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S. Zwerver, R.S.A.R. van Rompaey, M.T.J. Kok and M.M. Berk, (Eds.)

Effect of sea-level rise and climate change on groundwater salinity and agro-hydrology in a low coastal region of the Netherlands

L.C.P.M. Stuyt, P. Kabat, J. Postma and A.B. Pomper

DLO Winand Staring Center for Integrated Land, Soil and Water Research, P.O. Box 125, 6700 AC Wageningen, The Netherlands.

Abstract
Scenario studies to predict the effects of doubled CO_2 levels, a 1 °C temperature increase and a 1.2 m sea-level rise on seepage, groundwater and crop production were carried out. Climatic change was simulated, showing increased precipitation. Simulation of effects of sea-level rise on groundwater flow and salt transport showed changes in seepage to be negligible. Simulated crop growth was increased significantly by temperature and CO_2 increase, without increased demand for irrigation.

1. INTRODUCTION

Climate change will affect open water and groundwater levels and quality in coastal low-lying regions through sea-level rise and precipitation, and through changes in crop water-use, enhanced by doubled CO_2 . These changes may cause changes in water management.

Climate change was simulated using statistical weather relationships from the KNMI (3). Sea-level rise was simulated with the 2-D transient density-driven model MOC (4,5). Soil water dynamics and crop production were simulated using SWAP (2, 6).

2. METHODS

2.1. Climate Scenarios

A climate scenario 1 °C warmer then present was created with the climatic relationships from the KNMI, using data from the years 1966, 1976, 1979, 1985 and 1986, and called scenario(W). Radiation, humidity and wind and the pattern of rainfall are assumed to remain unchanged, CO_2 levels doubled. The present climate is scenario(P).

2.2. Groundwater Flow Modelling with MOC

Voorne-Putten, in the SW of the Netherlands, was selected for modelling as it lies at the coast, below sea level, with saline seepage. Dunes form the Western end. Groundwater flow was simulated with MOC 3.0 of 1989, a transient solute transport model. To suit the model for vertical application, density driven groundwater flow was added. The grid used is 100 by 20, west-to-east, 200 m deep and 25 km long. transversal to longitudinal conductivity and dispersivity ratios were set to 0.1. The boundary conditions imposed were:

- The vertical boundaries have constant piezometric levels.
- The upper boundary has constant phreatic levels in the polders, in the dunes there is a constant groundwater recharge (180 $mm.yr^{-1}$).

The geometry of the cross-section is shown below.

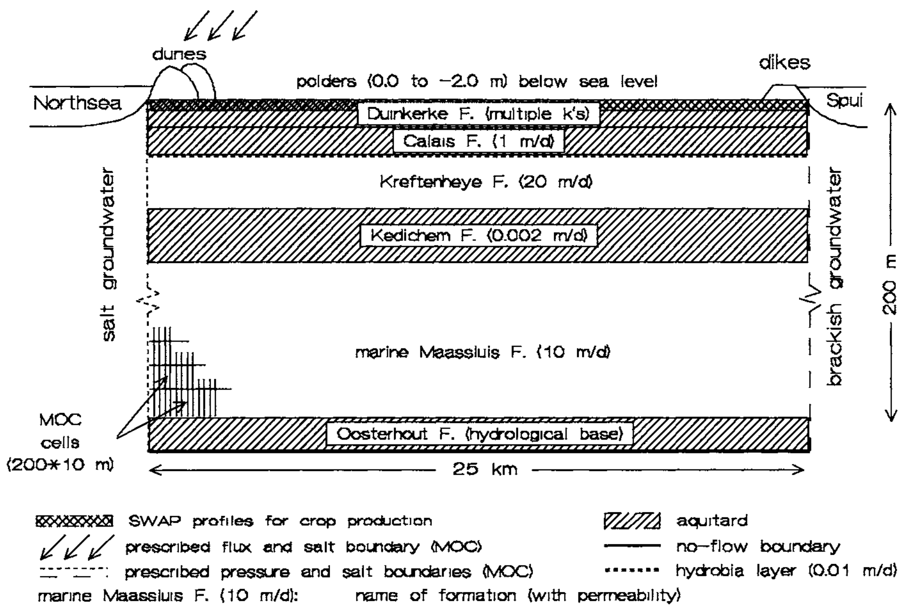

Fig. 1 The sub-soil of Voorne-Putten partitioned into aquifers and aquitards.

Calibration was done for seepage with measured rates (7) by varying k_{SAT}.

2.3. Calculating Crop Production with SWAP

Voorne-Putten was divided into 761 subareas, 461 of which are cultivated. Soil physical properties, open water levels, hydrological properties and land-use were established for each. Different crop-varieties chosen for scenario(W) to give a realistic yield, by adapting some of the physiological parameters of the crop models. An example is Table 1 for wheat.

Table 1.
Plant physiological parameters for scenario(W) in winter wheat (8,1).

	spec. leaf area ($m^2.kg^{-1}$)	light-use eff. ($kg.ha^{-1}.h^{-1}$ $/J.m^{-2}.s^{-1}$)	max. assim rate ($kg.ha^{-1}.h^{-1}$)	pre-anthesis temp. sum (°Cd)	temp. sum until maturity (°Cd)	surface resis. (s m^{-1})
Scen.(P)	18.0	0.45	40	1048	1258	40
Scen.(W)	14.4	0.55	80	1290	1171	44

Production of important crops was calculated, with scenario(P), calibrated with estimated actual harvests and then calculated again with scenario(W).

3. RESULTS OF SIMULATIONS

The effect of sea-level rise on seepage was assessed by comparing the results of two simulations. Both ran for 100 years, one with and one without sea-level rise. Figure 2 shows the resulting differences in groundwater salinity (mg/l). Seepage intensity increases, but is unimportant compared to the fresh water let in to maintain water quality.

On crop growth, climatic change has opposing effects: higher respiration, a longer growing season and higher water-use efficiency. The net result is increased crop production, as an example shows in Table 2.

Table 2.
Average crop production (tons (dm) ha^{-1}), for 1979, for scenario's (P)&(W), calculated with SWAP.

	sugarbeets	potatoes	wheat	grass
scen.(P)	12.4	13.0	6.8	9.8
scen.(W)	14.7	14.7	10.1	12.0

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Fig. 2. Differences in salinity (%) of the groundwater after 100 yrs simulations with and without sea-level rise.