The Application of the Two-source Model Using High/Low Spatial Resolution Imagery and LiDAR Data to Estimate the Evapotranspiration of Tamarisk

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ABSTRACT

The invasion of Tamarisk (Salt cedar) in the riparian zone of rivers in the southwest of the US has become a concern to the water resource management community. Because of its strong ability to extract water it out-competes native riparian vegetation species for moisture, lowers the water table and increases soil salinity. This study aimed to provide reliable estimates of the amount of the water lost by tamarisk through ET.

The advances in remote sensing techniques and related data quality made it possible to provide spatial estimates of ET at a considerably higher resolution and reliable accuracy over a wide range of surface heterogeneity. Here we tested one of the soil-vegetation atmosphere transfer models namely the Two Source Model (TSM) to estimate surface energy fluxes and ET. The TSM was applied using high spatial resolution airborne imagery at 1.0 m resolution in the visible and NIR bands and about 4 m in the TIR band. The model was also applied using Landsat imagery at relatively low spatial resolution at 30.0 m. Detailed LiDAR-derived vegetation height map was used on both cases. Model estimates were compared to ground based measured fluxes using Bowen ratio towers.

METHODS

The TSM with the series resistance formulation (Fig. 1) of Norman et al. (1995) with the recent modifications (e.g. Li et al. 2005) is used. The model treats the surface components (i.e. soil and canopy) separately and estimates the corresponding energy fluxes by applies the surface energy balance for each. It combines the sensible heat (H) components at a level above the ground called air-canopy interface and estimates the latent heat flux (LE) as a residual of the available energy. LE is then extrapolated to daily ET estimate. The model known to have better performance over heterogeneous areas with low fraction of green cover such as naturally vegetation and row oriented crops covers.

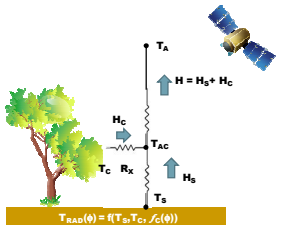

Fig. 1. Schematic of the Two-Source Model .

Generally, the TSM decomposes radiometric surface temperature into soil and canopy components based on fraction of vegetation $f_c(\phi)$ cover and view zenith angle ϕ (Eq. 1).

$$T_R(\phi) \approx \left[f_c(\phi) T_c^4 + (1 - f_c(\phi)) T_s^4 \right]^{1/4} \quad (1)\ ,$$

$$\left.\begin{aligned} H_c &= \rho C_p \frac{T_c - T_{ac}}{R_c} \\ H_s &= \rho C_p \frac{T_s - T_a}{R_s} \end{aligned}\right\} \quad (2)$$

It applies the resistance approach to estimate the relevant H_c and H_s (Eq. 2) with $H=H_c+H_s$. The net radiation, Rn, is estimated based on the physically based approach of Campbell and Norman (1998) (Eq. 3) and the soil heat flux (G) estimated as a fraction of Rn_s as $G=C_g\ Rn$.

$$\left.\begin{aligned} Rn_c &= Ln_c + \tau_s (1 - \alpha_c) S \\ Rn_s &= Ln_c + (1 - \tau_s)(1 - \alpha_c) S \end{aligned}\right\} \quad (3) \qquad \left.\begin{aligned} LE_c &= Rn_c - H_c \\ LE_s &= Rn_s - H_s - G \end{aligned}\right\} \quad (4)$$

The latent heat flux is calculated as the sum of its soil and vegetation components based on the surface energy balance (Eq. 4).

MATERIALS

The study was conducted over the Cibola National Wildlife Refuge (Fig. 2) in the riparian zone of the Lower Colorado River in southern California. The land cover dominated with Tamarisk trees (90%), Arrowweed, and shrubs interspersed with bare soil(Fig. 3 and 4). The data were collected during the summer of 2007-2008 as part of a project initiated and funded by the US Bureau of Reclamation for better water resources management over the Palo Verde Irrigation District.

Two airborne images were used with 1-m resolution in the visible and NIR bands and about 4-m in the TIR band in addition to two Landsat images with 30-m resolution in all bands (Fig. 5). Detailed vegetation height maps derived from LiDAR data (Fig. 3). Ground-based measurements include hydrometerological variables and surface energy fluxes were obtained from Bowen ratio systems deployed in the area (Fig. 2)

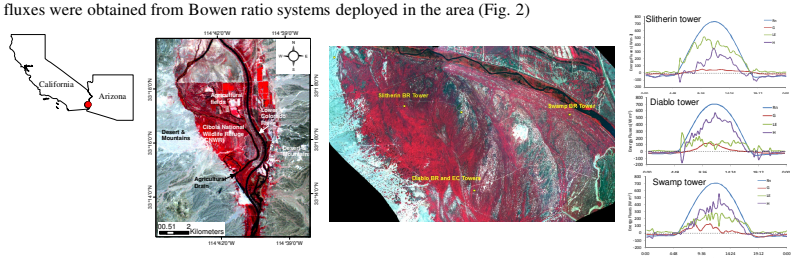

Fig. 2. Location of the study area , three BR towers were installed in the area based on the vegetation density and surface heterogeneity , and typical timeseries of energy fluxes measured by each tower on May 17th 2002.

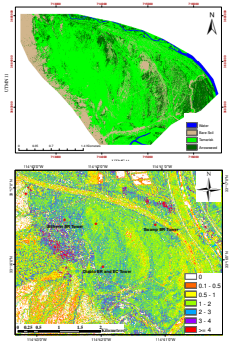

Fig. 3. Land cover/Land use (top) and LiDAR-derived canopy height (bottom) maps.

Fig. 4. Pictures showing the variability in the surface heterogeneity in the study area

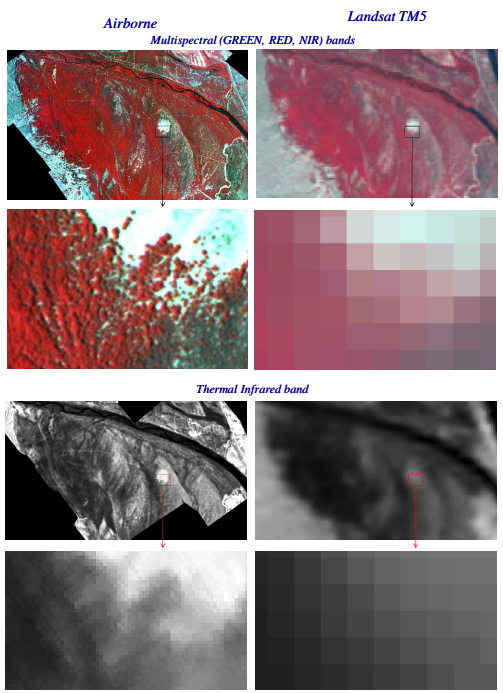

Fig. 5. Airborne (1-m) and Landsat TM5 (30-m) images in RGB for NIR, RED, and GREEN bands (top 4 images) and in the TIR (bottom 4 images) on June 16th 2002.

RESULTS

While this preliminary analysis are meant to see the applicability of the TSM using such high spatial resolution imagery; the results showed a reasonable agreement between estimated and measured with RMSE of 64 W m^{-2} when using Landsat images while it shows higher RMSE value of 90 Wm^{-2} with airborne images (Fig. 6 and 7). Estimates of Rn and G showed narrower scatters around the 1:1 line and a little wider scatter showed for H and LE. The estimated ET values showed RMSE of 1.46 and 1.68 mm day^{-1} based on Landsat and airborne images, respectively (Fig. 7). Similar results obtained in terms of the higher RMSE values with airborne compared to Landsat images over agricultural areas by Chavez et al 2009.

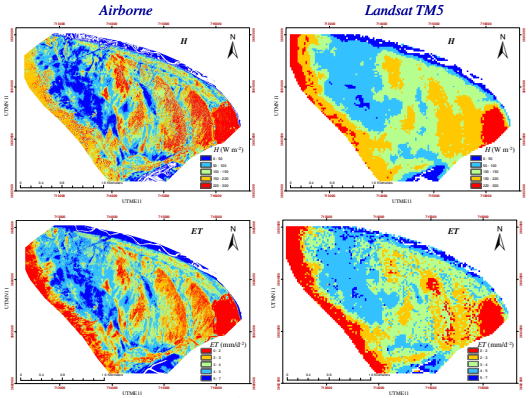

Fig. 6. Maps of instantaneous estimates Han d daily ET using airborne and Landsat imagery on June 16th 2002.

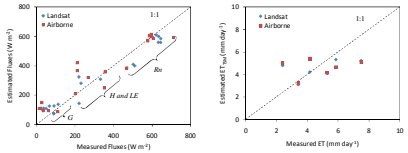

Fig. 7. Estimated vs. measured instantaneous energy fluxes and daily ET .

FUTURE

We will be testing the performance of the TSM using the parallel resistance formulation as well as a one-layer approach to see if there is any improvement.

More images will be included to cover to cover the seasonal growing pattern of Tamarisk.

Quantify the effects of using an offsite weather station instead of the in-situ measurements for models inputs.

REFERENCES

Li, F, W. P. Kustas, J.H. Prueger, C. M. U. Neale, and T. J. Jackson, 2005: Utility of remote sensing based two-source energy balance model under low and high vegetation cover conditions. *J. Hydrometeor.*, **6(6),** 878–891.

Norman, J. M., W. P. Kustas, and K. S. Humes, 1995: A two-source approach for estimating soil and vegetation energy fluxes in observations of directional radiometric surface temperature. *Agric. For. Meteorl.*, **77,** 263–293.

Chavez ,J. L., P. H. Gowada, T. A. Howell, C. M. U. Neale, and K. S. Copeland, 2009: Estimating hourly crop ET using a two-source energy balance model and multispectral airborne imagery. *Irrig. Sci.*, **28(1),** 79–91.

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