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ScienceDirect
Environmental Modelling & Software 23 (2008) 1182–1206
Environmental Modelling & Software
www.elsevier.com/locate/envsoft

Review

Review of soil water models and their applications in Australia

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Received 18 December 2006; received in revised form 2 February 2008; accepted 6 February 2008
Available online 12 May 2008

Abstract

Agriculture is the highest consumer of water resources in Australia. Soil water models play a vital role in agriculture in terms of estimating water use, water allocation and current water status at a given scale. This paper reviews widely-used soil water models developed in Australia over the last three to four decades that have been used to simulate soil water status at various temporal and spatial scales. These models are categorised in terms of their complexity. This paper provides an overview of soil water models and the basic modelling techniques employed by each model. Considerable emphasis is given to matching existing data availability with input data requirements for each model to identify the limitations of model application in terms of data availability. A comprehensive review of the application of soil water models is also given, supported by assessments of individual model performance. The limitations and assumptions made under various approaches to soil water modelling are subsequently examined. Research and policy agencies are focusing more and more on incorporating temporal models into spatial modelling frameworks for natural resources and water management purposes. These are consequently being used much more in the process of policy development. Complex models, whose wide-range application is often hampered by a lack of specific data, should have their processes simplified in order to be accommodated into spatial frameworks where appropriate. Biophysical processes within simple models should consider new data sources and understanding so as to gain more accurate predictions.

Keywords: Model review; Soil water modelling; Water balance; Simple models; Complex models; Data availability; Performances; Limitations; Applications

1. Introduction

Agriculture consumes the largest volume of collected surface water, representing two-thirds of consumption in Australia (ABS, 2000). This proportion is likely to increase when the water consumption by rain-fed agriculture is included in water accounts. Farmers have felt their water supplies squeezed recently by declining water allocations brought on by more-frequent droughts and less reliable effective rainfall. Agriculture, as the largest water-consuming industry, has become the centre of promoting water conservation.

Water resources are crucial for Australia's economic, social and environmental wellbeing. In 2004, the Australian Government in association with State and Territory governments, with the exception of Western Australia and Tasmania, announced a comprehensive strategy, known as the National Water Initiative, for improving water management across the country. This new initiative noted the imperative of increasing the productivity and efficiency of water use and the health of river and groundwater systems in Australia. Many research and policy frameworks are emerging to increase the efficiency of water use in agriculture, in which soil water models play a vital role.

Most soil water models developed in Australia combine plant water use, soil water storage and water table fluctuations in varying degrees of complexity to predict current and future soil water storage and plant water availability. Although model choice should be made using a "horses for courses" approach (CRC Catchment Hydrology, 2000), it is sometimes confusing and difficult to choose the right soil water model for a specific purpose because of often subtle differences between many of these models in terms of their original purpose and how they were designed. It was consequently realised that

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1364-8152/$ - see front matter
doi:10.1016/j.envsoft.2008.02.003

a comprehensive review of widely-used soil water models developed in Australia would be valuable. Within this review, current and potential users of soil water models should be able to assess existing models in terms of their complexity, input data required to run the model, current state of input data availability, model performances under various conditions and their limitations, in particular with respect to soil and vegetation types and applications.

Models that relate runoff to rainfall are usually applied at catchment or sub-catchment scales and are known as catchment water balance models. Since a review of 13 catchment water balance models in Australia, has been completed elsewhere (Boughton, 2005), most of these models were not included in this study. However, some catchment-based models with an explicit soil water component are discussed.

Similarly, an overview of salinity models and modelling can be found in Littleboy et al. (2003) and consequently this review does not explicitly cover salinity-related models, although a couple of salinity models are included because of their significance in soil water modelling. Effects of climate change on water availability have been modelled by Hood et al. (2006) for key agricultural enterprises in Victoria, Australia. A considerable effort has also been made into modelling biophysical and economic aspects of Australian farming systems and landscapes by Hook (1997).

We have chosen widely-used soil water models developed in Australia over the last three to four decades in this review. While every effort has been made to provide a comprehensive review, we acknowledge that there may be work, in both published and unpublished forms, not accounted for in this review. For example, there are several soil water submodels developed for crop models (O'Leary and Connor, 1996; Moore et al., 1997; Meinke et al., 1998), which are beyond the scope of this paper.

2. Categorisation of soil water models

Physically-based or mechanistic models differ from empirically-based models in terms of degree of complexity, which is often determined by the specific purpose of the model development. In reality there is a continuum between these extremes, from totally mechanistic to completely empiric, with most models at least containing a degree of physical or biophysical logic (White et al., 1993). The more empirical models are often more accurate at local or regional scales, providing they have been extensively calibrated and validated using local data, whereas more generic models tend to be more reliable on average when applied across an extensive geographic area.

It therefore seemed appropriate to start by categorising soil water models in terms of their degree of complexity based on the treatment of the soil profile, in addition to the number of processes employed (Fig. 1). "Simple models" have a fixed number of soil layers and a tipping bucket approach to water inflows and outflows, while "complex models" seek to incorporate a continuous soil profile. Within the simple (or fixed soil layer) modelling category, models are divided into single layer or multiple layer approaches. In the complex (or continuous soil profile) modelling category, models are considered more generally, but can be distinguished to some degree as one- or two-dimensional flow models. All the soil water models considered in this review are given in Table 1.

The major processes employed in soil water modelling are similar, but the level of detail in each component varies significantly. Table 2 identifies the method used by each model for estimating evapotranspiration losses from soils and plants and consideration of soil evaporation and canopy interception. Table 2 also identifies the method used to calculate surface runoff and consideration of subsurface runoff, drainage and infiltration processes.

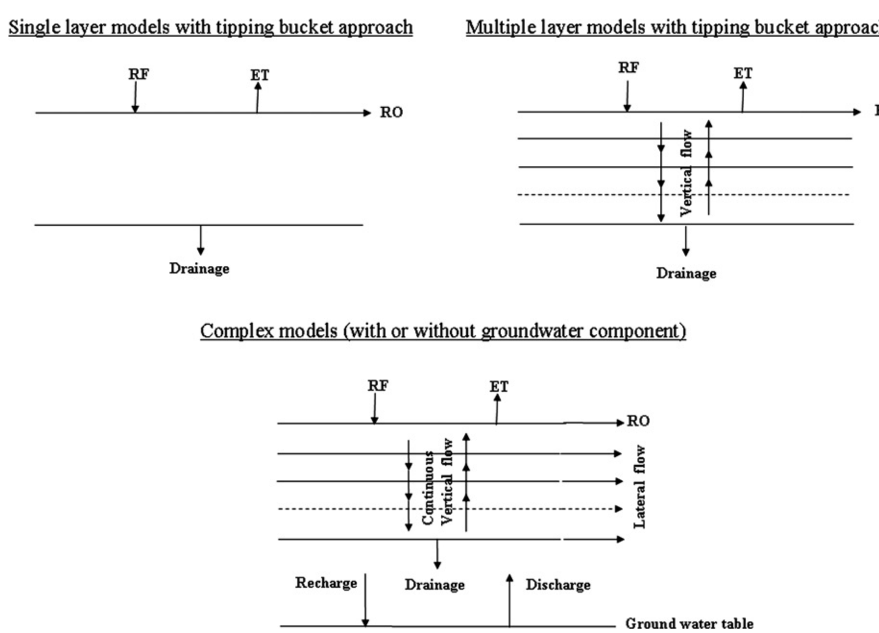

Fig. 1. Schematic diagram for basic processes employed by each category of water balance models identified in this review. RF, ET and RO refer to rainfall, evapotranspiration and runoff.