Impact of Sea level rise due to the Global warming on Soil and Ground water Environment: Case of Seyhan River Delta, Turkey

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1. Introduction

According to IPCC Third Assessment Report (TAR)[(1)], it is expected that global average surface temperature due to the global warming will increase by 1.4 to 5.8 °C, and that global mean sea level will rise by 0.09 to 0.88 meters. Finally, these changes will impact on hydrological environment, irrigation system, plant growth, and agricultural economy (Fig.1).

The purpose of this study is to predict changes of soil and groundwater environment on Seyhan river delta due to the global warming. We finished development of saturated- unsaturated, density-dependent flow model for the prediction, SIFEC (Salt-water Intrusion by Finite Elements and Characteristics). And the groundwater conceptual model became almost clear from results of field investigation by November 2004. Especially, it was guessed that fresh-saline interface is located in an inland from under the lagoon from the fact that the density of lagoon water is higher than sea water .

2. Development of saturated -unsaturated, density-dependent flow model for salt-water intrusion, SIFEC

2.1 Feature of model

Within a non-deformable porous media, the governing equation for flow of non-compressive fluids with variable density is given by

$$\nabla \cdot K_f \left(\nabla h_f + \frac{\rho}{\rho_f} \nabla y \right) = C_s \frac{\partial \rho}{\partial t} \qquad (1)$$

where ρ、ρ_f are the density of fluid and fresh water, K_f、h_f are the hydraulic conductivity and the pressure head in terms of fresh water, and y is the upward vertical coordinate.

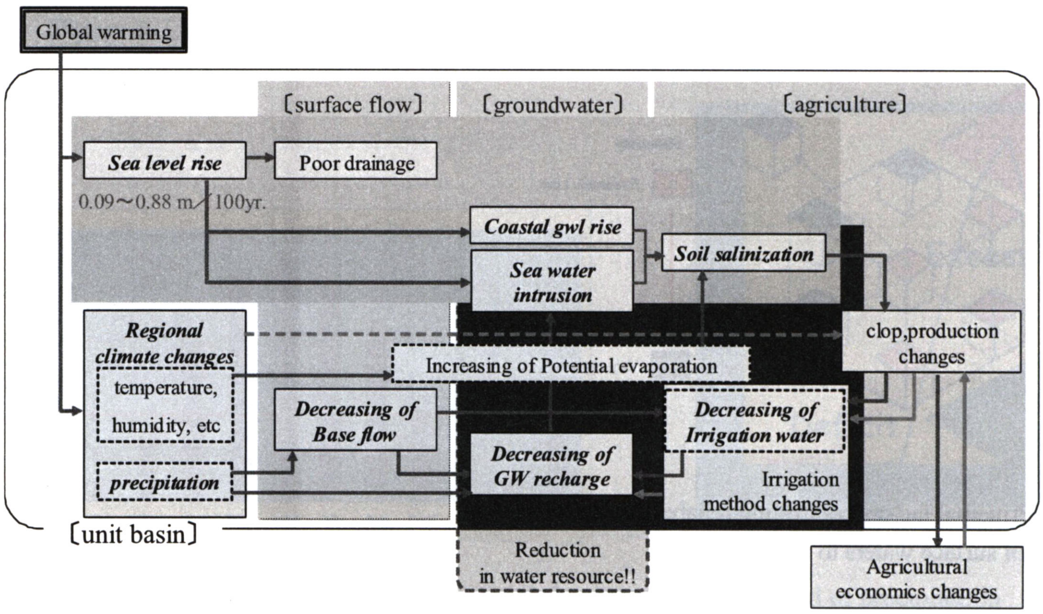

Fig.1 Relationship between global warming and its impacts on a basin

The governing equation for transport of conservative mass is given by

$$\nabla \cdot D\nabla C - \mathbf{v} \cdot \nabla C = \frac{\partial C}{\partial t} \tag{2}$$

where D is the dispersion coefficient, C is the concentration of salt, and $\mathbf{v}$ is the fluid flow velocity vector.

For solving the above mentioned variable density flow model which couples a fluid flow equation with a mass transport equation, we developed a simulation code, SIFEC, based on coupling of finite elements for density flow and method of characteristics linked with finite elements for mass transport. Table.1 shows any simulation codes for salt-water intrusion. Main feature of SIFEC is to adopt single-step reverse particle tracking with quadratic interpolation scheme for interpolating concentration in solving transport equation. And also, SIFEC allows calculating spring quantity under storage of surface water.

2.2 Accuracy of model

Masuoka et al.[2] investigated impacts of salt-water intrusion on groundwater systems in coastal aquifers due to sea level rise by experiments. Fig.2 shows results of comparison between experiments and simulations. On all experiments, excellent results were obtained.

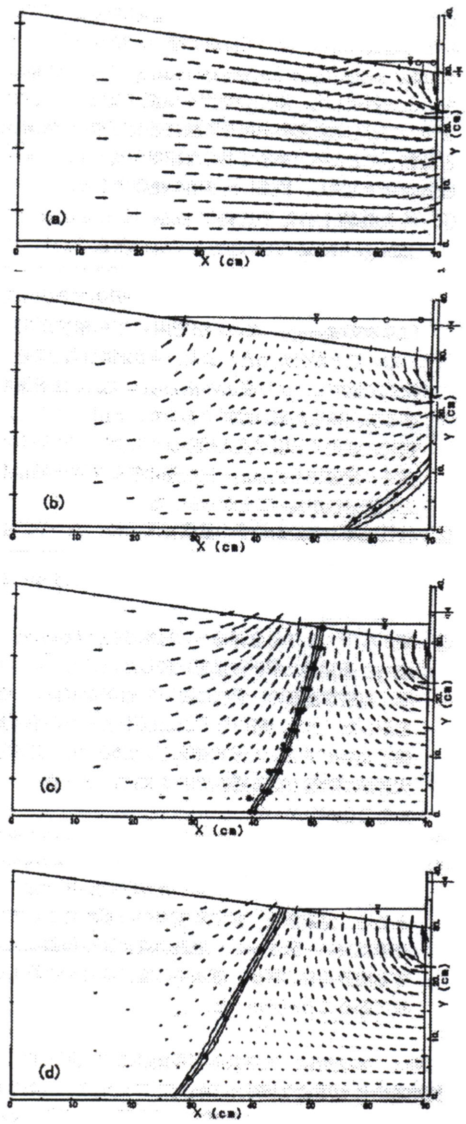

Fig.2 Comparison between experiments and simulation

Table.1 Comparison of Numerical simulation code for sea water intrusion

Code Name	Author	Numerical Solution for Mass Transport	Numerical Solution for Density-Dependent Groundwater Flow	Dimension	Analytical Domain	Specialities
SUTRA	Voss, C.I.	Galerkin Finite Elements	Galerkin Finite Elements	2	Saturated・Unsaturated	Consistent velocity calculation
FEFLOW	Diersch, H.J.G	Galerkin Finite Elements (Upwind)	Galerkin Finite Elements	2,3	Saturated・Unsaturated	Mesh refinement
MOCDENS3D	Essink, G.O.	Method of Characteristics (Advection part)＋Finite difference (Dispersion part)	Finite Difference	3	Saturated	Particle tracking
FEMFAT	Yeh, G	Eulerian-Lagrangian=Method of Characteristics (Advection part)-Galerkin Finite Elements (Dispersion part)	Galerkin Finite Elements	2,3	Saturated・Unsaturated	Adaptive local grid refinement
SIFEC	Fujinawa, K	Method of Characteristics (Advection part)-Galerkin Finite Elements (Dispersion part)	Galerkin Finite Elements	2	Saturated・Unsaturated	Single-step Reverse Particle Tracking, Quadratice interpolation of Concentration

3. Groundwater environment in Seyhan river delta

3.1 Topography and Geology

Seyhan river delta is very flat coastal plain, and the average slope is 0.5‰. Groundwater basin consists of diluvium and alluvium in the plain, which have located at north edge of the plain to Mediterranean sea in the direction from north to south, and River Berdan to River Ceyhan in the direction from west to east (Fig.3).

Fig. 4 shows a geological section from ADANA to the Mediterranean sea. Gravel is rich at upper part of the plain, but gravel become less and less toward lower part of the plain and clay become rich. Aquifers become deeper and deeper toward lower part of the plain.

According to Taylan[3], the transmissivity of aquifer is between 500 and 2000 m^2/day, and transmissivity at the northern part of the delta is higher. Kruttaş et al. [4] shows that the hydraulic coefficient in Seyhan river delta ranges between 10 and 150m/day.

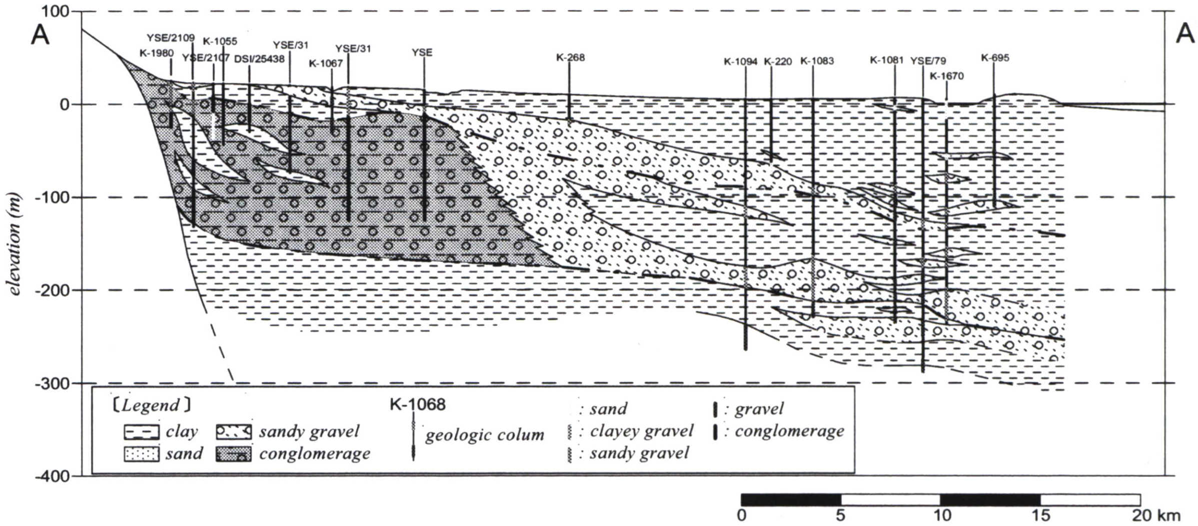

Fig.4 Geological profile in Seyhan delta

3.2 Groundwater

In comparing irrigation areas and potentiometric contour map in September 1983 which Taylan[3] created, it is clear that ground water level in the plain is shallow. Especially, in the middle and lower part of the plain, groundwater level is shallower than depth of about 1.5m from surface (Fig. 5). Çetin et al.[6] also mentions that areas around Solakli which groundwater level is shallower than 1.5 (GL.-m) increase in irrigation season. In a salinity filed on the north of Akyatan lagoon, which we visited for soil salinity survey, groundwater level in a bore hole was located in the depth of 1.05m from surface (Photo.1).

From data we measured on November 2003 and November 2004, it was clear that typical electric conductivity of groundwater is 500～1000μs/cm. On the other hand, electric conductivity of lagoon was higher than the sea, and highest in the deep part of lagoon. The difference of the electrical conductivity by the side of land and the sea was not accepted (Table.2, Photo.1).

Table.2 Result of electric conductivitiv measurement in Nov. 2003 and Nov. 2004

Classification	[ ]: number of sample	Electric conductivity (μs/cm) (mean)	(max)	(min)	Note
Groundwater	[13]	837	2,733	423	max value is located in the north side of Tuz lagoon.
Akyatan Lagoon (deep part)	[7]	100,386	104,300	94,700	
Akyatan Lagoon (other part)	[7]	78,229	99,900	60,100	
Mediterranean Sea(shore line)	[3]	57,500	58,400	56,100	
Other (Riv., Irrigation)	[3]	406	488	357	

3.3 Groundwater conceptual model

In a present stage, the groundwater conceptual model of Seyhan river basin is considered as follows (Fig.6).

1) The water of the lagoon where density is higher than the sea water flows to the base of the shallowest aquifer due to its density.
2) For this reason, it is thought that fresh-saline water interface in the shallowest aquifer is located in inland side from under the lagoon.

4. Conclusion

If it assumes that an above-mentioned conceptual model is right, we can guess qualitatively impacts of the global warming to groundwater environments of Seyhan delta as follows.

1) Lagoon level rise due to sea level rise will cause the pure drainage of surface water.
2) Then, groundwater level in the middle and lower part of the plain will go up and salinity field will increase.
3) If the density of the lagoon becomes high due to changes of climate condition, fresh-saline interface will advance to a inland side.

From now on, while collecting new hydrological data and reconstructing the groundwater conceptual model, we will predict quantitatively impacts of the global warming to groundwater environments using the developed model, SIFEC.

5. References

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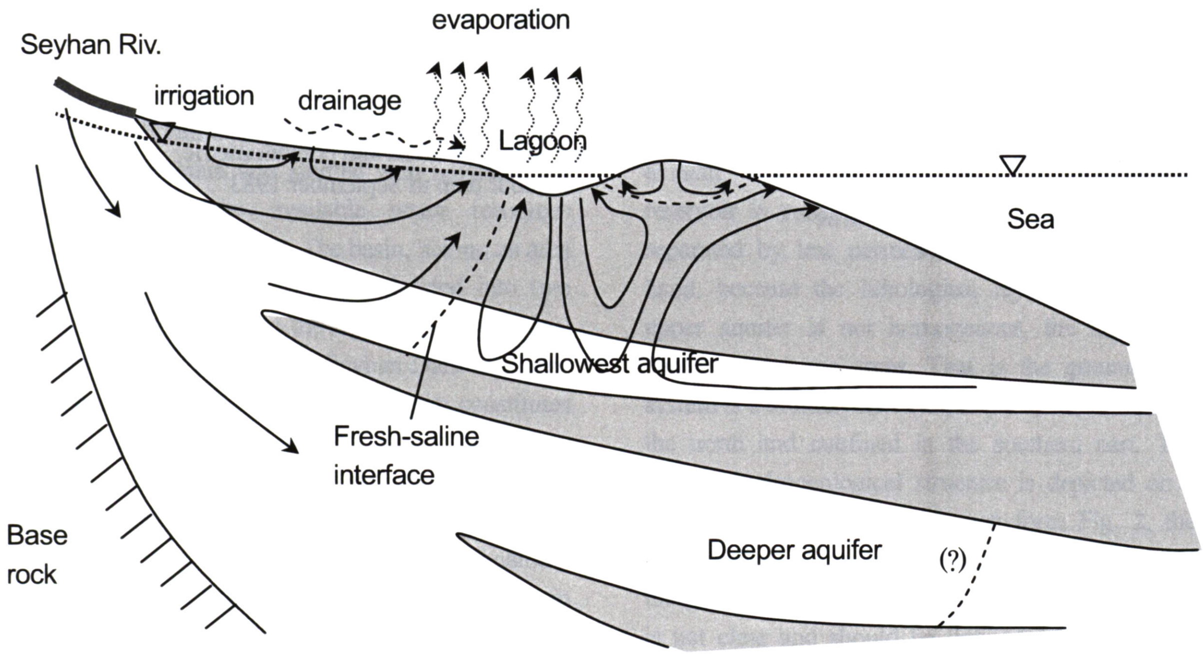

Fig.6 Groundwater conceptual model of Seyhan river basin

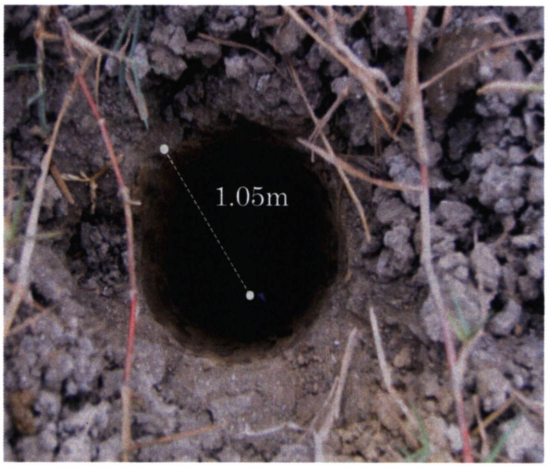

Photo.1 Shallow groundwater level in a bore hole on a salinity field

Photo.2 Electrical conductivity measurement in Akyatan lagoon

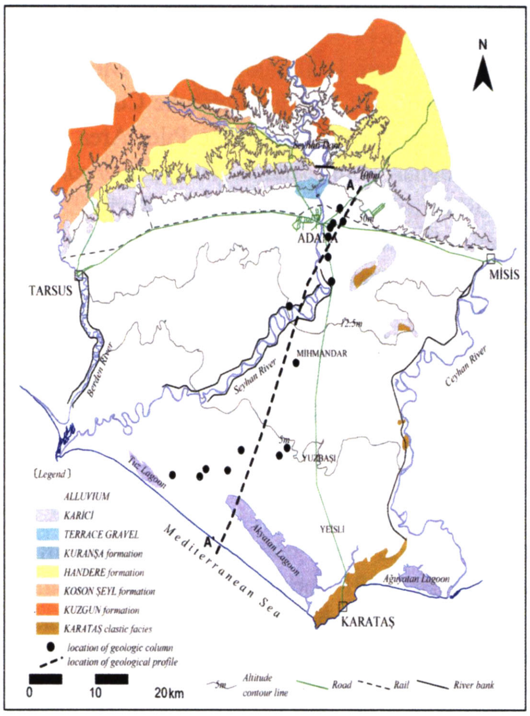

Fig.3 Surface geologic map around Seyhan delta

It was created from Taylan[3] and MTA[5]

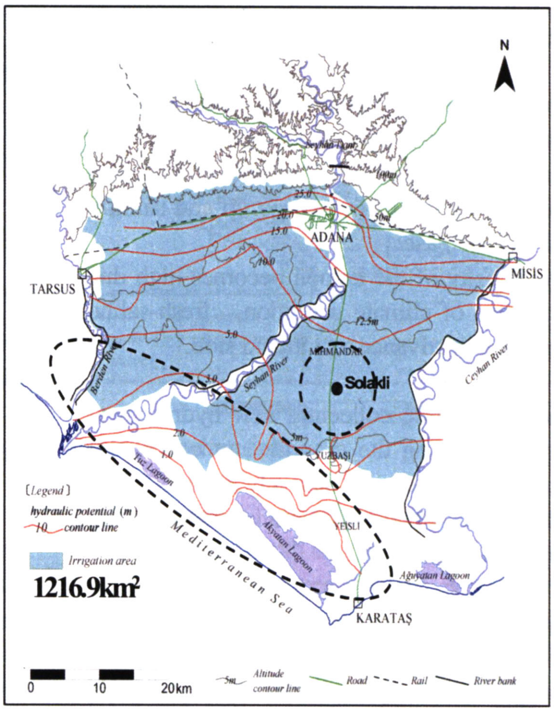

Fig.5 Irrigation areas and potentiometric contour map in September 1983.