Spatial Mapping of Actual Evapotranspiration and Water Deficit with MODIS products in the Songnen Plain, Northeast China

Lihong Zeng[1, 2], Kaishan Song[1], Bai Zhang[1], Zongming Wang[1]

(1. Northeast Institute of Geography and Agricultural Ecology, CAS, Changchun 130012, China;
2. Graduate University of Chinese Academy of Sciences, Beijing 100049, China.)

Extended Abstract

Evapotranspiration (ET) is the combined process whereby water is lost from the soil surface by evaporation and from the plant by transpiration. It is not only an important component in the hydrological cycle but also a significant part of energy balance because liquid water absorbs large amount of heat when if transfers into water vapor (Allen, *et al*., 1998). Spatial knowledge of land surface ET is of prime interest for environmental applications, such as optimizing irrigation water use, irrigation system performance, crop water deficit, drought mitigation strategies and accurate initialization of climate prediction models especially in arid and semiarid catchments where water shortage is a critical problem. Conventional techniques that based on the point measurements are representative only of local scales and will fail for large scales. In general, comparing with the traditional methods, remote sensing technology can provide more land surface information for the estimation of evapotranspiration, especially in the regional scale. With the quickly development and application of remote sensing technology, evapotranspiration calculation methods based on the remote sensing dada have been developed rapidly in the recent 20 years, and several models, such as SEBS (Su, 2002), TSEB (Norman, *et al*., 19995), S-SEBI (Roerink, *et al*., 2000) and SEBAL (Bastiaanssen *et al*., 1998a, 1998b) have been adopted by different research groups and used in related study area successfully. Among all those methods, SEBS and SEBAL are the most popular models.

The Songnen Plain located in the central part of Northeast China, between 121°38′~126°30′E and 43°59′~46°18′N, and situated on a transitional belt between the agricultural region and the pastoral region, with an area of about 192, 897 km2 . Its elevation is between 110m and 350 m. The study area is characterized by a temperate, semi-arid continental monsoon climate. Seasons alternate between dry and windy springs, humid and warm summers with intensive rainfall, windy and dry autumns and long, cold dry winters. Air temperature spatially increases from north to south with a mean annual value of 2~6℃. Precipitation varies greatly within and between years. Seventy to eighty percent of total precipitation occurs between the middle of June to mid-August. According to some research, water productivity and irrigation performance in the Songnen Plain in Northeast China is grossly under-performing and a major reason for increasing ecological problems in the region. Yet, this generalized statement is based upon inconsistent, outdated and unreliable data provided by different administrations or research organizations. Remote sensing may help filling this gap by improving the

understanding and assessment of the water using efficiency, water deficit and productivity at different spatial scales and may contribute to better-informed decision-making of water resources management. Especially performance indicators based on an accurate estimation of the actual amount of water consumption and water deficit for different land use types derived from remote sensing data have been found useful to assess the major principles of irrigation management, adequacy, equity, reliability, productivity, and sustainability (Bastiaanssen, *et al*., 1999).

This study aims to investigate the ET characterization in the Songnen Plain which represents one of the most important agricultural products bases for the country suffering from the water scarcity and inconsistency of data for strategic and operational water management. As a consequence, the area is characterized by advancing soil degradation and salinity, owing to overgrazing, and improper agricultural practice and water table decreasing problem. The specific objectives of this study were: (1) to compare both actual ET measured by eddy covariance system and actual ET estimated from the MODIS products; (2) to quantify actual ET over different land-use types in the Songnen Plain during the growing season of 2008a; (3) to calculate water deficit based on actual ET and precipitation data.

In this study, the Surface Energy Balance System Algorithm for Land (SEBAL) model based on land-surface energy balance principle was developed to estimate land surface fluxes by using MODIS remotely sensed data and meteorological observations collected from Chinese Meteorological Administer. All the MODIS remote sensing products used in this study distributed by the NASA, including daily land-surface temperature (MOD11A1), 16-days vegetation index (MOD13A2) and 16-days land-surface albedo, were imported into SEBAL model to estimated actual ET. Monthly and seasonal ET resulted from linear interpolation of the relationship between daily actual ET and reference ET which was calculated with Penman-Monteith suggested by FAO 56. Also, time series of 250m normalized difference vegetation index (NDVI) derived from 8-days MODIS reflectance data facilitated to classify land-use types.

After these processes, daily ET in cloud-free days and total ET in the growing season were calculated. The accuracy was estimated and verified by compare the actual ET measured by eddy covariance system, it is revealed that the ET estimated were consistent with the ET measured in the whole growing season with the average error within 20% (Fig.1), it indicated that the SEBAL model can basically meet the accuracy requirements of regional ET in Songnen Plain. Under the support of GIS software, spatial distribution characteristics of ET in the growing season were analyzed and the relationship between ET and land-use types was explored (Fig.2, Fig.3 and Tab.1). The results showed that regional ET during the growing season of 2008 increased from 300~400mm in the southeast part to 800~900mm in the northeast part. The spatial distribution

characteristic over Songnen Plain was affected by climate, soil water conditions and land-use types to a large extent. Among all the seven land-use types, water-body, woodland and wetlands represented the highest evapotranspiration rate with the average evapotranspiration amount 859.12mm, 794.56mm and 763.44mm for each type, respectively; crop land, built-up took the second place, while grassland was at the lowest evapotranspiration rate with 445.41mm. Water deficit in the growing season of 2008 was calculated based on precipitation and ET and its characteristics were analyzed by GIS spatial methods (Fig.4, Fig.5 and Tab.2). It found the water deficit roughly decreased from the southwest part to the northeast part, about 97% of Songnen plain was in the water deficiency state. Water deficit amount for water-body, wetlands and woodland was largest, with 464.43mm, 402.45mm and 380.16mm for each. Grassland obtained the minimum amount of water deficit with less than 100mm. Through this study, it would provide some supports for the assessment of crop growth in arid environments of Songnen Plain; help to assess the ecological water requirement and irrigation systems functions; and provide a basis for the determination of the program for the resource-based water district to build guidance to strengthen water resources management.

Keywords: evapotranspiration; water deficit; SEBAL model; MODIS products; Songnen Plain

Correlated figures and tables:

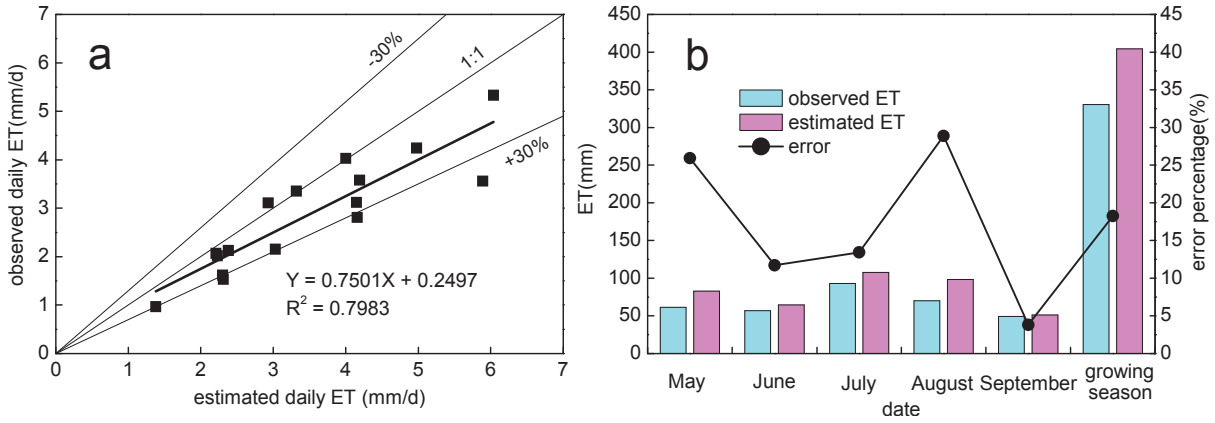

Fig.1 Comparison between observed ET and estimated ET

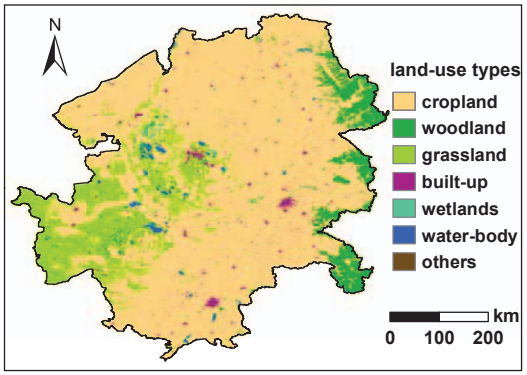

Fig.2 Distribution of land-use types over Songnen Plain, 2008

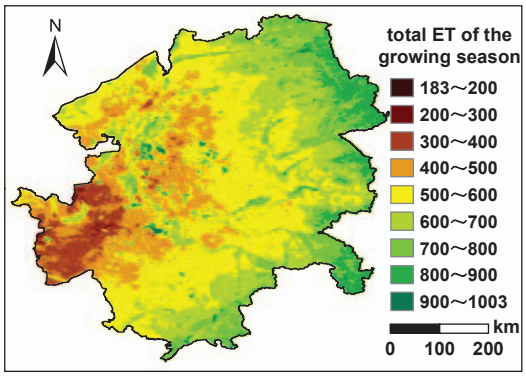

Fig.3 Total ET in the growing season of 2008 over Songnen Plain

Tab.1 Statistics for ET in the growing season of 2008 over different land use cover in Songnen Plain

	cropland	woodland	grassland	built-up	wetlands	Water-body
Average (mm)	596.31±93.41	794.56±106.97	448.38±92.06	561.60±70.50	763.44±82.91	859.12±88.47
Maximum (mm)	947.35	991.47	961.59	925.21	978.92	1002.40
Minimum (mm)	221.64	248.37	183.70	304.87	425.76	403.93
Variation coefficient (%)	15.67	13.46	20.53	12.55	10.86	10.30

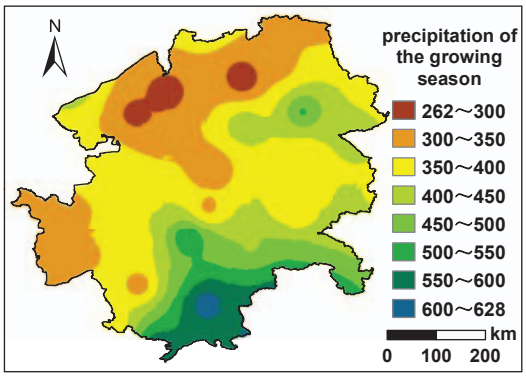

Fig.4 Total precipitation in the growing season of 2008 over Songnen Plain

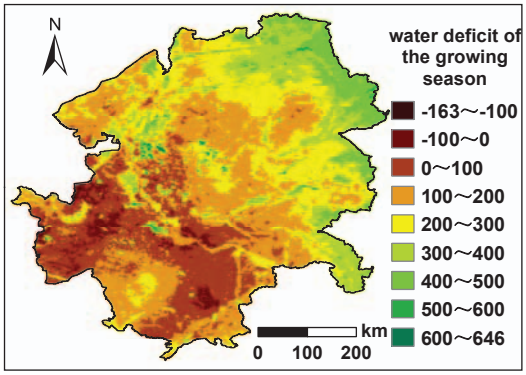

Fig.5 Total water deficit in the growing season of 2008 over Songnen Plain

Tab.2 Statistics for water deficit in the growing season of 2008 over different land use cover in Songnen Plain

	cropland	woodland	grassland	built-up	wetlands	Water-body
Average (mm)	196.02±102.01	380.16±103.36	91.75±92.65	145.19±101.16	402.45±87.38	464.43±104.23
Maximum (mm)	611.04	640.70	620.20	549.84	623.08	645.88
Minimum (mm)	-129.36	-127.93	-162.99	-127.93	56.39	41.20
Variation coefficient (%)	52.04	27.19	100.98	69.67	21.71	22.44

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