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A spatial reasoning approach to estimating paddy rice water demand in Hwanghaenam-do, North Korea

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ABSTRACT

The primary objective of this study was to estimate the agricultural water demand of paddy fields in Hwanghaenam-do, North Korea. Three Landsat TM images, GIS data including digital elevation maps, a Thiessen network and administration maps of North Korea, and meteorological data were synthesized for this study. In order to estimate water demand for agricultural use, the FAO Blaney–Criddle method and 10-day crop coefficients of the northern areas of South Korea were used. To classify the Landsat images, supervised and unsupervised classification methods were conducted. Topographical constraints based on paddy rice growing conditions, which are under 7% slope and 200 m above sea level, were taken into account. The results showed an annual net water demand of 611.7 mm/year (916.4 Mt/year) is required for the 150,079 ha of paddy fields and the average gross water demand and design water demand for paddy rice were estimated to be 939.6 mm/year (1408 Mt/year) and 1131.97 mm/year (1695.1 Mt/year), respectively.

1. Introduction

The Hwanghaenam-do province is a supplier of staple foods to North Korea. As such, the agricultural water demand of the region is considered to be the primary factor for assessing current water use and future water requirements. Water demand associated with agricultural water use in North Korea must be considered for near-future investment in agricultural production and to prepare for future Korean unification.

Agricultural water demand is generally estimated using the water balance concept (Haque et al., 2004). The water balance is determined by first collecting regional data including observed meteorological data, cultivated land distribution, and farming practices. Secondly, water requirement is computed from daily evapotranspiration and effective rainfall using water balance models developed with the observed data. Lastly, gross water demand considering lot-management water requirement and canal-system-management water requirement is calculated. South Korea has applied the water balance models based on field experimental data, which had been measured over the long-term, to the development and management of agricultural water resource facilities. Through the water balance methods, the Ministry of Agriculture and Forest (1999) predicted that the total water demand in 2010 would be 15,472 Mt/year for 1,100,000 ha of paddy fields in South Korea. However, for remote sites that cannot be easily accessed by researchers due to political, economical or natural conditions, the typical computational procedures cannot be conducted due to the lack of essential data of appropriate quality. These difficulties are especially relevant in places separated by political barriers, such as North Korea, as it is commonly difficult to reach relevant information from the outside world. Thus, different data collection methods must be applied to gain relevant information for the inaccessible regions.

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Many researches have shown that spatial reasoning using remote sensing and geographic information system (GIS) is adequate for ascertaining data in such limited conditions as those mentioned above. Spatial reasoning is a modeling process that comprises the formation of ideas through the spatial relationships between geographic objects (Crawford, 1992–1993). Spatial reasoning is a situation where the process and procedures of manipulating maps transcend the mere mechanics of GIS interaction (input, display and management), leading the user to think spatially using the language of spatial statistics, spatial process models, and spatial analysis functions in GIS (Berry, 1995). It is widely used for assessing land cover that is either too remote or extensive for researchers to access directly. Such advanced technologies make possible the affordable collection of a wide range of land cover information in the face of political and geographical barriers. In the case of North Korea, the land use information including cultivated lands is not clear because the North Korea government has never opened the statistics officially and the preceding studies showed considerably different results. For example, Food and Agriculture Organization [FAO] (2001) estimated the paddy area was about 1,000,000 ha in 1993, but it was changed into 600,000 ha in just 1 year. Also, the FAO (2005), which published a digital global map of irrigated areas over the world since 1999, declared that no map of irrigated areas had been available for North Korea. Largely, the total paddy area is evaluated as 580,000–600,000 ha but the spatial distribution is still obscure (Shin et al., 1998). In order to set up the water resources development plan for agriculture and also to predict the crop yields in secluded regions like North Korea, a reasonable estimation for arable area and the geographical distribution should be found first.

The objective of this study was to determine the agricultural water demand for a remote site, Hwanghaenam-do in North Korea. To achieve this study goal, paddy rice cultivation areas were classified using a spatial reasoning method for satellite images of Hwanghaenam-do, and water demand associated with irrigation requirement was estimated considering topographically suitable areas for paddy rice cultivation.

2. Site selection and methods

2.1. Site description

Hwanghaenam-do province has an area of about 8578 km^2. Hwanghaenam-do is broadly representative of the cultivation areas of North Korea and includes the nation's largest paddy fields, the Jaeryeong plain (1300 km^2). Hwanghaenam-do serves as the principal agricultural base of North Korea. Its 3300 km^2 of agricultural areas comprise about 17% of the whole cultivation area of North Korea, and the paddy rice cultivation areas comprise about 26% (1500 km^2) of the total North Korean paddy area.

Hwanghaenam-do is located very close to South Korea (Fig. 1) and has similar conditions to northern South Korea in terms of agro-climate and farming methods. The annual mean accumulated temperature is 3400–3600 °C, and the mean precipitation is about 1238 mm per year in Hwanghaenam-do (Korea Rural Economic Institute, 1996; Cheon et al., 2003). The cultivation calendar of Hwanghaenam-do can be inferred from that of Kyungki-do, which is the South Korean province closest to North Korea.

2.2. Methods

Two procedures were carried out in parallel. One was to classify paddy areas from satellite images and the other was to compute agricultural water demand per unit area using meteorological data (Fig. 2). Image processing and classification methods were used to extract the distribution of paddy fields in the study area. Spatial analysis performed based on

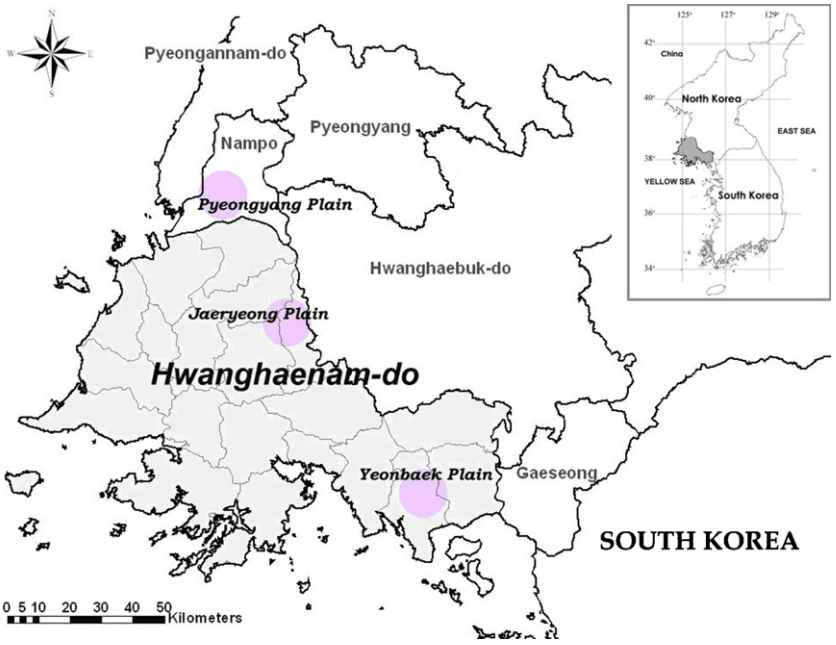

Fig. 1 – Study site (Hwanghaenam-do Province, North Korea).