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MODELING ACTUAL EVAPOTRANSPIRATION FROM FORESTED WATERSHEDS ACROSS THE SOUTHEASTERN UNITED STATES[1]

Jianbiao Lu, Ge Sun, Steven G. McNulty, and Devendra M. Amatya[2]

ABSTRACT: About 50 to 80 percent of precipitation in the southeastern United States returns to the atmosphere by evapotranspiration. As evapotranspiration is a major component in the forest water balances, accurately quantifying it is critical to predicting the effects of forest management and global change on water, sediment, and nutrient yield from forested watersheds. However, direct measurement of forest evapotranspiration on a large basin or a regional scale is not possible. The objectives of this study were to develop an empirical model to estimate long-term annual actual evapotranspiration (AET) for forested watersheds and to quantify spatial AFT patterns across the southeast. A geographic information system (GIS) database including land cover, daily streamflow, and climate was developed using long term experimental and monitoring data from 39 forested watersheds across the region. Using the stepwise selection method implemented in a statistical modeling package, a long term annual AET model was constructed. The final multivariate linear model includes four independent variables - annual precipitation, watershed latitude, watershed elevation, and percentage of forest coverage. The model has an adjusted R^2 of 0.794 and is sufficient to predict long term annual AFT for forested watersheds across the southeastern United States. The model developed by this study may be used to examine the spatial variability of water availability, estimate annual water loss from mesoscale watersheds, and project potential water yield change due to forest cover change.
(KEY TERMS: regional evapotranspiration; land use change; forest hydrology; modeling; regression.1

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INTRODUCTION

Evapotranspiration (ET) is a major component of the hydrological balance representing the water flux that returns to the atmosphere from land surfaces. On the global scale, it represents more than 60 percent of precipitation inputs (Vörösmarty *et al.*, 1998) and more than 70 percent of the annual precipitation for the entire United States (Brooks *et al.*, 1997). In the southeastern United States, more than half the land area is forested, and ET from forested watersheds can vary from 85 percent of annual precipitation in coastal Florida flatwoods to 50 percent in the cool southern Appalachian Mountains (Sun *et al.*, 2002). In general, forest ecosystems have higher ET rates than nonirrigated agricultural or urban settings (Arnold and Gibbons, 1996).

Qualifying evapotranspiration is essential in ecological research on global change. The most direct effect of climate and land use change on watershed ecohydrology is alteration of the magnitude and distribution of evapotranspiration (Dow and DeWalle, 2000), and consequently on streamflow and water quality. Evapotranspiration is also an indicator of ecosystem productivity; in fact, it is the only variable that links hydrology and biological processes in most current ecosystem models (Aber and Federer, 1992). Evapotranspiration also is a measure of available environmental energies and can be used as an indicator of biodiversity. For example, Currie (1991) found that in the four vertebrate classes studied, 80 to 93 percent of the variability in species richness could be statistically explained by a monotonically increasing function of a single variable, potential evapotranspiration (PET). In contrast, tree richness was more closely related to actual evapotranspiration.

Actual evapotranspiration (AET) depends on climatic conditions and land surface characteristics. The

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[2]Respectively, Graduate Assistant and Research Assistant Professor, Department of Forestry, North Carolina State University, 920 Main Campus Drive, Venture II, Suite 300, Raleigh, North Carolina 27606; Project Leader, Southern Global Change Program, USDA Forest Service, 920 Main Campus Drive, Venture II, Suite 300, Raleigh, North Carolina 27606; and Research Hydrologist, Center for Forested Wetland Research, USDA Forest Service, 2730 Savannah Highway, Charleston, South Carolina 29414 (E-Mail/Sun: Ge_Sun@ncsu.edu).

key controls on forest evapotranspiration are rainfall interception, net radiation, advection, turbulent transport, leaf area, and plant available water capacity (Zhang *et al.*, 2001; Fritschen and Simpson, 1985). Direct or semidirect (scaling involved) measurements of southeastern forest transpiration at the tree and stand levels by the porometer or eddy flux methods have been reported for slash pine (Riekerk, 1985; Liu, 1996; Clark *et al.*, 2001), pond cypress (Liu, 1996), melaleuca (Chin, 1998) and Appalachian upland hardwoods (Wullschleger *et al.*, 2001). However, for watershed-level ET, the most practical approach is still the water balance method that calculates ET as the difference between precipitation and runoff and change on water storage (Ewel and Smith, 1992; Wilson *et al.*, 2001). One way to estimate regional scale AET is by scaling up measurements at the point or small watershed scales by statistical analysis.

Evapotranspiration changes in space and time. Accurate quantification of evapotanspiration at a regional scale would better prepare us for future changes in water resources management and conservation (Saxton and Cordery, 1988; Szilagyi, 2001). The objective of this study was to develop a regression model that uses readily available data to estimate long term annual AET for forest dominated watersheds across the southeastern United States. A reliable evapotranspiration model will allow us to understand the variability of water availability and predict potential changes of water resources in the southeastern United States.

METHODS

Study Sites and Database Development

Databases for streamflow, climate, land cover, and watershed properties were compiled from 39 watersheds across the southeastern United States that had either long term forest hydrology research records or were basins gauged by the U.S. Geological Survey (USGS) with long term runoff data (Figure 1). For the large basins, we intended to select those that are dominated by forest covers. As indicated by the long term annual runoff ratio (Runoff/Precipitation) that ranges from 0.18 in Florida to 0.67 in western North Carolina, the selected watersheds cover a large spectrum of hydrologic conditions (Table 1). Among the 39 watersheds, six were small watersheds (0.25 to 29.5 km^2): Bradford Forest (control watershed) in north central Florida (Riekerk, 1989; Sun *et al.*, 1998), Carteret and Parker Tract watersheds in coastal North Carolina (Amatya and Skaggs, 2001; Amatya *et al.*, 2002), Walker Branch watershed in Tennessee (Johnson and Hook, 1989), Coles Forks watershed in the Robinson Experimental Forest, Kentucky (Arthur *et al.*, 1998; R. Kolka, University of Kentucky, unpublished data), and Santee Experimental Forest (watershed 80) in coastal eastern South Carolina (Sun *et al.*, 2000). Both Walker Branch and Coles Forks watersheds are located on uplands of the Appalachian Mountains. Other USGS gauged watersheds (200 to 8,213 km^2) include 12 in North Carolina that

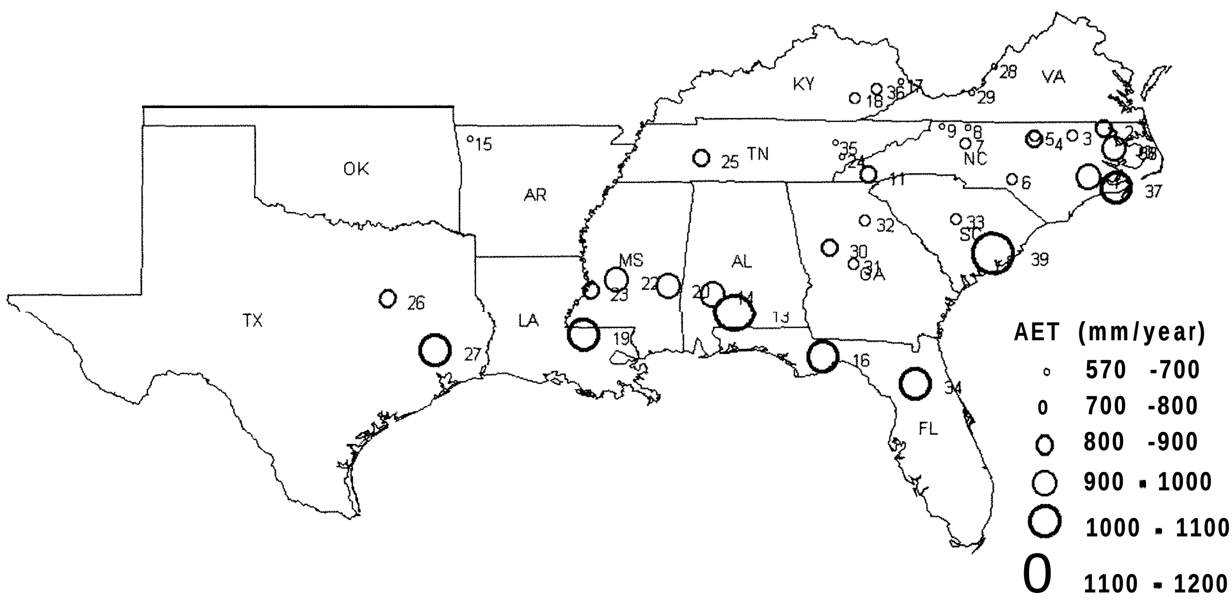

Figure 1. Watershed Location and Actual Evapotranspiration Estimated by the Water Balance Across the Southeastern U.S. (numbers represent watershed IDs).

TABLE 1. Physical and Hydrometeorology Characteristics of Watersheds Across the Southeastern U.S.
Three watersheds (ID 10, 12, 21) were eliminated as outliers from the database.

Watershed ID	Watershed	Area (km^2)	Forest Cover (percent)	Elevation (m)	No. of Years of Hydrology Data	Avg. Temp. (°C)	Rainfall (mm/yr)	Runoff (mm/yr)	Runoff/ Rainfall Ratio
1	Trent River, N. Carolina	435.12	71.6	30	29	11.73	1,321	398	0.30
2	Potecasi Creek, N. Carolina	582.75	65.2	24	30	14.17	1,151	350	0.30
3	Fishing Creek, N. Carolina	458.43	82.3	47	30	15.43	1,123	324	0.29
4	Eno River, N. Carolina	365.19	72.8	193	27	14.64	1,213	317	0.26
5	Flat River, N. Carolina	385.91	69.1	135	30	14.27	1,122	331	0.29
6	Drown. Creek, N. Carolina	473.97	74.4	149	30	12.32	1,183	480	0.41
7	Hunting Creek, N. Carolina	401.45	68.2	322	30	15.24	1,188	476	0.40
8	Fisher River, N. Carolina '	331.52	74.6	322	30	14.56	1,159	502	0.43
9	New River, N. Carolina	530.95	79.6	955	29	15.65	1,441	755	0.52
11	Little Tennessee, N. Carolina	362.60	89.9	897	30	10.05	1,825	971	0.53
13	AL03140303	455.84	84.8	109	16	18.90	1,628	516	0.32
14	AL03150203	253.82	74.1	70	30	17.90	1,486	486	0.33
15	AR11010001	1,036.00	62.0	432	27	13.97	1,124	480	0.43
16	FL03120003	264.18	68.8	41	26	19.12	1,665	637	0.38
17	KY05070203	533.54	97.0	312	30	11.77	1,076	412	0.38
18	KY05100203	1869.98	97.1	358	30	12.55	1,235	521	0.42
19	LAO8070202	375.55	63.0	56	30	18.64	1,617	575	0.36
20	MS03170002	2,377.62	81.8	99	30	17.37	1,427	505	0.35
22	MS03180002	8,212.89	66.2	110	30	17.82	1,458	506	0.35
23	MS08060203	1,693.86	72.5	83	29	18.64	1,338	478	0.36
24	TN06010204	5,146.33	83.6	576	30	13.55	1,517	832	0.55
25	TN06040004	1,157.73	78.5	238	30	13.93	1,485	616	0.41
26	TX12030201	367.78	45.0	112	22	18.63	1,051	200	0.19
27	TX12040103	841.75	73.6	62	30	20.32	1,263	259	0.21
28	VA02080201	852.11	87.1	633	30	10.93	1,069	418	0.39
29	VA05050002	577.57	78.7	760	30	10.42	1,053	480	0.46
30	GA03130005	704.48	74.9	213	30	16.21	1,306	469	0.36
31	GAO3070103	471.38	72.5	205	30	18.12	1,134	364	0.32
32	GAO3070101	1,015.28	66.8	270	30	16.47	1,263	493	0.39
33	SC03050110	155.40	66.9	72	24	18.39	1,197	435	0.36
34	Bradford, Florida	1.40	100	44	13	20.88	1,241	226	0.18
35	Walker Branch, Tennessee	1.01	100	308	22	13.88	1,331	660	0.50
36	Coles Fork, Kentucky	16.60	100	378	18	11.65	1,155	377	0.33
37	Carteret, N. Carolina	0.25	100	3	13	16.29	1,539	520	0.34
38	Parker, N. Carolina	29.50	100	6	5	15.03	1,249	288	0.23
39	Santee-80, N. Carolina	1.50	100	7	5	18.13	1,382	246	0.18

represent three topographic regions (costal plains, Piedmont, and mountains), 17 studied by Liang *et al.* (2002), and four supplemental watersheds in South Carolina and Georgia.

Detailed procedures on database development are found in Lu (2002). Three watersheds (watersheds 10, 12, 21) were found to be outliers where precipitation measurements were suspected of having significant errors (mismatch between weather station and watershed) or that did not meet our criteria for land compositions. Therefore, only 36 watersheds were used for final statistical analyses (Table 1).

The following watershed characteristic and meteorological variables were acquired or derived from historic hydrometeorlogic records: (1) watershed location (latitude, longitude) and elevation; (2) percentage of five land cover types, including deciduous forests, conifer forests, water body, crop grass, and other; (3) annual precipitation (P) and annual streamflow (Q); and (4) monthly mean air temperature (T), maximum temperature (T_{max}), minimum temperature (T_{min}), relative humidity (RH), solar radiation (R_s), extraterrestrial solar radiation (R_a), and net radiation (R_n). Land cover types were derived from the 1992 National Land Cover Data set (Vogelmann *et al., 2001).* Watershed boundaries for the USGS watersheds were derived from the Digital Elevation Model (DEM) using GIS, and then the boundaries were used to derive land cover percentages. Since net radiation (R_n) is not available for any of the selected sites, this variable was derived empirically from solar radiation (Castellvi *et al.,* 2001).

"Measured" annual watershed scale AET values were estimated by the water balance equation, assuming change in water storage is negligible (Church et al., 1995; Zhang, *et al.,* 2001). On the long term annual basis, AET for each site was simplified as the difference between precipitation and runoff.

AET Model Building

Since AET is highly correlated to PET and often is a fraction of it (Federer *et al.,* 1996), we considered PET that was estimated by six methods as independent variables. The six PET methods are three temperature based methods, Thornthwaite (Thornthwaite and Mather, 1955, uncorrected), Hamon (1963), and Hargreaves-Samani (1985), and three radiation-based methods, Turc (1961), Makkink (1957), and Priestley and Taylor (1972). We conducted a comparison study to identify preferred PET methods using the same watershed hydrology datasets (Lu, 2002). We found that these six PET methods gave significantly different PET values and thus care must be taken when using a particular method, especially temperature based models that tend to yield higher (Hargreaves-Samani) or lower (Thornthwaite) annual estimates than others. We concluded that the Priestley and Taylor, Turc, and Hamon methods had the highest potential for regional applications in the southeastern United States (Lu, 2002).

Twenty-three variables were initially used for building the model (Table 2). A linear relationship is assumed between the dependent variable (AET) and the independent variables. Multiple linear regression analysis was used to fit one line to the observed data. The goal is to develop a model to predict AFT in terms of least squares (Rawlings *et al., 1998).* The SAS 8.2 (SAS Institute Inc., 2001) was used as a tool to derive the model using the stepwise selection and R squared methods.

The stepwise selection method has two criteria: one for variables to enter the model and the other for variables to stay in the model. The variable selection process terminates when all variables in the model meet the criterion to stay and no variables outside the model meet the criterion to enter.

The R squared method was also used to assist selecting the best independent variables. This method can compute all possible regressions; in other words, it considers all possible combinations of independent variables. For each particular number of variables in the model, the five best subset regressions are selected by R^2, which is defined as the ratio of the regression sum of squares to the total sum of squares and which is used as a standard to measure the dependent variable variation associated with the independent variables.

Regression Diagnostics

"Regression diagnostics" refers to the general class of techniques for detecting problems in regression raised either by the model or the data set. In this study, rigorous regression diagnostics composed of residual analysis, influence statistics, and collinearity diagnostics were conducted after model building (Rawlings *et al.,* 1998). Residual analysis, or analysis of some transformation of the residuals, is very useful for detecting inadequacies in the model or problems in the data. The purpose of influence statistics is to detect influential points that have negative effects on the regression results and cannot be detected by residual analysis. In this study, Cook's D (Rawlings et *al.,* 1998) was used to determine influential points. Cook's D is a combined measure of the impact of influential point on all regression coefficients. Collinearity diagnostics serves to detect collinearity among the independent variables in the regression model. The presence of collinearity implies that there are near-redundancies among the independent variables. The impact of the collinearity on least squares is very serious if primary interest is in the regression coefficients per se or if the purpose is to identify "important" variables in the process. The estimates of the regression coefficients can differ greatly from the parameters they are estimating, even to the point of having incorrect signs. Condition index was used to detect collinearity in this study. These three model diagnostics ensure that the regression model gives unbiased estimation when applied in the region.

TABLE 2. Variables Used in the AET Model Building.

Variable	Description
Rainfall	Long Term Mean Annual Precipitation (mm)
Temp	Long Term Mean Daily Temperature (°C)
R_s	Long Term Mean Daily Solar Radiation ($MJ/m^2/day$)
RH	Long Term Mean Daily Relative Humidity (percentage)
R_n	Long Term Mean Daily Net Radiation ($MJ/m^2/day$)
R_a	Long Term Mean Daily Extraterrestrial Solar Radiation ($MJ/m^2/day$)
T_{max}	Long Term Mean Daily Maximum Temperature (°C)
T_{min}	Long Term Mean Daily Minimum Temperature (°C)
Thorn	Long Term Mean Annual PET Estimated by the Thornthwaite Method (mm)
Hamon	Long Term Mean Annual PET Estimated by the Hamon Method (mm)
Turc	Long Term Mean Annual PET Estimated by the Turc Method (mm)
PT	Long Term Mean Annual PET Estimated by the Priestley-Taylor Method (mm)
Makk	Long Term Mean Annual PET Estimated by the Makkink Method (mm)
HS	Long Term Mean Annual PET Estimated by the Hargreaves-Samani Method (mm)
Latitude	Watershed Latitude by the Stream Gauging Station (degree)
Longitude	Watershed Longitude by the Stream Gauging Station (degree)
Elevation	Mean Watershed Elevation (m)
Deciduous	Long Term Percentage of Watershed Covered by Deciduous Forests
Conifer	Long Term Percentage of Watershed Covered by Conifer Forests
Water	Long Term Percentage of Watershed Covered by the Water Body
Crop, Grass	Long Term Percentage of Watershed Covered by the Crop or the Grass
Others	Long Term Percentage of Watershed Covered by Others
Forest	Long Term Percentage of Watershed Covered by Forests

RESULTS

Regional AET Distribution

Long term annual AET calculated by the watershed water balance method (AET = precipitation - streamflow) varies greatly in the southeastern United States, ranging from less than 600 mm in Virginia uplands (Watershed ID 29) to greater than 1,100 mm in coastal Alabama (Watershed ID 13) and South Carolina (Watershed ID 39) (see Figure 1 and Table 3). It appears that both atmospheric demands represented by PET and water availability indicated by rainfall amount play dominant roles in water loss from southeastern ecosystems. For example, the watershed in Texas (Watershed ID 26) received moderate precipitation (1,051 mm) but a high Priestley-Taylor PET (> 1,200 mm), while the AET was much higher (851 mm) than at a Kentucky site (ID 17; AET = 666 mm) that received similar precipitation (1,076 mm) but was much cooler (PET < 900 mm). For a similar reason, there is an obvious AET gradient from the coastal plains to the Appalachians in North Carolina (Figure 1).

The AET Regression Model

At a significance level of 0.25 for both entry and stay level, out of 23 variables only rainfall, latitude, elevation, conifer, and water were included in the regression model (Table 4) by the stepwise selection method. The R squared method confirmed that it was the best subset model among those that include five independent variables. It is interesting to note that extraterrestrial solar radiation (R_a) and relative humidity (RH) immediately entered the model as the first two sets of variables but eventually were removed from the final model after rainfall and latitude were introduced (Table 4). However, we found a negative coefficient for the water variable. The negative sign of water suggests that more water bodies will result in lower AET; thus the model is contrary to the hydrological principle. Therefore, the water variable was eliminated from the variable list, and we

TABLE 3. Residual Analysis, Influence Statistics, and Collinearity Diagnostics for the AET Model.

Watershed ID	AET Data (mm/yr)	Predicted AET (mm/yr)	Residuals (mm/yr)	R Student	Student	Cook's D
25	869	866	3	0.05	0.05	0.00006
3	798	804	-6	-0.09	-0.09	0.00017
7	712	721	-9	-0.14	-0.14	0.00029
22	953	941	13	0.18	0.19	0.00063
19	1,042	1,034	8	0.13	0.13	0.00069
14	999	985	14	0.22	0.22	0.00077
15	643	655	-12	-0.18	-0.19	0.00094
37	1,019	1,010	9	0.14	0.14	0.00107
30	837	863	-26	-0.39	-0.39	0.00128
32	771	802	-31	-0.48	-0.49	0.00273
34	1,015	1,022	-7	-0.14	-0.14	0.00357
2	801	782	19	0.31	0.31	0.00392
20	922	969	-47	-0.72	-0.73	0.00682
5	791	753	38	0.61	0.61	0.00781
18	714	756	-42	-0.65	-0.66	0.00957
8	657	717	-60	-0.92	-0.93	0.01054
29	573	545	28	0.46	0.47	0.01230
31	770	817	-47	-0.73	-0.74	0.01343
1	923	874	49	0.77	0.78	0.01376
23	859	930	-71	-1.09	-1.09	0.01493
17	664	711	-47	-0.76	-0.76	0.01824
33	761	837	-76	-1.18	-1.17	0.01909
36	778	726	52	0.84	0.84	0.02107
6	703	802	-99	-1.55	-1.51	0.02255
13	1,113	1,052	61	0.97	0.97	0.02664
16	1,029	1,078	-49	-0.81	-0.81	0.02738
27	1,004	952	52	0.84	0.84	0.02771
28	651	588	63	1.02	1.02	0.03770
38	961	898	63	1.03	1.03	0.04002
4	896	774	122	1.98	1.89	0.05197
24	684	789	-105	-1.70	-1.65	0.07022
9	687	631	56	0.99	0.99	0.07747
11	854	814	40	0.79	0.80	0.09000
26	851	783	68	1.20	1.19	0.10692
35	672	833	-161	-2.80	-2.53	0.13875
39	1,135	1,000	135	2.33	2.18	0.15942

rebuilt the model by using the same procedures with 22 variables. Consequently, the stepwise selection method identified R_a, rainfall, elevation, and forest (Table 5) as the most significant independent variables. The R squared method also suggested that these four variables were the best variable combination for building the regression model (R^2 = 0.818). However, we found that the second best model (R^2 = 0.817) with four variables, including latitude, rainfall, elevation, and forest, was equally acceptable for the regression model. Furthermore, from the point of view of regional data availability, latitude is much easier to obtain than extraterrestrial solar radiation (R_a), so we chose the second set of variables as a finalist (Equation 1).

The multivariate linear regression equation takes the following form.

$$ET = 1098.786 + 0.309\ \text{Rainfall} - 0.289\ \text{Elevation} - 21.840\ \text{Latitude} + 1.96\ \text{Forest} \quad (1)$$

where ET is the long term mean annual evapotranspiration of the watershed (mm); rainfall is the long term

TABLE 4. Summary of the Stepwise Selection Process for Building the AET Model With the Water Variable.

Step	Variable Entered	Variable Removed	Variable Number	Partial R^2	Model R^2	Mallows' C_p	F Value	Pr > F
1	R_a		1	0.55	0.55	45.71	42.25	< 0.0001
2	RH		2	0.12	0.67	26.83	11.54	0.002
3	Elevation		3	0.04	0.71	21.80	4.52	0.041
4	Rainfall		4	0.09	0.80	8.44	13.82	0.001
5	Water		5	0.03	0.83	4.68	6.03	0.020
6		RH	4	0.005	0.83	3.56	0.93	0.344
7	Conifer		5	0.01	0.84	3.80	1.90	0.178
8	Latitude		6	0.01	0.85	3.85	2.18	0.150
9		R_a	5	0.004	0.85	2.61	1.09	0.364

TABLE 5. Summary of the Stepwise Selection Process for Building the AET Model Without the Water Variable.

Step	Variable Entered	Variable Removed	Variable Number	Partial R^2	Model R^2	Mallows' C_p	F Value	Pr > F
1	R_a		1	0.55	0.55	33.31	42.25	< 0.0001
2	RH		2	0.12	0.67	18.38	11.54	0.002
3	Elevation		3	0.04	0.71	14.4	4.52	0.041
4	Rainfall		4	0.09	0.80	3.33	13.82	0.001
5	Forest		5	0.02	0.82	2.62	3.05	0.09
6		RH	4	0.0004	0.82	0.69	0.07	0.79

mean annual precipitation of the watershed (mm); latitude is the watershed latitude at the outlet, (degree); elevation is the mean watershed elevation (m); and forest is the percentage of watershed covered by forests multiplied by 100.

The model is highly significant with all the independent variables at the a = 0.05 significance level.

Regression Diagnostics

Residuals ranging from 161 mm/yr to 135 mm/yr for the AET regression model scatter randomly above and below the zero line (Figure 2). The large residuals occurred for watershed ID 4, 35, and 39 (Table 3). The largest absolute value of the studentized residual (Student) and R student (2.80) was less than 3.25, the standardized flag value for residuals, indicating that there were no outliers in the 36 watershed hydrology data sets. Normality tests of the residuals suggested that the assumptions of least squares were valid.

The Cook's D values were used to evaluate influential points that may cause model bias (Table 3). Since the 25 percent ellipsoid flag value is 0.53 and the largest Cooks D value in Table 3 was 0.16, there were no influential points in the data set.

A condition index of about 10 would indicate weak collinearity among the independent variables, a condition index of 30 to 100 would indicate moderate collinearity, and a condition index that is larger than 100 would indicate severe collinearity (Rawlings et *al.*, 1998). Our collinearity diagnostics gave the Condition index with values of 1.00, 1.21, 1.45, and 2.63, suggesting that there was no collinearity among the independent variables. Thus, with high confidence the model developed in this study can be used to predict long-term annual evapotranspiration for forested watersheds across the southeastern United States.

DISCUSSION AND CONCLUSIONS

A couple of surprises were encountered in this AET modeling study. First, against our presumption, the PET calculated by the six PET methods was not included in the final regression model. It appears that other climatic variables such as temperature that correlates well with watershed elevation (Calvo-Alvarado and Gregory, 1997) and its combination with precipitation performs better than PET to explain the variation of the evapotranspiration. Similarly, relative

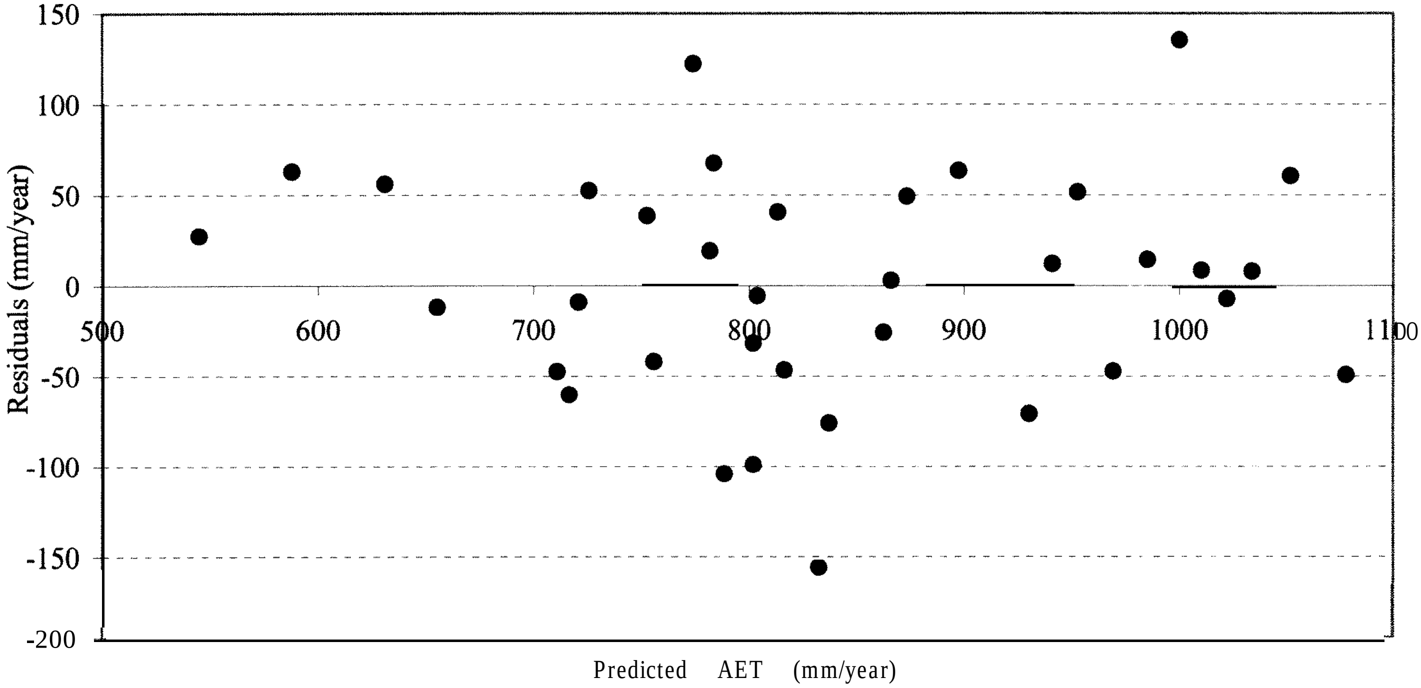

Figure 2. Prediction Residuals of the AET Model.

humidity and solar radiation are important in affecting AET, but their influences were weakened when compared with the combination of precipitation and elevation. Second, instead of the percentage of hardwoods, the percentage of water body was initially included with a negative sign in the final AET model. We believe this might be caused by the data bias when watersheds with water bodies are located inland and have lower AET than those small, fully forested watersheds with higher AET but no water bodies.

While the percentage of total forest cover was identified as a significant variable affecting regional AET, we believe that the sample size in this study is not large enough to detect the delicate relationship between forest cover type (i.e., conifer versus deciduous) and AET. Furthermore, the vegetation effects are easily masked by the large spatial variations of climate, not to mention the potential influences of geology and soils. We consider that factors other than climate and vegetation play minor roles in regional evapotranspiration in the southeastern United States.

An empirical multivariate linear regression model for predicting regional evapotranspiration was developed by integrating long term forest hydrological data across the southeastern United States. We found that the most important environmental variables that explain the spatial variability of regional AET of forest dominated watersheds are precipitation received, watershed latitude, watershed elevation, and percentage of the forest cover. These four independent variables are readily available from regional GIS databases, and therefore the regression model is easily implemented at the regional scale to predict spatial patterns of AET and water yield. Most importantly, the model is sensitive to climate change variables (precipitation) and a land cover variable (percentage of forest), and thus it can be used to examine the sensitivity of regional AET to precipitation and land cover change. However, we must caution that the model is an empirical model derived from heavily forested watersheds. The regression model was carefully inspected for potential application problems in prediction, and the results showed that the model should perform well with sufficient confidence. The next logical step is validating the model using existing watershed scale hydrology data across the southeastern United States. There have been few studies to examine the relationship between AET (water yield) and vegetation cover at the regional scale. This can be achieved by using historical time series land cover and hydrologic data and methods described in this study

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