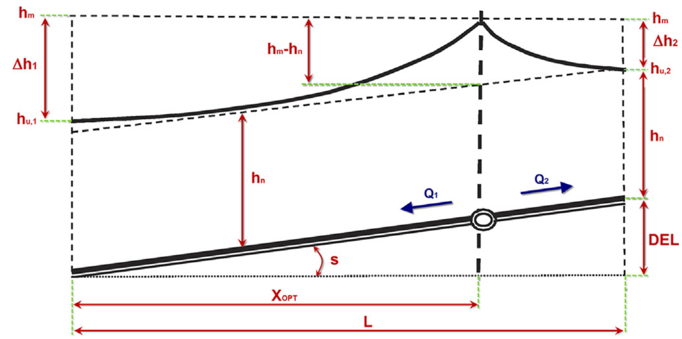

Fig. 2. Distribution of pressures in an irrigation lateral fed from an intermediate point.

According to Blasius's law for the friction coefficient of a turbulent pipe flow, the friction factor for smooth tubes can be obtained using this equation (Celen et al., 2013):

$$f = \frac{0.3164}{R_e^{0.25}} \quad (7)$$

Using these Eqs (1)–(7), the head loss gradient J in a lateral can be easily calculated.

2.1. Design of laterals fed from an extremity

When the length of the lateral is going to be determined as a function of the pressure tolerance, the head loss in the lateral h_f (mwc) can be calculated by the following expressions (Rodrigo and Cordero, 2002):

$$\mathrm{Je} = J \frac{\mathrm{Se} + \mathrm{fe}}{\mathrm{Se}} \quad h_f = \mathrm{Je} F \frac{l}{100} \quad (8)$$

where Je is the head loss gradient in the lateral with emitters (mwc per 100 m); J is the head loss gradient in the lateral (mwc per 100 m) with diameter D_i (mm) and flow Q (l s^{-1}); Se is the constant separation between the emitters in the pipe (m); fe is the head loss caused by the connection of the emitter, expressed in equivalent length (m); l is the length of the lateral (m); and F is the Christiansen reduction coefficient. This F coefficient is determined as a function of the number of emitters n_e and the flow exponent of the Darcy–Weisbach equation ($m = 1.75$), and it can be calculated using the following equation, assuming that the distance from the tap to the first emitter is equal to the separation between emitters (Rodrigo and Cordero, 2002):

$$F = \frac{\sum_{i=1}^{i=\mathrm{ne}} i^{1.75}}{n_e^{2.75}} \quad (9)$$

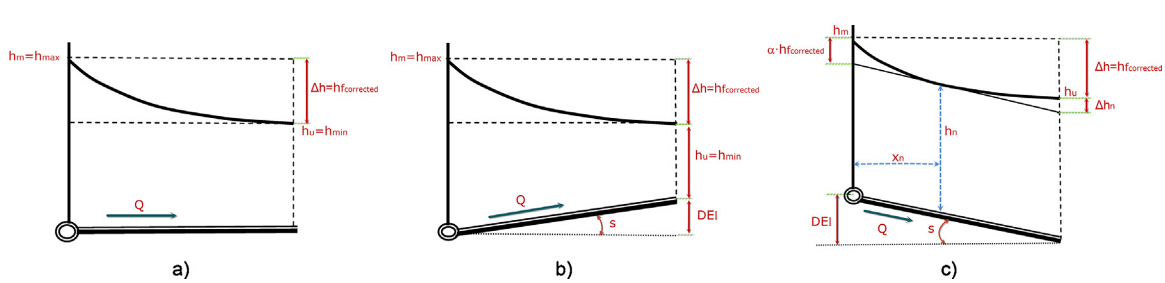

Fig. 1. Distribution of pressures in an irrigation lateral fed from an extreme in: (a) horizontal terrain, (b) ascending terrain, and (c) descending terrain.