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Development and application of a weather data service client for preparation of weather input files to a crop model

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ABSTRACT

Crop yield prediction has been made using a crop growth model that relies on four categories of input data including soil, crop, management, and weather. Most crop models are single column models, which require individual weather inputs for each site of interest. The objectives of this study were to develop a weather data service client that prepares weather input files for a crop growth model and to examine its application to yield prediction at a national scale. The weather data service client downloads daily weather data from the web-based weather data service portal operated by the Korea Meteorological Administration (KMA). The client also prepares weather input files for the ORYZA 2000 model at minimum effort. In total, 4950 input files were prepared to predict rice yield in 2011 and 2012 using the weather data service client. To prepare nearly 5000 weather input files, it would take more than a month for a skilled person to download weather data from the KMA database and to reorganize those data to the input data format for the ORYZA 2000 model manually. Using the weather data service client, several hours were enough to prepare all the input files without error associated with manual preparation as well as with minimum effort and labor.

1. Introduction

Crop growth models have been developed to increase the understanding of the dynamic behavior of crops, and to make predictions about crop growth and yield under various agronomic conditions (Bouman et al., 1996). For research purposes, these models are used to simulate exchange of energy and matter, e.g., latent heat, CO_2, or nitrogen, between the crop and its environment. For example, crop models are integrated into land surface models to improve the simulation of energy exchange between croplands and the atmosphere (van den Hoof et al., 2011; Lokupitiya et al., 2009). For efficient crop management and precision agriculture, crop models have been used as components of decision support systems (Hammer et al., 2002; Jones et al., 2003; Jame and Cutforth, 1996; Kim et al., 2014). In addition, crop models have been used to provide information for the assessment of national food security, especially under climate change conditions (Matthews et al., 1995; Chung et al., 2006; Lee et al., 2012).

Requirements of input data differ by crop models. For example, the EcoCrop model, which is a basic mechanistic model, has been used to predict climatic suitability of a crop as well as crop yield using monthly temperatures and precipitation as inputs (Ramirez-Villegas et al., 2013). The ORYZA 2000 model, which is a comprehensive crop growth model, simulates biophysical processes within the crop canopy, e.g., matter and energy exchange between soil and atmosphere through the crop. The ORYZA 2000 model requires input data that characterize conditions of soil, genetics, crop management, and weather (Bouman et al., 2001).

Comprehensive crop growth models, which are usually single column models, use a separate set of input data for simulation of

Abbreviations: APE, absolute percentage error; CV, coefficient of variation; DSSAT, decision support system for agrotechnology transfer; FTP, file transfer protocol; GCM, general circulation model; GSOD, global summary of day; GUI, graphical user interface; HTTP, hypertext transfer protocol; KMA, Korea meteorological administration; KOSTAT, statistics Korea; MIPSS-DPO, meteorological information portal service system for disaster prevention organizations; NCDC, national climate data center; PDAH, prediction date after heading; UML, unified modeling language.

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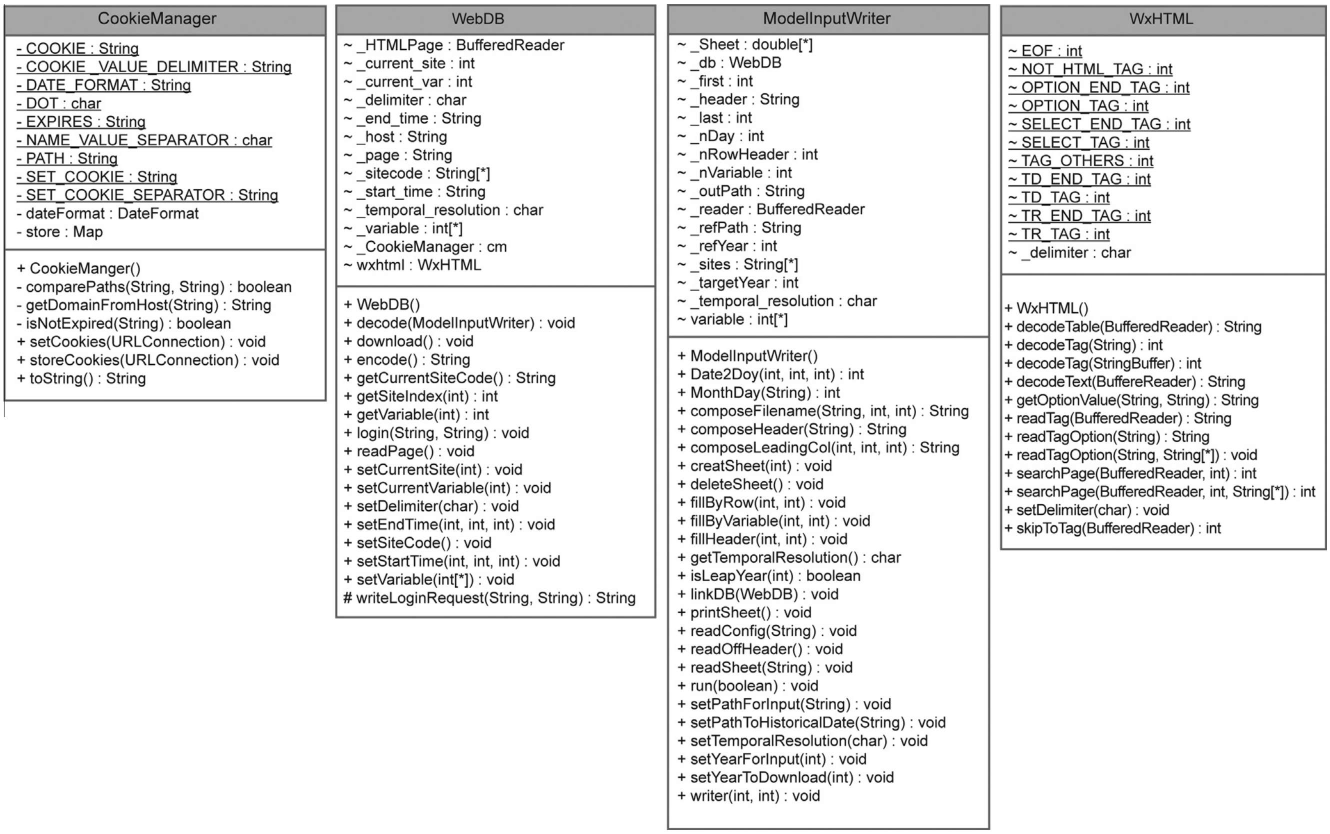

Fig. 1. Class diagrams of modules associated with a weather data service client to prepare weather input files for a crop model using weather data downloaded from a weather data service portal.

crop growth at each site of interest. The properties of soil are spatially variable yet temporally invariable in a reasonable period, which makes it feasible to use the same soil input data at a given site for a long simulation period. A standard crop management would be performed by growers. The chracteristics of a given crop cultivar is unchanging although new crop cultivars have been produced and adopted by farmers regularly. Thus, input data for these factors could be assumed to be invariable temporally when a small number of seasons are considered for prediction of crop production. In contrast, weather is spatially and temporally variable, which requires preparation of input data at each site of interest for each season of simulation. Therefore, it would require considerable effort to prepare weather input files for a comprehensive crop growth model when many simulations are to be performed.

Different approaches have been developed to prepare weather input files for comprehensive crop growth models, which usually use daily weather data as inputs to the model. For example, daily weather data have been generated from monthly climate data using various weather generators. Richardson (1981) developed a daily weather generator based on a Markov chain-exponential model and multivariate model to produce daily precipitation, maximum temperature, minimum temperature, and solar radiation. Kilsby et al. (2007) developed a Neyman–Scott point process model to produce daily precipitation from monthly data more accurately. Jones and Thornton (2013) used MarkSim®, which is a third-order Markov rainfall generator, to produce daily weather data compatible with the DSSAT (Decision Support System for Agrotechnology Transfer) system from the outputs of General Circulation Models (GCMs).

Tools were rarely developed for preparation of weather input files from a weather observation network although daily observation data at a large number of weather stations are available through the Internet. For example, the National Climate Data Center (NCDC) provides the Global Surface Summary of the Day (GSOD) data, which includes maximum temperature, minimum temperature, and rainfall observed at over 9000 weather stations worldwide. Such weather observation data can be used for prediction of crop yield at a national scale, which would benefit policy makers. Still, it is challenging to perform crop yield prediction at the national scale because considerable effort and labor are needed for preparation of a large number of weather input files from the observed weather data.

The objective of this study was to develop a weather data service client, WiseDownloader, for preparation of weather input files to a crop model from an internet weather data service portal. Such a client would make it easy to perform a large number of simulations for crop yield prediction at a national scale. The elements of the client, including retrieval of weather data from a weather data service portal and preparation of weather input files for a crop model, were described. This paper also explores application of WiseDownloader for prediction of rice yield at the national scale in Korea using a comprehensive crop growth model.

2. Development of a weather data service client

A weather data service client, WiseDownloader, was developed to automate retrieval of weather data from an internet weather database and preparation of weather input files to a crop model. It would be preferable for the client to have wide compatibility with crop models, which allows preparation of weather input files for various crop growth models. It would also be helpful for the client to have a means of accessing a wide range of weather data services through Internet protocols such as the HypterText Transfer Protocol (HTTP) or the File Transfer Protocol (FTP). To