A simulation model to assess the effect of afforestation on ground-water resources in deep sandy soils+

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Abstract

The ACRU agrohydrological modelling system has been extended to simulate and assess impacts on water resources resulting from afforestation in deep sandy soils. A ground-water routine has been developed aimed at simulating the transpiration losses from soil-water extraction by deep roots, both within the intermediate soil zone and from the capillary fringe above the ground-water table. The subsequent influence on soil-water budgets, ground-water recharge, ground-water flux, water-table depletion and effective radius of the depression area are modelled on a daily basis. Verification studies show a very good fit between observed and simulated water-table fluctuations. Simulations of the effect of *Eucalyptus* plantations on the hydrological regime, which were performed for an area in Northern Zululand, are illustrated as an application of the model.

Introduction

The growth and survival of forests in marginal rainfall regions are influenced by the ability of the trees to extract soil water. Water supply for transpiration through the so-called intermediate zone below the conventional root zone and from the capillary fringe above the ground-water table can be a decisive factor in the water budget, particularly under forest plantations (Van Slycken and Vereecken, 1990). This supply of water is determined, *inter alia,* by the depth of the water table and the heterogeneity of texture and structure of the successively deposited soil layers.

The water-table depth is a function of the rate at which the vegetation is extracting water by the transpiration processes, the lateral ground water in- and outflows and of the rate at which the ground water is being recharged. Exotic timber plantations of, for example, *Eucalyptus* species and their clonal varieties, may disturb the natural water-table equilibrium as a result of their high transpirational demand throughout the year and their deep rooting system. Consequently, exotic timber plantations can lead to reduced streamflow and a local depletion of the ground-water table (Bosch and Hewlett, 1982). This is particularly applicable when the lateral ground-water inflow is slow and the utilised water cannot be replenished sufficiently by recharge. Similar to the cone of depression around an active well, a ground-water depression area may develop around a plantation (Rawlins and Kelbe, 1990). Water-table levels may be drawn down several metres due to afforestation (SRK Inc., 1985). This may result in the drying up of wetlands and streams close to the plantation, Wells could become dry because of the creation of such ground-water depression areas in their vicinity.

The ACRU agrohydrological modelling system serves as an existing infrastructure with which to simulate, *inter alia,* daily infiltration, evaporation, transpiration, land-use change effects and the soil-water budget (Schulze, 1989). A subroutine was developed to simulate water uptake by tap roots, capillary rise, ground-water recharge, ground-water fluxes and water-table fluctuation. A pilot study was undertaken, which was aimed at simulating and assessing the impacts on the water resources due to afforestation of *Eucalyptus* hybrids in deep sandy soils in Northern Zululand.

In this paper ACRU's ground-water submodel, its verification and an application south of Lake Sibaya in Northern Zululand are presented.

The ACRU agrohydrological modelling system

The core of the ACRU agrohydrological modelling system is a multi-purpose, multi-layer soil-water budgeting model based on physical conceptual principles and with a wide range of capabilities (Fig. 1). The model uses a daily time step and is structured to be sensitive to land cover and has been described in detail by Schulze (1989). The simulation of the water budget of the extended model is based on the principles described in the following sections.

Intermediate zone

Water which percolates through the lowest subsoil horizon, i.e. the B horizon, enters the so-called intermediate zone, which by definition is the zone between the B horizon and the top of the capillary fringe (Fig. 2). The soil physical parameters of the intermediate zone, i.e. its texture, porosity, field capacity and wilting point, have to be determined by laboratory investigations or estimated from field work or soil maps. The simulation of the soil-water content in the intermediate zone is based on average physical properties of the soil in that zone and is based on a cascading "tank"-type model.

Capillary fringe

The capillary fringe is located above the ground-water table. The height of the capillary fringe is a function of the soil texture. It is assumed as a working rule in this subroutine that the bottom 10% of the capillary fringe is saturated (thus, strictly speaking, belonging to the ground water). The water content of the remaining capillary fringe is in linear transition from a saturated soil moisture condition to the actual soil moisture content above the capillary fringe, which may be below FC (Fig. 2). This

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