Mapping Annual Riparian Water Use Based on the Single-Satellite-Scene Approach

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Abstract

The accurate estimation of water use by groundwater-dependent riparian vegetation is of great importance to sustainable water resource management in arid/semi-arid regions. Remote sensing methods can be effective in this regard, as they capture the inherent spatial variability in riparian ecosystems. The single-satellite-scene (SSS) method uses a derivation of the Normalized Difference Vegetation Index (NDVI) from a single space-borne image during the peak growing season and minimal ground-based meteorological data to estimate the annual riparian water use, and this method was applied along a section of the Lower Colorado River for a 23-year period (1988-2010).

A pixel-based comparison with the estimates of a previously validated remotely sensed energy balance (RSEB) model for year 2008 showed good correlation ($R^2 = 0.86$), with a mean residual error of less than 104 mm·year^{-1} (18%). This error reduced to less than 95 mm·year^{-1} (15%) when larger areas were used in comparisons. The average annual water use over this period was 748 mm·year^{-1} for the entire study area, with large spatial variability depending on vegetation density. The MODIS evapotranspiration (MOD16) was 82% smaller, and the crop-coefficient approach employed by the US Bureau of Reclamation was 96% larger, when compared against SSS-ET.

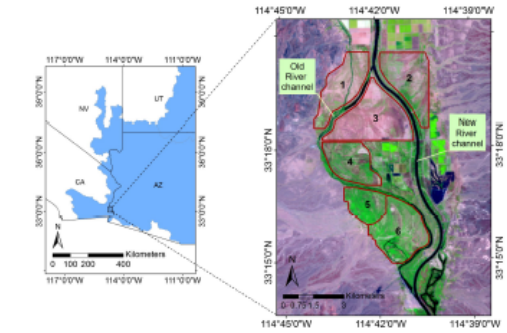
Objectives

To evaluate the performance of the SSS method using previously validated RSEB results, and to apply it over a 23-year period (1988–2010) to investigate inter-annual riparian ET variations across parts of the Cibola National Wildlife Refuge in the Lower Colorado River Basin.

Study Area

Cibola National Wildlife Refuge (CNWR) in the Lower Colorado River Basin

- established by the US Bureau of Reclamation in 1964
- about 70 sq. km. in the floodplains of the lower Colorado River
- average air temperature ranges from 4.0 °C in Dec. to 38.0 °C in Aug.
- average annual rainfall less than 100 mm
- more than 90% of CNWR is covered by tamarisk, followed by mesquite, cottonwood, willow, arrowweed, qualibush, and fourwing saltbush



Single-Satellite-Scene (SSS) Approach

A simple method of estimating annual riparian ET based on one mid-summer satellite image and ground-based meteorological data (Groeneveld et al. 2007).

$$ET = (ET_o - \text{Precipitation}) \times NDVI^* + \text{Precipitation}$$
$$NDVI^* = (NDVI - NDVI_o) / (NDVI_s - NDVI_o)$$

where ET_o is annual reference ET, NDVI* is a scaled NDVI, $NDVI_o$ is NDVI at zero vegetation cover and $NDVI_s$ is NDVI at saturation.

Assumptions:

- presence of shallow groundwater
- arid/semi-arid environment
- similar conditions before and after (homeostasis) the selected scene

Results

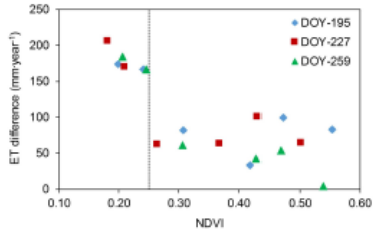
❑ *Sensitivity of the SSS method to the selection of a Landsat scene*

- maximum NDVI values of 0.49, 0.47, and 0.49 observed on day of year (DOY) 195 (13 July), 227 (14 August), and 259 (15 September)

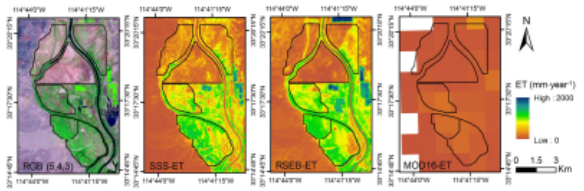
Scale	DOY	SSS-ET (mm·year^{-1})	RSEB-ET (mm·year^{-1})	R^2	Residual Error (mm·year^{-1})	Percent Error
Pixel-based	195	693	589	0.86	104	17.7
	227	692	589	0.87	103	17.5
	259	673	589	0.86	84	14.3
Area-wide	195	732	637	0.97	95	14.9
	227	727	637	0.96	90	14.1
	259	708	637	0.98	71	11.1

❑ *Sensitivity of the SSS method to NDVI*

- percent errors reduced to 6.8% (58 mm·year^{-1}), 5.0%, (42 mm·year^{-1}) and 2.4% (20 mm·year^{-1}) for DOYs 195, 227, and 259 when areas with NDVI less than 0.25 (low or no vegetation) were eliminated from analysis.

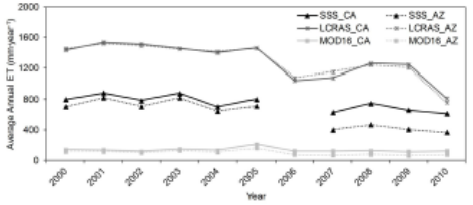


❑ *Comparison with RSEB-ET and MOD16-ET for year 2008*

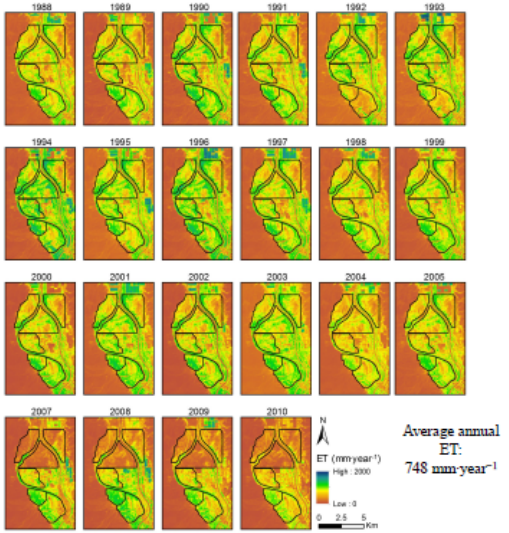


Results (continued)

❑ *Comparison with the USBR Lower Colorado River Accounting System (LCRAS) and MOD16 for CNWR areas in CA and AZ*



❑ *Interannual variation of riparian water use based on the SSS method*



Conclusions

- results showed good correlation with mean residual error less than 18% for pixel-based and 15% for area-wide comparisons
- errors reduced by more than a half after excluding areas with low vegetation
- MOD16-ET was 82% smaller and USBR LCRAS-ET was 96% larger than SSS-ET on average

References

Groeneveld, D.P.; Baugh, W.M.; Sanderson, J.S.; Cooper, D.J. Annual groundwater evapotranspiration mapped from single satellite scenes. *J. Hydrol.* **2007**, *344*, 146–156.

Acknowledgments

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