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Modelling of basin irrigation systems: A review

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ABSTRACT

Basin irrigation layouts are used extensively for irrigation of various types of crops worldwide. Basin irrigation is characterised by ground levelled to zero slope in both directions and each unit enclosed by dykes. Single closed level basins and sequential multiple basin layouts offer potentially high uniformity of application, reduced runoff and low labour requirements. Several simulation models have been developed to study the flow processes involved during an irrigation event in basin irrigation to improve the design and operation of these basin layouts. These simulation models are based on governing equations in the form of the full hydrodynamic Saint–Venant equations or the simplified zero-inertia approximation (neglecting inertial terms). This paper reviews various simulation models that have been developed and discusses various issues involved in modelling of basin irrigation layouts. Application of these models for use in the design and management of basin irrigation layouts is also discussed. It is concluded that two-dimensional rather than one-dimensional models are required to simulate all the flow processes involved in irrigation events in basin systems due to the non-linear nature of flow over the basin. Inclusion of basin topography through soil surface elevation even in laser levelled basins improves the quality of simulation and prediction of performance parameters. The availability of accurate values of surface irrigation parameters such as Manning's roughness coefficient and infiltration coefficients for the empirical equations is often a problem in the application of these models.
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1. Introduction

Basin irrigation is defined as the application of water to an area typically levelled to zero slope and surrounded by dykes or check banks to prevent runoff. Basins are flat areas of land, surrounded by low bunds which prevent the water from flowing to the adjacent fields. Basin irrigation is one of the most popular types of on-farm surface irrigation in which water application can achieve high uniformity (Clemmens et al., 1981). It is used for crops planted on beds, furrows, corrugations, or on the flat. This type of system has become common due to the ability to reduce runoff and lower labour requirements (Clemmens et al., 1981). Basin irrigation is commonly used for rice grown on flat lands or in terraces on hillsides. Trees can also be grown in basins, where one tree is usually located in the middle of a small basin. In general, the basin method is suitable for crops that are unaffected by standing in water for long periods. Basin irrigation is generally not suited to crops which cannot stand in wet or waterlogged conditions for periods longer than 24 h. These are usually root and tuber crops such as potatoes, cassava, beet and carrots, which require loose, well-drained soils. Rice grows best when its roots are submerged in water and so basin irrigation is the best method to use for this crop. Other crops which are suited

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to basin irrigation include: pastures (Lucerne, clover), trees (citrus, banana), crops which are broadcast (cereals), and to some extent row crops such as tobacco. The shape and size of basins are mainly determined by the land slope, the soil type, the available stream size (the water flow to the basin), the required depth of the irrigation application and farming practices.

Water is applied to the basin in such a way that it will cover the basin relatively quickly. Check banks/dykes around the field keep the water within the basin until all the water infiltrates. Thus, the water remains on all parts of the basin for about the same duration with only minor differences occurring because of the advance time required for the water to cover the basin completely.

2. Water flow patterns in basin irrigation

2.1. Closed basins

Basin irrigation systems can be of the closed type in which water applied to an individual basin and all of that applied water is allowed to infiltrate. Each basin in the irrigation block is hydraulically independent. Typically, the waterfront advances from the inflow point towards the downstream end of the basin in a regular pattern, which may be distorted by surface irregularities. Inflow is normally shutoff before the waterfront reaches the downstream end of the basin.

2.2. Sequential basins

These types of basins are characterised as surface runoff basin systems, in which each basin is irrigated separately by a supply channel running along the boundary with a number of adjacent basins (Dedrick, 1984a). In each basin, the water level in the supply channel controls the water application. When a basin is irrigated, the water level in the channel is raised higher than the soil surface elevation and overflows onto the basin. When the irrigation is completed, the water level in the channel is lowered below the soil surface elevation of the basin and supply is diverted to the next basin. The excess water from the first basin drains back to the supply channel. The next basin is irrigated with the supply discharge plus the overflow drainage water from the upstream basin (or basins). Dedrick (1984b) found that 25% of the inflow was runoff from the higher basins and found it to be a useful method for decreasing the infiltrated depth.

A similar kind of sequential basin system is practiced in the Ebro River area in Spain. These basins are linked by outflow points located at the upstream and downstream ends of each basin. The relative location and elevation of the basins and the characteristics of the water conveyance structures controls the outflow. The system of outflow is set up such that no human intervention is needed to operate outflow points. A series of five sequential terraced basins were evaluated by Zapata et al. (2000a) and their performance was compared with conventional basin irrigation systems using a simulation model. The sequential basin irrigation system was found to have a higher application efficiencies and distribution uniformities. The authors concluded that basin irrigation can achieve high application efficiency and distribution uniformity when the basin is well designed and the soils are deep- and medium-textured, with high water holding capacity.

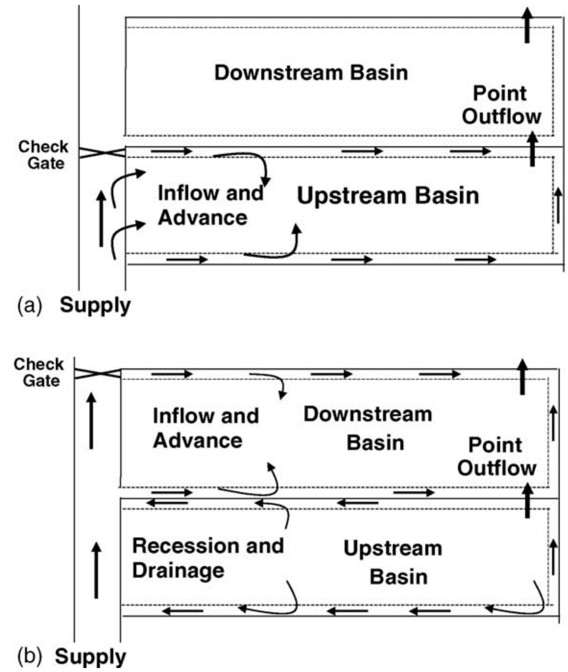

Fig. 1 – (a) Water flow pattern during the advance phase in the upstream basin of a multiple sequential basin system. (b) Depiction of simultaneous recession phase in the upstream basin and advance phase in the downstream basin.

Contour basin irrigation layouts found in southeast Australia can also be classified as sequential basin irrigation systems. These systems are used for irrigating rice and other crops, predominantly on soils with low infiltration rates. The banks of these contour basins are erected along the contours of the land. These banks are built by borrowing soil from the inside edges of the bank. The resulting borrow pit or toe-furrow serves as a supply channel as well as a drainage channel for the basin. The water supply channels are constructed down slope in order to provide a direct water supply to each basin over the entire length of the basin inlet.

Irrigation of these layouts is carried out progressively from the first basin to the bottom basin. Fig. 1a shows a typical flow pattern during the inflow-advance phase in the first basin and Fig. 1b shows a typical flow pattern during the recession-drainage phase in the first basin and inflow-advance phase for the second basin. Water is allowed to flow into the first basin until the entire basin is flooded at which time the inflow ceases and the water is allowed to drain back into the supply channel and, by opening the check bank gates, to flow into the downstream basin. This process continues until all the basins in the irrigation block are fully irrigated. Drainage runoff from the last basin in a sequence may be diverted into storage for recycling. Normally 5–10 basins of different sizes and shapes are included in an irrigation block.

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