ENVR 420
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Using the Horton Index to Describe Catchment-Scale Evapotranspiration: *A case study of the Umpqua River Catchment, OR.*

1. INTRODUCTION

1.1 Background

Brooks et al. (2011) provide a framework for evaluating vegetation response to variability in precipitation using catchment hydrologic data to quantify the relationships between different hydrologic parameters at the catchment scale. This gives us a way in which we can predict ecosystem responses to changes in the availability of water, especially the proportion made available as evapotranspiration – which is essentially a response to precipitation, runoff and temperature which controls terrestrial productivity at varying scales [Brooks et al., 2011; Schimel et al., 2001; Webb et al., 1983]. Horton Index (HI) is used to represent the ability of catchment vegetation to use plant available water, which is a key parameter for addressing ways in which hydrological partitioning can be telling of catchment runoff responses [Brooks et al., 2011]. The objective of this paper is to describe how patterns of hydrological partitioning are influencing catchment scale evapotranspiration (ET), described by changes in (HI).

1.2 Study Area

For this paper, data from a single catchment was used. Our study area is located near Elkton, Oregon, United States – which was randomly selected from a list of U.S. catchments with available hydrological and land-use (MOPEX) data.

Table 1. Descriptive Summary of the Umpqua River Catchment near Elkton, OR

Umpqua River Catchment	
Latitude [deg,mm,ss]	43º 35' 10'' NAD27
Longitude [deg,mm,ss]	123º 33' 15'' NAD27
Descriptive Location	Douglas County, OR
Hydrological Unit	17100303
Drainage Area (ha)	953893
MOPEX #ID	USGS 14321000

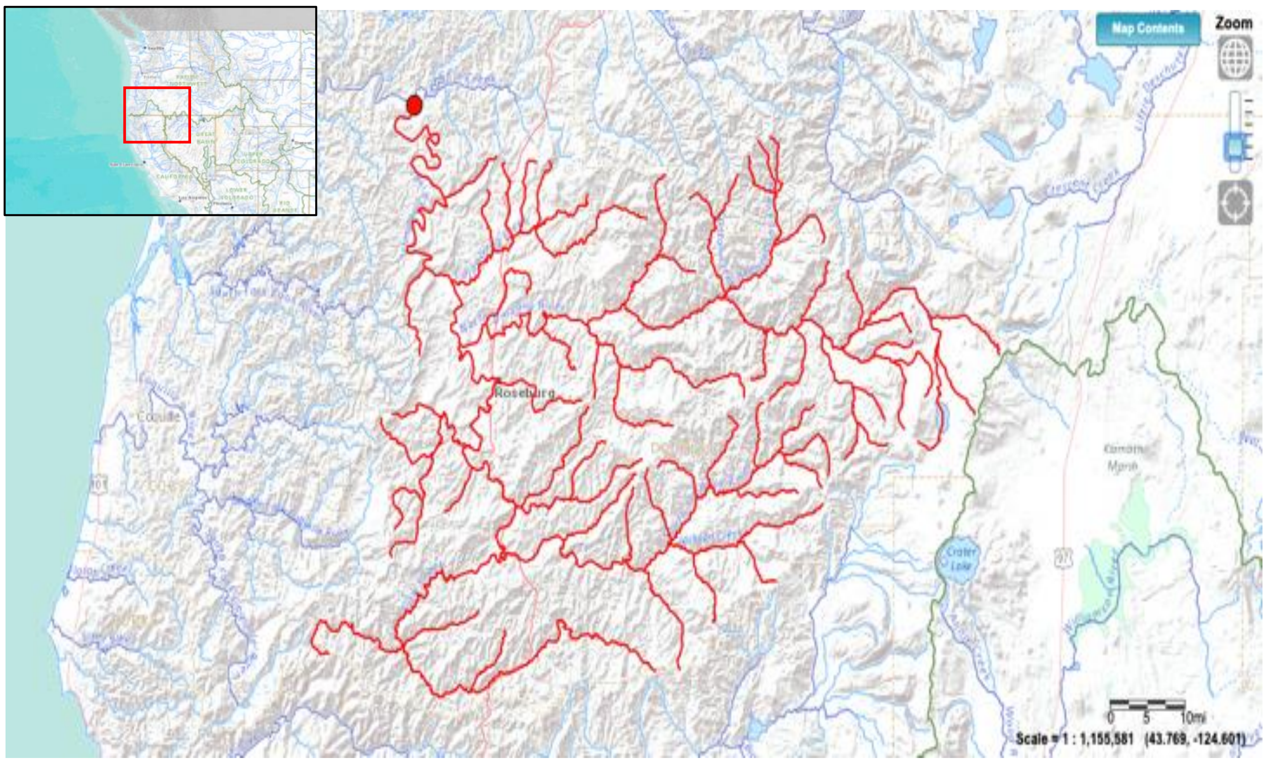

Figure 1. General location and drainage network of the Umpqua River catchment near Elkton, OR. Maps and drainage data taken from the USGS Streamer tool available at https://txpub.usgs.gov/DSS/streamer/web/

2. METHODS

2.1 MOPEX Dataset

The MOPEX data set (retrieved from: http://www.nws. noaa.gov/oh/mopex) contains hydrological and land cover data for 438 US catchments from 1948-2003 2003 [Brooks et al., 2011; Duan et al., 2006]. The Umpqua River catchment near Elkton, OR (#14321000) was chosen from this data set. Data was only considered for the years 1948-2000 due to missing values during 2000-2003 for this catchment.

2.2 Deriving Hydrological Variables

Data concerning evapotranspiration (ET) and catchment wetting (W) were obtained from catchment surface water flux data: precipitation (P), streamflow Q) and quickflow (S); where (S) can be described as the proportion of precipitation being routed as discharge [Eq. 1 and 2 - Brooks et al., 2011].

Horton Index, which is described as a dimensionless number {ranging from 0,1} that represents the proportion of catchment wetting (W) used in evapotranspiration (ET) [Eq. 3 - Brooks et al., 2011].

Streamflow (Q) was divided into components of baseflow (BF) and quickflow (QF); being the proportions of streamflow that are not due to precipitation (BF) and due to precipitation (QF).

2.3 Data Analysis in RStudio

Data for the Umpqua River catchment near Elkton, OR extracted from the MOPEX dataset by selecting the row associated with this watershed, and was given as daily values for precipitation, potential evapotranspiration, streamflow (also divided into baseflow and quickflow) and max / min temperature. This data was parsed into annual averages by taking the mean value for each year. The annual dataset was used in our calculations and figures.

3. RESULTS

3.1 Summary of annual variables

A summary table of annual variables was created by taking the mean of all average values from 1948 – 2000, expressed in mm/day (Table 2). Variables such as Precipitation (P), Runoff (Q) and Quick-flow (S) showed significantly high variability, whereas the Horton Index (HI) showed very low variability between years (Table 2).

Table 2. Annual summary table of variables from 1948 – 2000. Values are expressed as mean +/- standard deviation.

Variable	Mean	SD
(P) Precipitation [mm/day]	3.50	1.37
(Q) Runoff [mm/day]	2.02	1.05
(S) Quickflow [mm/day]	1.03	1.00
(W) Wetting [mm/day]	2.49	0.72
(ET) Evapotranspiration [mm/day]	1.50	0.73
(BF) Baseflow [mm/day]	0.99	0.20
(HI) Horton Index	0.60	0.03
(T) Temperature [Deg. C]	6.19	0.279

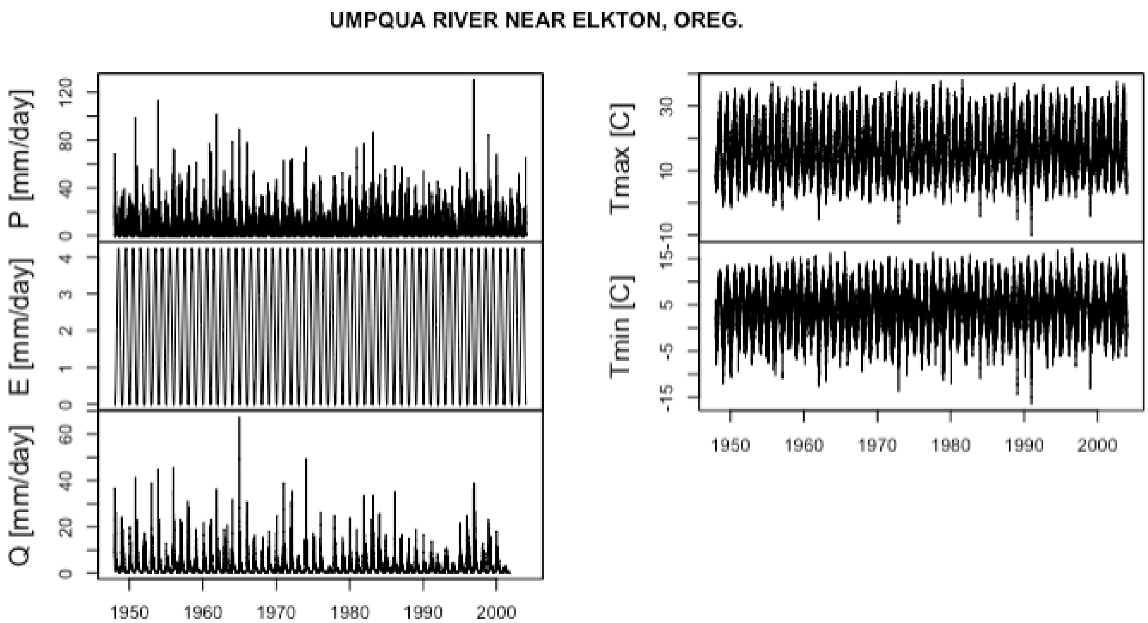

Figure 2. Time series of annual data for the Umpqua River Watershed for the duration of the study period. Plots provide context for mean annual data presented in Table 2.

3.2 Horton Index

Across all sites and years, the Horton Index average was shown to be 0.60 +/- 0.03 (Table 2), which indicates that 60% of catchment wetting (W) was used as ET. [Brooks et al., 2011]. This means that the Umpqua River watershed used less than two-thirds of available water as ET (HI < 0.67) [Brooks et al., 2011]. Figure 2 shows HI increasing over time, which indicates that the proportion of available water used as ET has been decreasing over time, since HI = ET / W [Brooks et al., 2011].

An average annual standard deviation of 0.03 (Table 2) means that on average, the proportion of available water used as ET varied by 3%, which is fairly consistent at the watershed scale (Brooks et al., 2011). Looking at the time series of annual HI variability (Figure 4), we can see no significant linear trend over the duration of the study period.

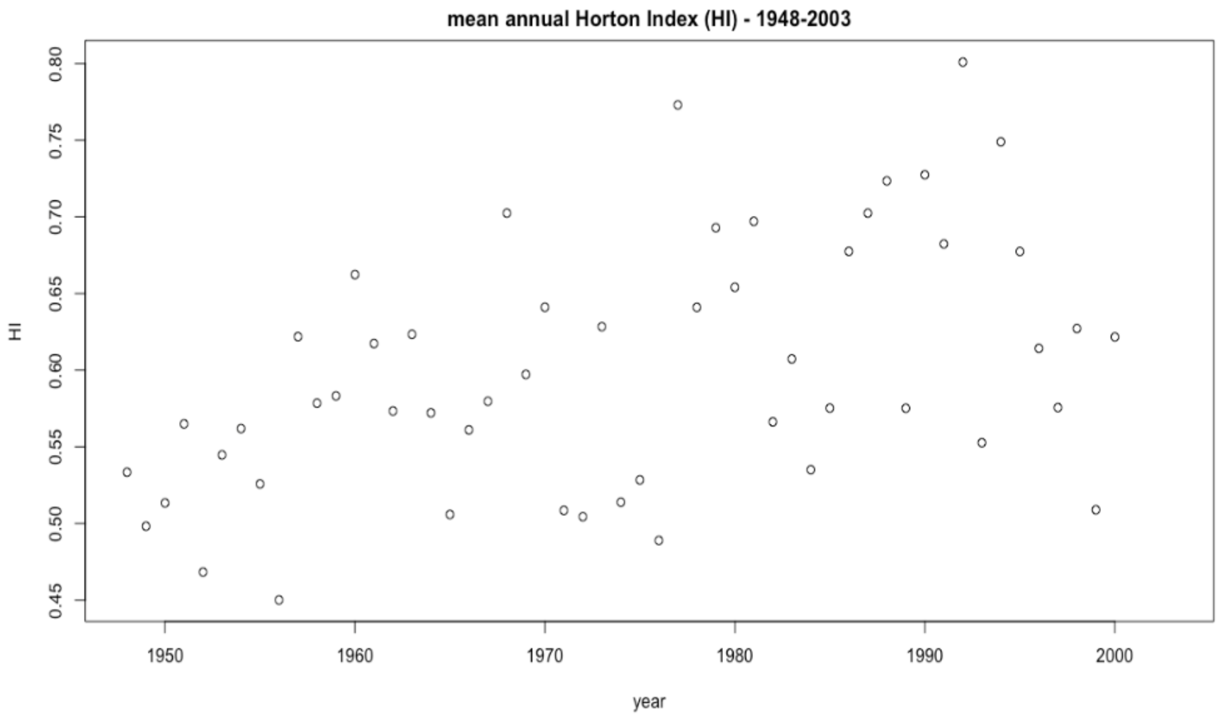

Figure 3. Mean annual Horton Index (HI) expressed as ET / W proportion shows a positive linear relationship; increasing over the years 1948 – 2000.

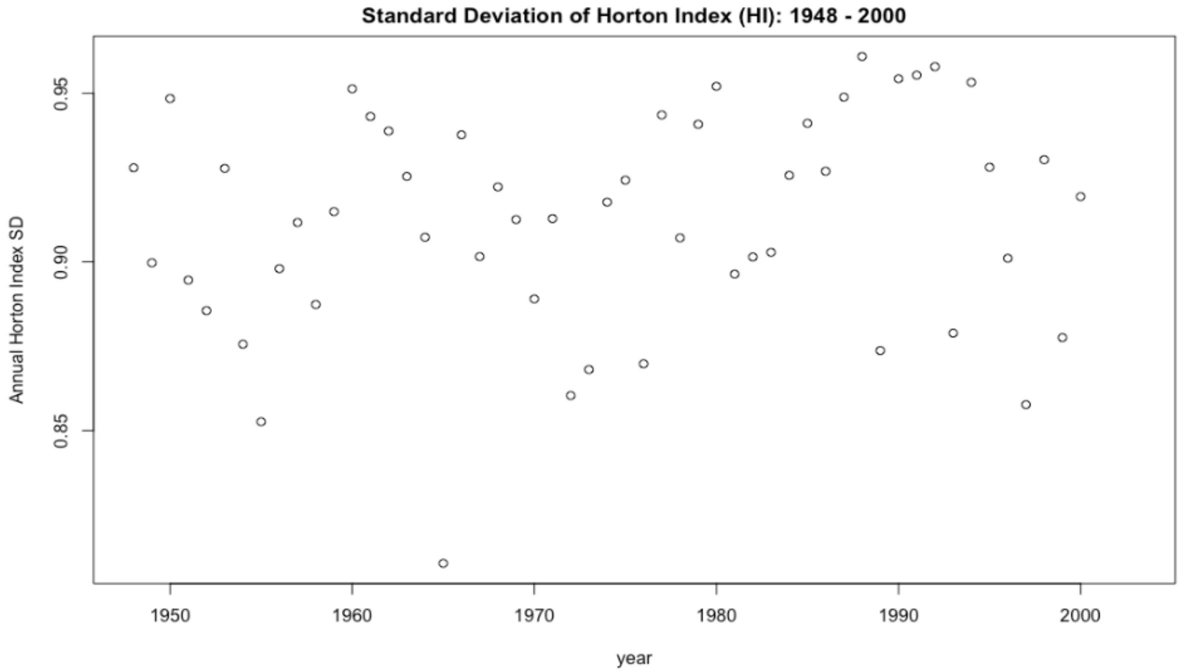

Figure 4. Time series of annual Horton Index (HI) standard deviations from 1948-2000.

4. DISCUSSION

4.1 Interpretation of Horton Index

The relationship between available water (W) to water use (ET) allows us to measure the limitations of water use by vegetation which are controlled by changes in precipitation [Brooks et al., 2011]. When looking at trends in annual Horton Index values, we can establish a connection between the proportions of available water used as ET and W (Brooks et al., 2011). With that in mind, we have seen that the proportion of available water used as ET decreased over the duration of the study period; from 1948 – 2000, since HI has been increasing over time (Figure 3). Given that no significant trends in max/min temperature, precipitation and runoff have been established over time (Figure 2), we must check the correlation between ET and other variables in order to make any statements about trends occurring in ET over time.

4.2 Interpretation of changes in Evapotranspiration

Figure 5 shows the connection between ET and Precipitation / Temperature. The highest correlation coefficient was seen between ET and Minimum annual temperature (T Min): $r = 0.7047$. This indicates ET may be driven in part by lower temperatures usually seen in Pacific North-West winters (November – March), when the catchment is experiencing a massive influx of water; most of which is lost as streamflow. Our results are not necessarily able to demonstrate the effects of seasonality on ET due to annual data expressed as the average for the given year. Therefore, we should note that these correlations only represent long term trends in the Umpqua River catchment.

The effects of logging and forestry in the Umpqua River catchment may also be having effects on the available plant water being used as ET. Since this watershed is heavily forested, land use changes will drastically alter the Horton Index; changing soil properties will alter the proportion of incoming precipitation being routed as quickflow (i.e. catchment wetting (W)), as well as the amount of water not only being taken up as ET by plant transpiration but being recycled as ET at the catchment scale.

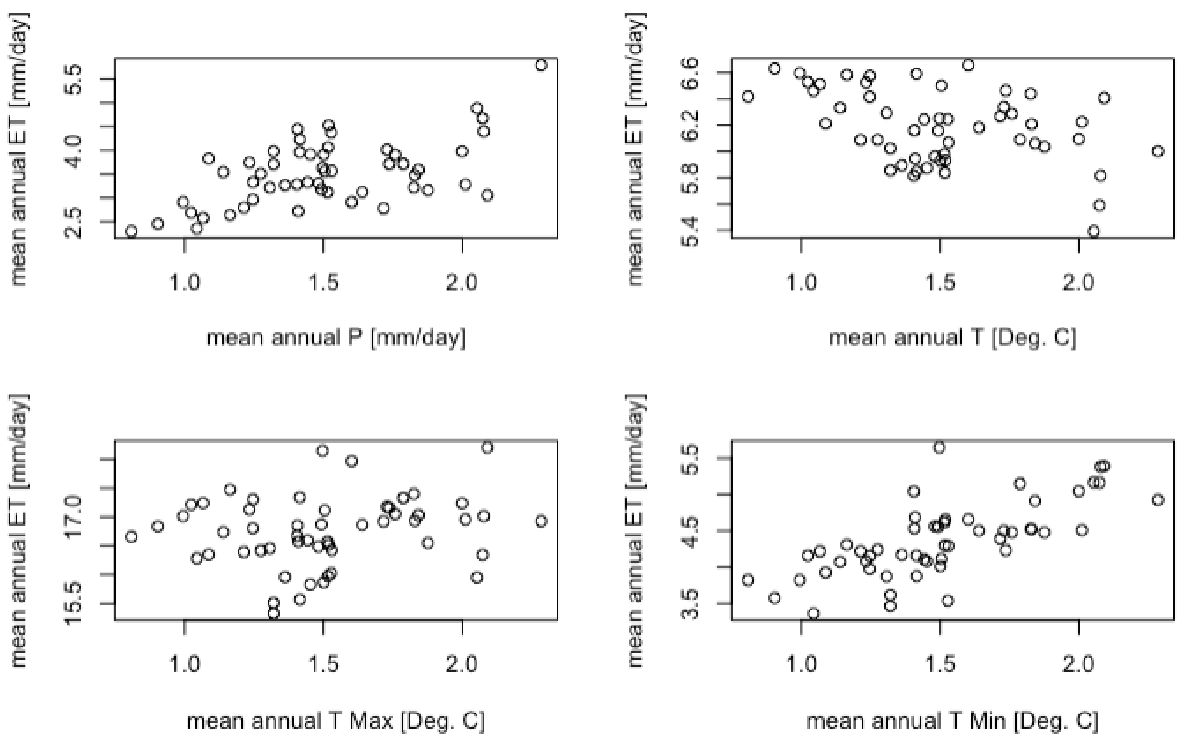

Figure 5. Correlation between ET and Precipitation (P): r = 0.5763, Average Temperature (T): r = -0.4389, Maximum Temperature (T Max): r = 0.1825, and Minimum Temperature (T Min): r = 0.7047. Values expressed as the mean every year from 1948 – 2000.

5. CONCLUSION

In summary, the Horton Index (HI) can be used as a method for representing the ability of catchment vegetation to use plant available water, and helps to quantify the effects of hydrological partitioning on catchment runoff responses. The objective of this paper was to use

(HI) in describing how patterns of hydrological partitioning are influencing catchment scale evapotranspiration (ET). The proportion of plant available water used as ET have decreased from 1948 – 2000, which may be explained by the variation in catchment seasonality over time. A strong correlation between ET and Minimum mean annual temperature was shown, but does not necessarily explain this trend. Further research into the effects of land-use change and ET may be relevant in explaining the precise relationship between hydrological partitioning and catchment runoff responses.

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