1. INTRODUCTION
Paddy field performs important functions in an ecosystem such as maintenance of groundwater supply, water purity, nitrogen cycle control, mitigation of local climate, and so on. In the Dozen plain (Fig. 1), the area of paddy field has been decreasing with the urbanization in the recent decades and changing to other land uses such as residential area, roads, etc (Fig. 2). To investigate the impact of these land use changes on the groundwater recharge in the coastal plain, a lumped water balance model was developed. The percentage of the paddy field area in the whole Dozen plain was adjusted to simulate the impact of land use change on the groundwater recharge.

2. SITE DESCRIPTION
The study site chosen for this study is located in the Dozen plain of the Shikoku Island, Japan. It is surrounded by mountains in the south, west, east, and by the Seto Inland Sea in the north. In the Dozen plain the Nakayama River is the main river and the groundwater is composed by a large groundwater flow along the Nakayama River and another groundwater flow along the Sin River. Based on the measured hydrogeologic and meteorological data in this coastal plain, the lumped water balance model has been constructed to simulate the average groundwater level fluctuation.

3. LUMPED WATER BALANCE MODEL
The water cycle in the Dozen plain is expressed by the conceptual water balance model which is shown in Fig. 3. The elements expressing the water input and output are discussed as follows.

1) Input elements
(1) Rainfall: The rainfall is the main input element for paddy field and other fields in the surface region.

(2) Discharge from background watersheds: The river discharge from background watershed will flow into the Dozen plain and some of it will be used as irrigation water for paddy field and thus this part will be an input element of paddy field.

(3) Dozen irrigation water: The irrigation water used for agricultural purpose from the Omogo dam is an input element for paddy field.

2) Output elements
(1) River outflow: The water of paddy field and other fields has two output ways. One is the infiltration to the subsurface region and another is to flow as surface discharge and lastly convert to a part of river discharge. The flow to subsurface region is also output to rivers as subsurface discharge.

(2) Evapotranspiration: The evapotranspiration is a part of output element for paddy field and other fields and it will revert to atmosphere from earth surface.

Fig. 1 Study site in the coastal Dozen Plain.

Fig. 2 Ratio and descended trend of paddy field area in the coastal Dozen Plain.

Fig. 3 Schematic figure of the water balance model.
Groundwater outflow: The percolation from the subsurface region will be the source for groundwater region and the groundwater will partly outflow to the Seto Inland Sea.

Pumped water for industrial and domestic purpose: The pumped water from groundwater region for industrial and domestic purpose will directly flow into the Seto Inland Sea.

Pumped water for agricultural purpose from groundwater region: The pumped water for agricultural purpose from groundwater region is a source for paddy field and also contributes to the flow to rivers and the infiltration from surface region to subsurface region.

The average measured groundwater level in the Dozen plain was obtained by using the Thiessen method. In the aforementioned water balance model, the groundwater level could be calculated from the groundwater storage height ($S_3$: mm) divided by the effective porosity.

4. RESULTS AND CONCLUSIONS

The model parameters were optimized by comparing the calculated and observed groundwater level for the coastal Dozen plain (Yamane, et al., 2003). Results indicated that calculated groundwater levels were able to describe the actual behavior of the shallow aquifer adequately. Using the proposed water balance model, the groundwater level in the Dozen plain would be simulated and results shows good fit with the measured one. For further analyzing the groundwater recharge change with different ratios of paddy field in the Dozen plain, the ratio of paddy field area has been assumed as the following two cases of scenarios. Case 1 and 2 present for 60% and 30% of the original actual paddy field area at present, respectively. The simulated groundwater level fluctuation in typical hydrologic year of 1992 (normal flow year), 1993 (high flow year), and 1994 (droughty year) in different cases of paddy field area ratio have been shown in Fig. 4. From the analysis, the following results could be obtained:

1. With the decreasing of the paddy field area, the regional groundwater level decreased as expected, especially in the irrigation seasons from June to October in each hydrologic year. The groundwater levels that dropped in the droughty year is the biggest, in the normal flow year is the second, and in the low flow year is the smallest.

2. For the normal flow year 1991 and 1992, the dropped groundwater level after the irrigation seasons of 1991 would increase and this increase would continue to next year 1992 if the paddy area decreased. Following the normal flow year 1992, the groundwater difference of the high flow year 1993 did not appear in December because of the sufficient water supply in this year.

3. For the droughty year 1994, the difference of groundwater levels would increase greatly from June to December and continue to increase until the following year’s first two months - January and February of 1995. Moreover, this effect would be imposed on the whole year of 1995.

4. Comparing case 1 and 2, the paddy field’s area decreased half but the groundwater level dropped more than half in most periods of all simulation years. From the above analysis, the impact of the land use changes on the groundwater recharge was large, especially in droughty seasons. The results showed that the paddy field played a significant role on the hydrological cycle in the coastal plain. Future work will be emphasized on the water balance analysis and development of policy scenarios for sustainable utilization of water resources.

REFERENCE:

KEYWORDS: Land use change, paddy field, groundwater recharge, water balance model.