ESTIMATING AND MODIFYING THE EFFECTS OF AGRICULTURAL DEVELOPMENT ON THE GROUNDWATER BALANCE OF LARGE WHEATBELT CATCHMENTS

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Abstract

Seven large catchments, cleared progressively from 1912 to 1985, were studied to determine the groundwater conditions responsible for salinization of both the pristine and disturbed environments. Detailed drilling was conducted to provide information on the nature and distribution of the physical and chemical properties of these groundwater systems. First-order estimates of recharge and discharge rates were derived from the groundwater balance, chloride mass balance, and specific yield techniques.

Recharge rates under pristine conditions estimated from the groundwater balance method were of the order of 0.02-0.14 mm/yr and 0.05-3.0 mm/yr using the chloride method. Recharge was greatest in the deep sandplain and arkosic-outcrop soil associations and least in the heavy textured mid-slope and valley soils. Higher rates were obtained from the specific yield technique, where recharge under current agricultural conditions was considered to be between 6 and 10 mm/yr. Recharge rates of up to 30 mm/yr were noted when flooding of the sandy-textured, valley floor soils occurred.

Clearing of the native vegetation for agriculture is estimated to have increased groundwater recharge by between one and three orders of magnitude. Equilibrium groundwater balance estimates suggest that discharge rates have only increased ten-fold. As a result of the changes to the water balance, 5-30% of particular catchments may need to become discharge areas to balance increased recharge of 6-10 mm/yr. Native woodlands and halophyte communities are considered to have played an important role in providing a complex discharge mechanism before clearing.

The management of catchments to contain soil salinity should include improved recharge control systems using specialized crop rotations. To date, however, little evidence of the success of this method exists. Therefore, discharge enhancement should also become a part of catchment management systems. Discharge can be manipulated by planting phreatophytic vegetation and by pumping groundwater from basement aquifers to improve agricultural water supplies. The results presented in this paper suggest that discharge enhancement has an important role to play and, as a part of integrated catchment water management, has the potential to control and eventually reduce dryland salinity.

Résumé. Estimation et modification des effets du développement agricole sur le bilan d'eau souterraine de grands bassins de la région des Terres à blé. Sept grands bassins versants, défrichés progressivement de 1912 à 1985, ont été étudiés afin de déterminer les conditions de salinisation des eaux souterraines pour des environnements primitifs et modifiés. Une campagne de forages a fourni des informations sur les caractéristiques physiques et chimiques des eaux souterraines et sur leur répartition. Les estimations de premier ordre des taux de recharge et d'écoulement ont été déduits du bilan hydrique, du bilan de masse de chlorure et des techniques donnant le débit spécifique.
Les taux de recharge sous environnement primitif, estimés à partir du bilan hydrique de la nappe, sont de l'ordre de 0.02-0.14 mm/an, alors que la méthode du bilan de chlorure donne 0.05-0.30 mm/an. La recharge est la plus forte dans la plaine à formation sableuse profonde et dans les associations d'affleurements arkosiques et de sols; elle est la plus faible dans les sols lourds de mi-pente et de fond de vallée. Les taux les plus élevés ont été obtenus grâce à la technique du débit spécifique; sous des conditions de cultures courantes, la recharge s'établit à 6-10 mm/an. Des taux de recharge atteignant 30 mm/an ont été observés lors de l'inondation de sols sableux de fond de vallée.

Le défrichement de la végétation primitive pour l'agriculture a pour effet d'accroître le taux de recharge d'un à trois ordres de grandeur. L'estimation du bilan d'eau souterraine montre que le taux d'écoulement n'a augmenté que de dix fois (unordre de grandeur). Du fait des modifications du bilan hydrique, 5 à 30% des bassins peuvent devenir des zones de décharge pour équilibrer l'augmentation de recharge de 6 à 10 mm/an. On considère que les forêts primitives et les communautés halophytes ont joué un rôle important en alimentant avant le déboisement un mécanisme de décharge complexe. L'aménagement des bassins en vue de limiter la salinité des sols comporterait, pour le contrôle de la recharge, des systèmes adaptés s'appuyant sur la rotation de cultures spécialisées. Cependant, pour le moment, la réussite de cette méthode n'est pas évidente. Par conséquent, l'augmentation du débit deviendrait aussi une part des dispositifs d'aménagements des bassins. Le débit peut être manipulé en plantant une végétation phrènatique et en pompant l'eau souterraine pour l'irrigation. Les résultats présentés ici font apparaître que la hausse du débit doit jouer un rôle important et que, en tant qu'élément de la gestion intégrée de l'eau des bassins versants, elle peut être utilisée pour contrôler et éventuellement réduire la salinité des terres arides.

INTRODUCTION

The progressive clearing of 15.7 million hectares of native vegetation for the development of dryland agriculture has occurred in southwestern Australia during the past century (George, 1990a). As a consequence of this clearing, soil salinization has occurred over much of the agricultural zone (Williamson and Bettenay, 1979). Clearing is considered to be responsible for decreased transpiration and increased groundwater recharge (Peck, 1978). Salinization of previously arable land currently affects 4,430 km2 or 2.8% of land developed for agriculture, having grown at an average rate of 10,000 ha/yr since 1955 (George, 1990a).

The chloride and water balance methods (Peck and Hurle, 1973; Bestow, 1976) have been used to estimate groundwater recharge and discharge in catchments affected by secondary salinity in the higher rainfall (600-1,200 mm/yr), mainly forested fringe of Western Australia (Sharma, 1987). However, there is a lack of quantitative research in the drier agricultural areas. The methods used in these areas have included the bore hydrograph, or specific yield technique (Loh and Stokes, 1981; McFarlane et al., 1989).

Loh and Stokes (1981) suggested that recharge under agricultural conditions is proportional to the rate of water table rise and rainfall. They considered that recharge increases from 12-30 mm/yr in the 390-600 mm/yr rainfall region, to 30-100 mm/yr in the 600-1,150 mm/yr rainfall zone. Their estimates concur with those of Peck and Hurle (1973), who estimated recharge rates of between 23 and 65 mm/yr in the high rainfall area. The recharge estimates of up to 45 mm/yr by McFarlane et al. (1989) for the lower rainfall (≈400 mm) valley soils are higher than those suggested by Loh and Stokes (1981). Both authors assumed a specific yield of 0.05 to calculate recharge, because, at the time there were no published data from aquifers in the low rainfall areas.

Alternative methods of recharge estimation have been proposed by several authors. Sedgley et al. (1981), Nulsen and Baxter (1982), and Nulsen (1984) estimated recharge by using water balance methods based on measured evapotranspiration data from agronomic species. Sedgley et al. (1981) estimated that recharge rates over the winter period (≈200 mm of rain), in a 300 mm annual rainfall zone, were of the order of 7-21 mm. Later, Nulsen (1984) reported that, under annual pastures (subterranean clover) grown on sandy soils, recharge ranged from 86 to 150 mm/yr, even though growing season rainfalls were only 162 and 258 mm, respectively. The inclusion of deeper-rooted legume crops such as lupins and cereals (wheat and barley), at the expense of subterranean clover was considered to reduce recharge to between 44 and 72 mm/yr (Nulsen, 1984).