Inferring long-term water balance dynamics in forested watersheds: Tracing vegetation cover transitions

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HYDROLOGY

Single disturbance scenario

Validation of the K-curve through comparison of theoretical AET recovery with AET recovery from:

1) $dAET_{obs}$ from two FLUXNET sites following artificial disturbance from forest cutting (temperate forest in Campbell River, British Columbia)

2) $dAET_{WB}$ from paired-watershed studies (one treated- one non treated) over the last 40 years. Neglecting storage, annual AET_{WB} was estimated as annual P-Q.

Long-term water balance observations from three different sites experimental sites in Western North America:

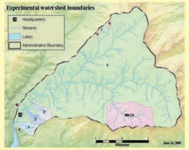
Flux Sites

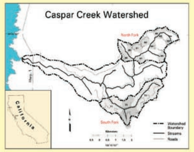
AET_{obs} at the plot scale from Eddy Covariance Fluxes (FLUXNET) from a forest chrono-sequence located on Vancouver Island, BC

Watershed	EC10	EC22	EC61
Latitude	49°52'14"N	49°32'5"N	49°52'2"N
Longitude	125°17'27"W	124°54'2"W	125°20'1"W
Elevation, m	175	170	300
MAT, °C	8.8	9.6	8.6
MAP, mm/yr	1410	1610	1470
Disturbance year	2000	1988	1949
Tree height, m	2.4	7.5	33
Leaf Area Index	1.1	5	7.3

Paired Watersheds

Long-term Precipitation (P) and streamflow (Q) observations from six paired watersheds located in HJ Andrews (Oregon) and Caspar Creek (California)

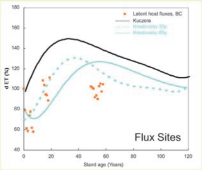


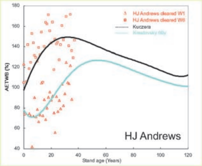


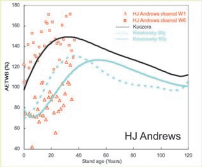
Watershed	HJA WS1	HJA WS2	HJA WS6	HJA WS8	Caspar N	Caspar S
Area, km^2	0.95	0.60	0.13	0.21	4.73	4.24
Elev. range, m	450-1027	572-1079	893-1029	968-1182	85-317	46-329
MAP, mm/yr	2300	2300	3550	3550	1200	1200
P-Q data	1959-2002	1959-2002	1963-2002	1963-2002	1978-2006	1963-2006
Stand history	100% clearcut 1962-1966	Control	100% clearcut 1974	Control	60% CC-burned 1985-1991	60% PC 1971-1973

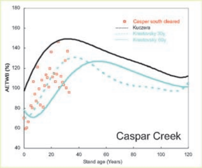
Results

Single disturbance: comparison of observed AET with K-curve









Introduction

The impact of environmental change on the dynamics of catchment water balance poses challenging questions in hydrology. This includes the separation of the response of of water balance components to land cover change from that of climate forcing. One important global land cover change is forest disturbance either by forest harvesting or natural disturbances.

Understanding the temporal and spatial variability of this response is relevant for prediction and regionalization. Among the water balance components actual evapotranspiration (AET) is the most difficult to measure and estimate but it is also the component that varies highly with climate and vegetation cover.

Aims

To develop and test an approach that allows the attribution of changes in actual evapotranspiration (dAET) in disturbed forested watersheds. The approach will provide a basis to study the role of long-term land use history in the long-term water balance variability in forested watersheds.

Specific aims:

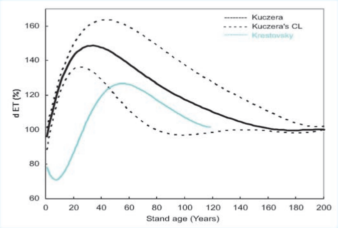
1) to validate an empirical model of water balance response to forest disturbance and regrowth for Western North America using existing data from **single disturbance** experiments.

2) to apply the model to a range of watereseds with **multiple historic disturbances** to reconstruct changes in evapotranspiration.

The K-curve

Time recovery models based on experimental data were proposed for evapotranspiration (Krestovsky, 1983) and streamflow (Kuczera, 1987). The shape of both recovery curves is relatively similar, but due to the characteristics of soil, vegetation and climate in both sites (Soviet Union and Australia) timing and magnitude of the curve differ.

Is the K-curve applicable in Western North America?



1) Plot scale: Despite climate noise most of the observed annual evapotranspiration values stay within the Krestovsky curve and Kuczera confidence limits. Largest differences and variablity were found for mature and old stand age periods. In Saskatchewan (not shown), climate and elevation may slow down the late stages of the K-curves.

2) Paired watersheds: at the HJ Andrews, the Krestovsky curve fits AET_{WB} in the one watershed (upper W6) while Kuczera was more suitable at another (lower W1). Long-term AET_{WB} in Casper Creek oscillated between Kuczera's lower confidence limit and Krestovsky's curve,

3) There is a correlation between AET_{WB} and the reconstructed AET by convolution of LCH. Nevertheless, the magnitude of the dAET (%) deviates from AET_{WB}.

Conclusions

The K-curves models are generally valíd to water balance recovery within 100 years after disturbances in a range of environments, but need to be adapted to regional conditions.

The growing season appears to play an imortant role in the magnitude and timing of recovery. Water storage as snow complicates the analysis based on AET_{WB}.

Climate change as well as other biogeographical variables are likely to influence the temporal water balance dynamics in forested watersheds under vegetation cover transitions.

The study supported the hypothesis that land cover history should be considered when performing statistical analysis of hydroclimatic data.

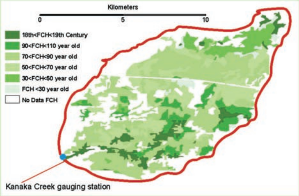
Multi-disturbance scenario

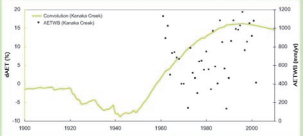
In reality land cover changes are not uniform in space and multiple distubances occur over a period of time.

Tracing vegetation cover transitions:

Here, dAET for a given watershed can be reconstructed by a convolution of forest cover history (FCH) with the K-curve model, and validated through comparison, e.g. correlation with known AET_{WB} where observations of P and Q exist for sufficiently long periods.

$$\Delta AET(t) = \sum_{t-m}^{t} FCH(\tau) Kr(t-\tau) d\tau$$



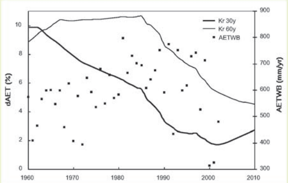


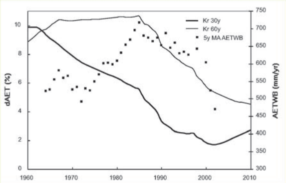
Long-term precipitation (P), streamflow (Q) and forest cover history (FCH) from six watersheds of unregulated rivers across British Columbia, Canada

Watershed Characteristic	08GA061 Mackay	08MH076 Kanaka	08EE008 Goathorn	08NH115 Sullivan	08NE087 Deer	08NF001 Kootenay
Area (km^2)	3.6	47.7	132	6.2	80.5	420
Elev. range (m.a.s.l)	98-1006	17-1046	642-2038	1082-1961	577-2157	1170-2783
P-Q (mm/yr)	1973-2002	1961-2002	1961-2002	1964-2002	1959-2002	1945-2002
MAP (mm/yr)	2622	2495	898	945	930	1075
Forest, %	57	64	72	97	95	71
Stand history (yr)	1756-1988	1755-1797	1754-1999	1773-1988	1757-2000	1668-1999
r^2 (MAP-AET_{WB})	0.04	0.13	0.68	0.58	0.50	0.59

Results

Multi-disturbance: comparison with K-curve





Correlation coefficients between reconstructed AET and observations

WB component	08GA061	08MH076	08EE008	08NH115	08NE087	08NF001
P-Q	0.54	0.24	0.18	0.18	0.31	-0.23
MA Q 5yr	-0.55	-0.59	-0.21	-0.42	-0.54	-0.20
MA P-Q 5yr	0.84	0.58	0.46	0.45	0.13	-0.33
MA (P-Q)/P 5yr	0.79	0.64	0.49	0.52	0.48	-0.32

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