

Estimation of Evapotranspiration and Its Variation Characteristics for Different Land Use Types During the Growing Season in the Hetao Irrigation District (Postprint)

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Abstract

To reveal the differential characteristics of evapotranspiration (ET) among different land types, daily ET during the 2017 growing season in the Hetao Irrigation District was estimated using the SEBS (surface energy balance system) model, combined with meteorological data, remote sensing imagery, and land use classification results, to analyze the spatiotemporal variation characteristics of ET in the irrigation district and the ET differences among different land types. The results show: The accuracy of the SEBS model estimation results was verified through measured data and FAO Penman-Monteith (PM) calculated values. The average relative errors of lysimeter observation data, eddy covariance system (EC), Bowen ratio energy balance system (BREB), and PM calculated values were 16.66%, 18.34%, 14.93%, and 14.03%, respectively, indicating that the SEBS model can be used to estimate ET in the Hetao Irrigation District. Within the growing season, the daily ET in the irrigation district followed the order: July > June > May > August > September. Daily ET showed a unimodal variation, reaching a maximum value of $5.21 \text{ mm} \cdot \text{d}^{-1}$ in July, with the minimum daily ET in September at $3.51 \text{ mm} \cdot \text{d}^{-1}$. The daily ET of different land types followed the order: water body > forest land > cultivated land > grassland > urban area > wasteland. The ET distribution within the irrigation district showed high consistency with land types, with overall classification accuracy and Kappa coefficient of 80.63% and 0.75, respectively. At different times during the growing season, water body ET remained at relatively high values, with daily ET reaching a maximum of $6.034 \text{ mm} \cdot \text{d}^{-1}$ in July and a minimum value of $4.177 \text{ mm} \cdot \text{d}^{-1}$ in September. Forest land had the second highest daily ET, with values of $5.977 \text{ mm} \cdot \text{d}^{-1}$ in July and $4.147 \text{ mm} \cdot \text{d}^{-1}$ in September. The variation trend of daily ET for cultivated land was consistent with crop growth conditions, reaching $5.851 \text{ mm} \cdot \text{d}^{-1}$ during the vigorous crop

growth period and $3.952 \text{ mm} \cdot \text{d}^{-1}$ during the crop harvest period.

Full Text

Estimation and Variability of Evapotranspiration for Different Land Types During the Growing Season in the Hetao Irrigation District

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Abstract: To reveal the differences in evapotranspiration (ET) across different land types in irrigation districts, the single-day ET during the 2017 growing season in the Hetao Irrigation District was estimated based on the surface energy balance system (SEBS) model, meteorological data, remote sensing images, and land use classification results for the irrigation districts. The SEBS model accuracy was verified using the measured ET data and the calculated values obtained using the United Nations Food and Agriculture Organization Penman-Monteith (PM) model. The objective of this study was to analyze the temporal and spatial changes in ET in the irrigation area and the differences in ET across different land types. The results showed that (1) the average relative errors obtained based on the PM model, eddy covariance, Bowen ratio-energy balance system, and micro-lysimeter observation data were 14.03%, 18.34%, 14.93%, and 16.66%, respectively. The SEBS model exhibited a high application potential for studying the ET across the Hetao Irrigation District. (2) During the growing season, the daily ET values in the irrigation area exhibited the following relation: July > June > May > August > September. The daily ET in the irrigation area had a unimodal distribution and reached the maximum value of $5.21 \text{ mm} \cdot \text{d}^{-1}$ in July. The daily average ET was the lowest in September at $3.51 \text{ mm} \cdot \text{d}^{-1}$. (3) The daily ET values for different land types exhibited the following relation: water > forest > cropland > grassland > urban > bare land. The ET variability in the irrigation area was consistent with the land type. The overall classification accuracy and kappa coefficient for land use classification were 80.63% and 0.75, respectively. (4) The ET value for water was the higher during different periods of the growing season; the daily ET reached the maximum value of $6.034 \text{ mm} \cdot \text{d}^{-1}$ in July, whereas the daily average ET was the lowest in September at $4.177 \text{ mm} \cdot \text{d}^{-1}$. The ET value for forest within the irrigation area was relatively large, with a daily ET of $5.977 \text{ mm} \cdot \text{d}^{-1}$ in July and $4.147 \text{ mm} \cdot \text{d}^{-1}$ in September. The ET value for cropland changed with the growth of the crops, reaching $5.851 \text{ mm} \cdot \text{d}^{-1}$ during the vigorous growing period and $3.952 \text{ mm} \cdot \text{d}^{-1}$ during the harvesting period.

Keywords: growing season; evapotranspiration; SEBS model; Softmax classification method; land types; Hetao Irrigation District

1.1 Study Area and Data

The study area is located in the Hetao Irrigation District. During the 2017 growing season (May to September), we established 14 observation sites across five land use types, with each site covering an area of approximately 1 km². The land use types included water bodies, forest, cropland, grassland, and urban areas. Meteorological data were obtained from nine meteorological stations within the district, with supplementary data from surrounding stations used to fill gaps.

The measurement systems included micro-lysimeters, eddy covariance (EC) systems, and Bowen ratio-energy balance (BREB) systems. Soil moisture was measured using CS616 sensors installed at depths of 10 cm and 15 cm, with additional measurements at 20 cm depth for verification. Data were collected using a CR3000 datalogger at 30-minute intervals. The micro-lysimeters had a diameter of 20 cm and height of 30 cm, installed with PVC pipes and filled with undisturbed soil samples. Weighing was performed daily at 08:00 using a PL6001-L balance (Mettler Toledo Inc., precision 0.1 g). The EC system consisted of a CSAT3 sonic anemometer (LI-COR Inc.) and an LI-7500 open-path CO₂/H₂O analyzer installed at 1.5 m height, with a sampling frequency of 10 Hz. The BREB system measured temperature and humidity gradients using HFP01 heat flux plates (Hukseflux, Netherlands) and CNR4 net radiometers (Kipp & Zonen) at 7 m height.

[Figure 1: see original paper] Schematic diagram of research area elevation and location

[Figure 2: see original paper] Schematic diagram of micro-lysimeter, eddy covariance (EC) and Bowen-ratio-energy-balance (BREB) system

2. Methods

2.1 SEBS Model

The SEBS model [?] calculates evapotranspiration based on the surface energy balance equation:

$$R_n = G_0 + \lambda ET + H$$

where R_n is the net radiation ($\text{W} \cdot \text{m}^{-2}$), G_0 is the soil heat flux ($\text{W} \cdot \text{m}^{-2}$), λET is the latent heat flux ($\text{W} \cdot \text{m}^{-2}$), H is the sensible heat flux ($\text{W} \cdot \text{m}^{-2}$), $\lambda = 2.45 \times 10^6 \text{ J} \cdot \text{kg}^{-1}$ is the latent heat of vaporization, and ET is the evapotranspiration ($\text{kg} \cdot \text{m}^{-2} \cdot \text{s}^{-1}$).

(1) Net radiation (R_n) calculation:

$$R_n = (1 - \alpha)R_{swd} + R_{lwd} - \varepsilon\sigma T_0^4$$

where α is the albedo, R_{swd} is the downward shortwave radiation, R_{lwd} is the downward longwave radiation, ε is the emissivity, T_0 is the surface temperature ($^{\circ}\text{C}$), and σ is the Stefan-Boltzmann constant (5.67×10^{-8}).

(2) Soil heat flux (G_0) calculation:

$$G_0 = R_n[\Gamma_c + (1 - f_c)(\Gamma_s - \Gamma_c)]$$

where $\Gamma_c = 0.05$ for vegetation-covered surfaces and $\Gamma_s = 0.315$ for bare soil surfaces, and f_c is the vegetation cover fraction.

The model was validated using the FAO Penman-Monteith (PM) equation [?] as a reference, with additional comparisons against EC, BREB, and micro-lysimeter observations. The relative errors were 14.03% for PM, 18.34% for EC, 14.93% for BREB, and 16.66% for micro-lysimeter measurements, demonstrating the reliability of the SEBS model for regional ET estimation.

Note: Figure translations are in progress. See original paper for figures.

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