Land Use Implications to Evapotranspiration and Water Budgets

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Agricultural Crop Land

Much lower/or negligible canopy;
Much shorter/less rooting depth;
Smoother surface microtopography;
Uniform vegetation & Negligible/No understory
Larger albedo (fraction of reflected radiation)
Annual/Seasonal growth cycle

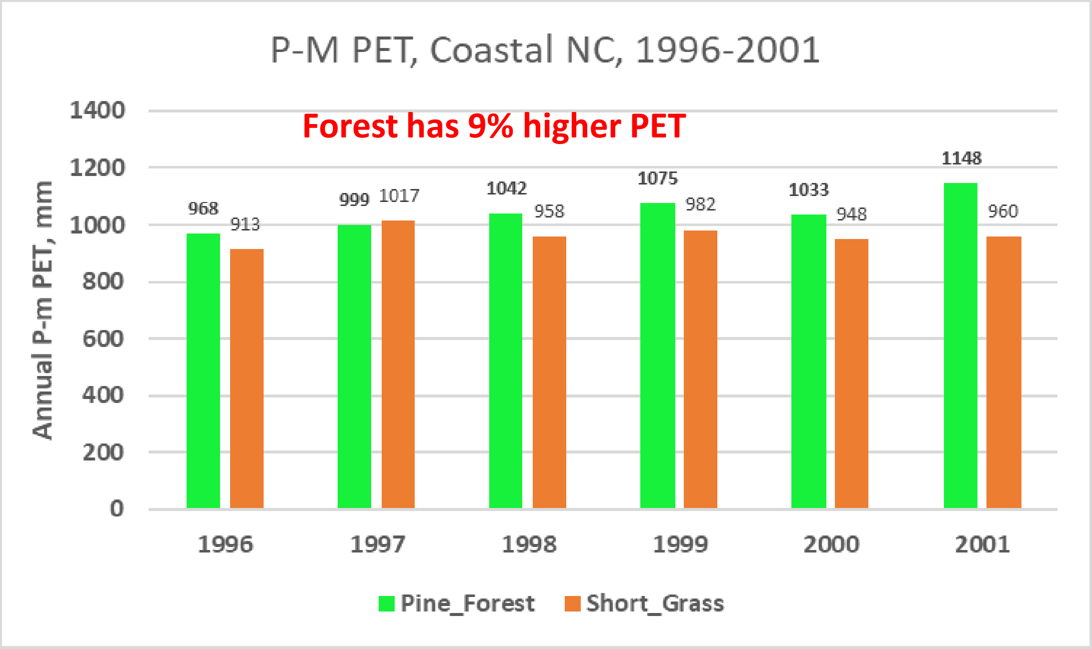
Water Budget: $P - [E_i - E_{sl} - E_t] - [R_o - R_{gw}] - DS = \Delta S$

$$P - ET - R - DS = \Delta S$$

ET = f (PET, SM, Soils, vegetation); PET = f (Micrometeorology, surface vegetation, location)

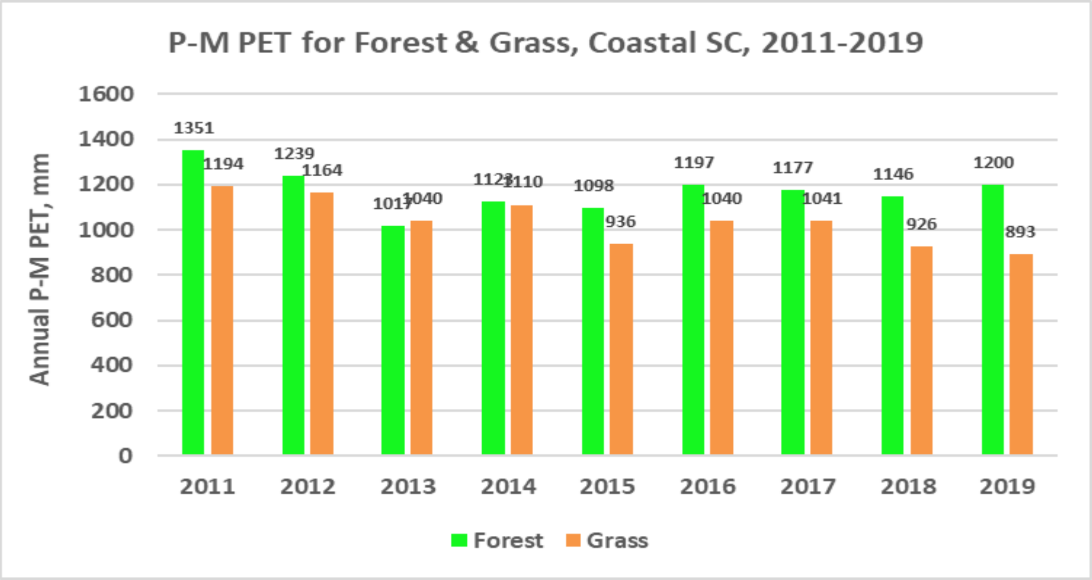
Silviculture – Forest Land

Penman-Monteith Potential Evapotranspiration (PET), NC

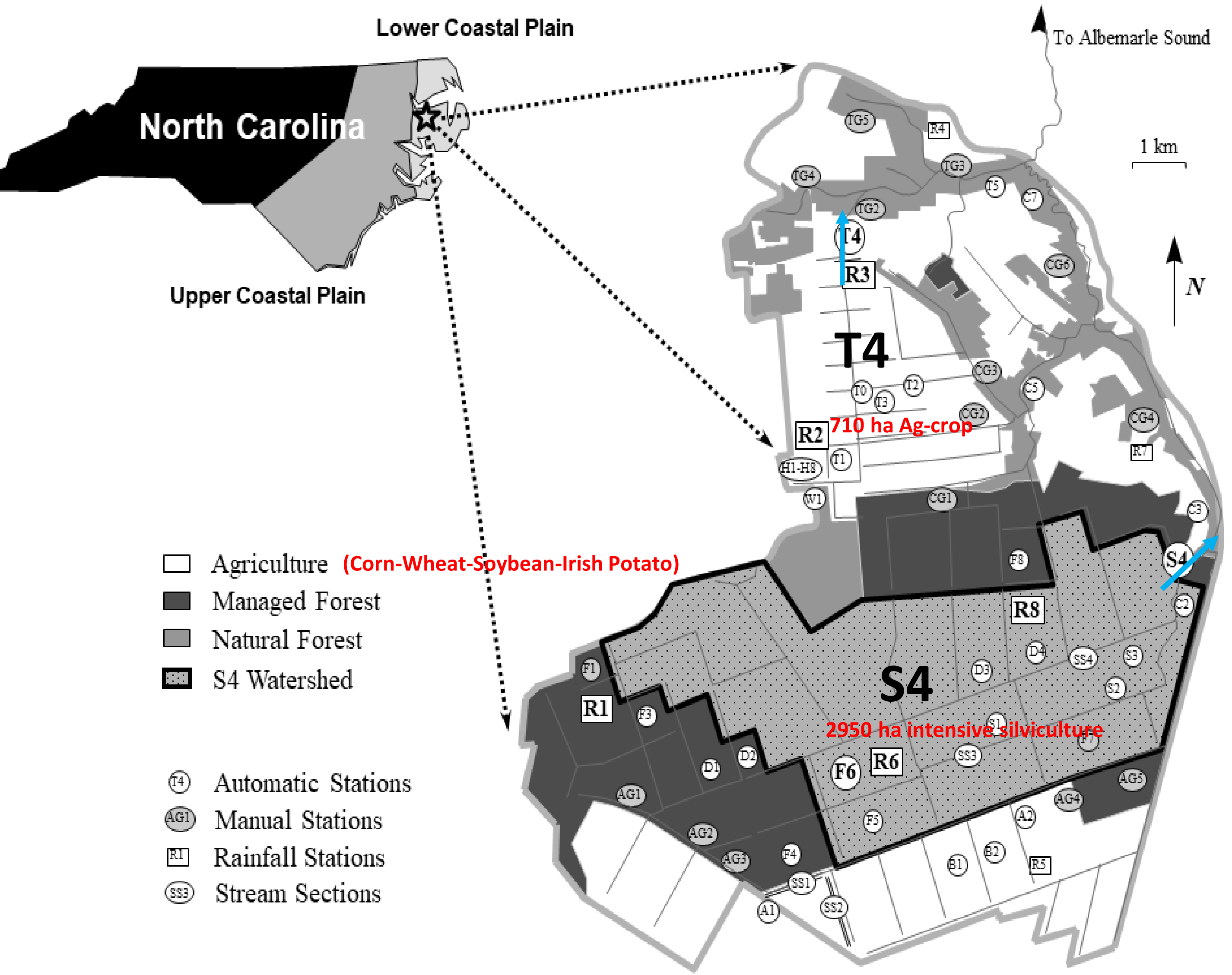


Forest has 14% higher PET

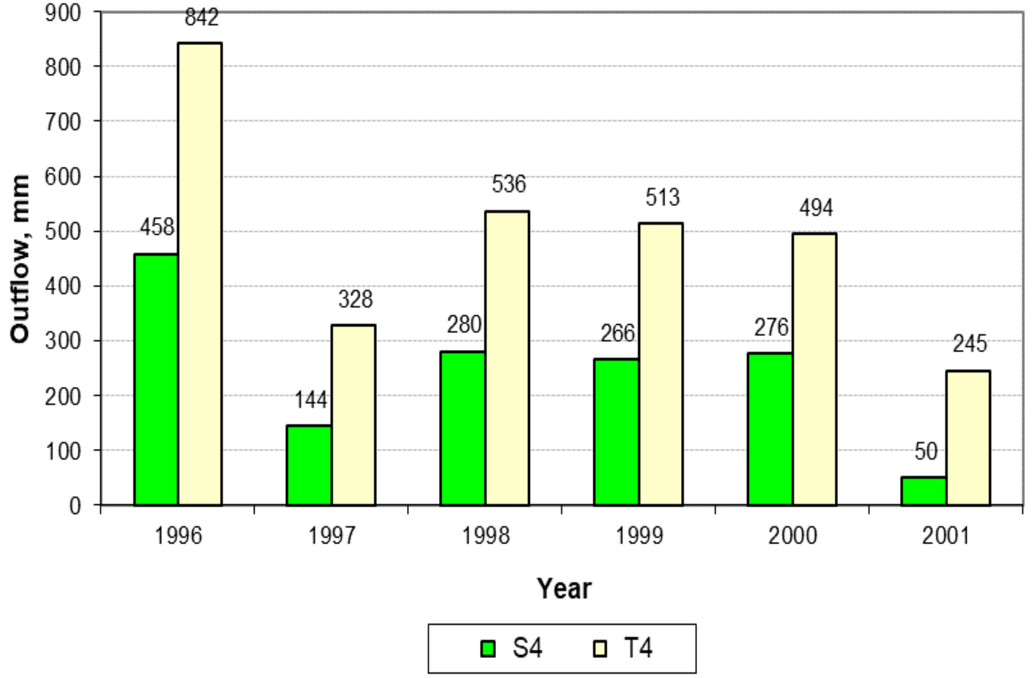
Penman-Monteith Potential Evapotranspiration (PET), SC



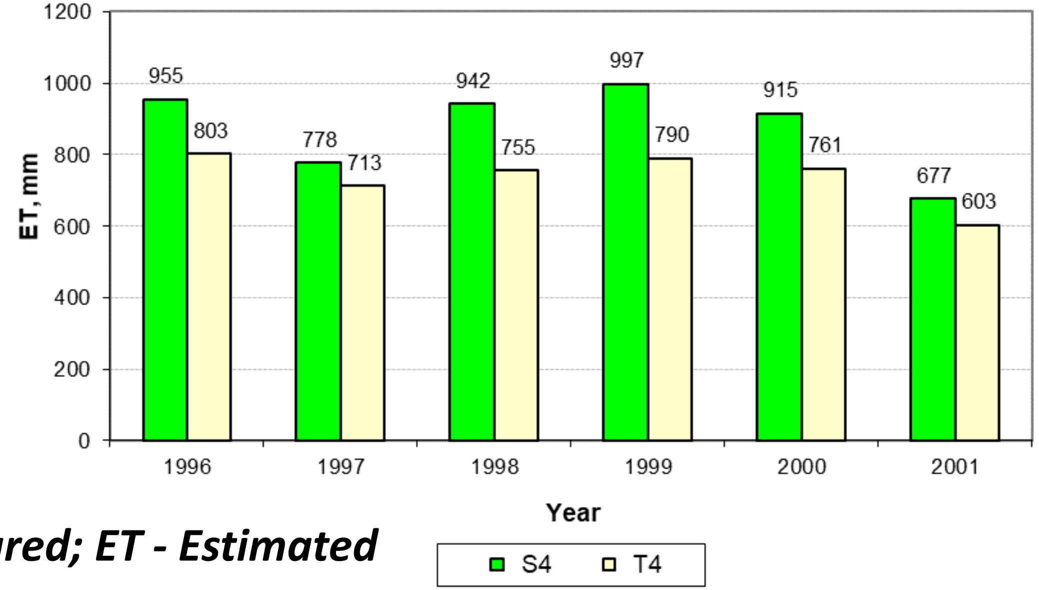
Rain (mm) = 757 (2001) – 1410 (1996)



79% (2000) to 390% (2001) Outflow



9% (1997) to 26% (1999) with avg of 19% higher ET



Amatya et al. (2002): Outflow or Runoff – Measured; ET - Estimated

Skaggs et al. (2011) – A DRAINMOD model simulation study results

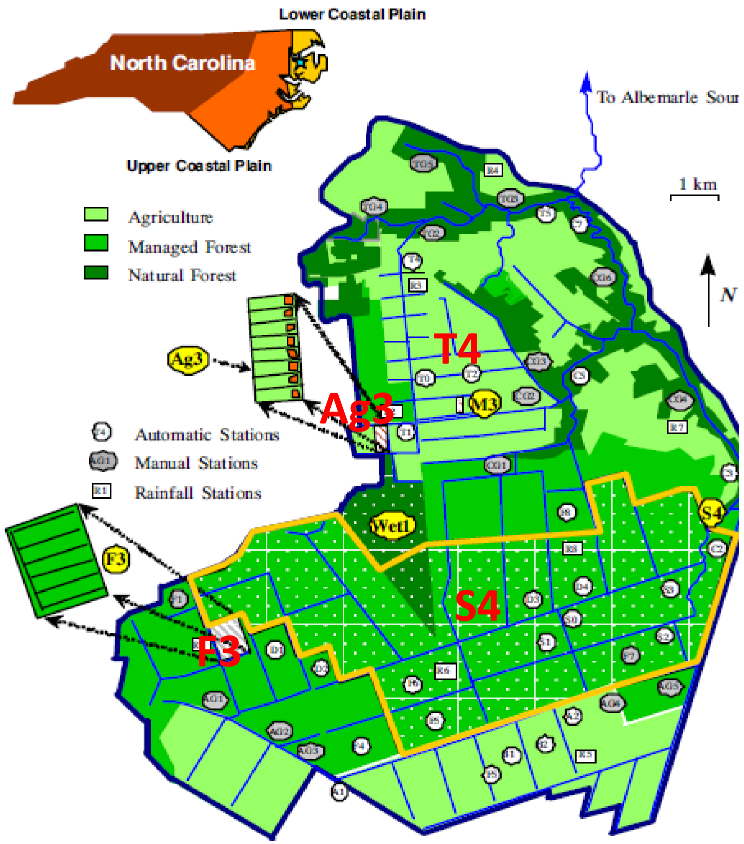


Figure 1. Plot of the Kendricks Creek watershed, Plymouth, North Carolina, showing the location of monitoring stations (Wet1), and the boundary and outlet of watershed S4.

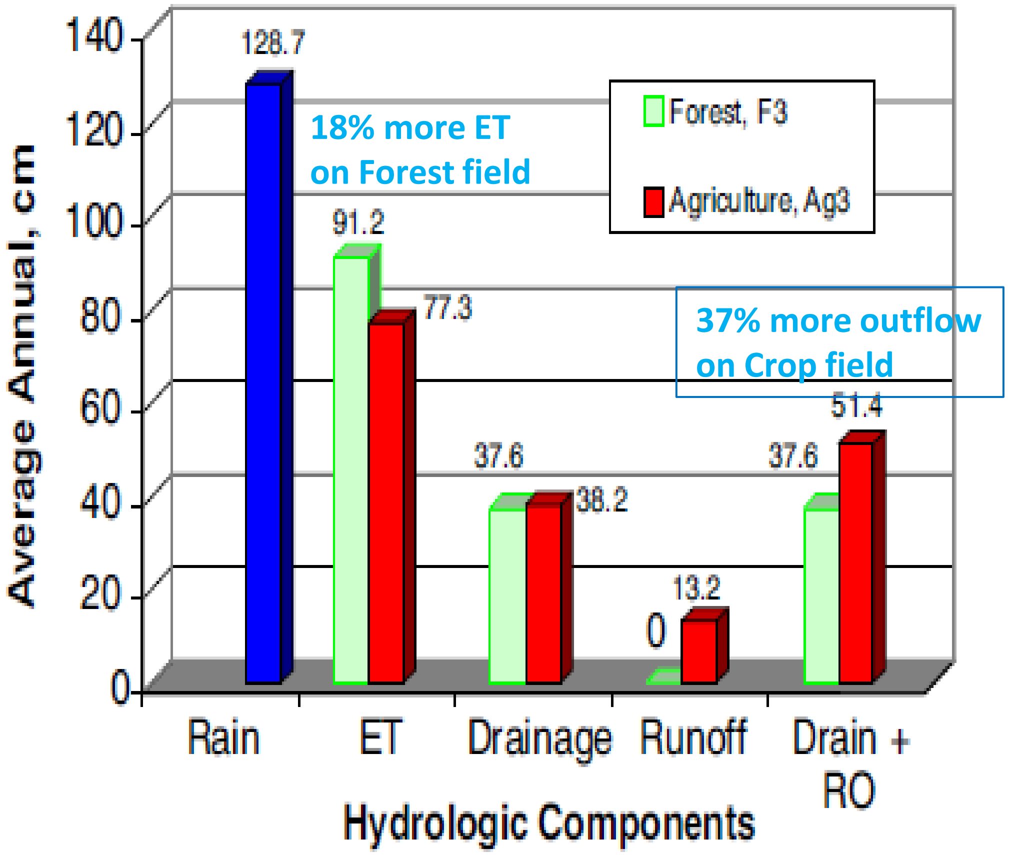
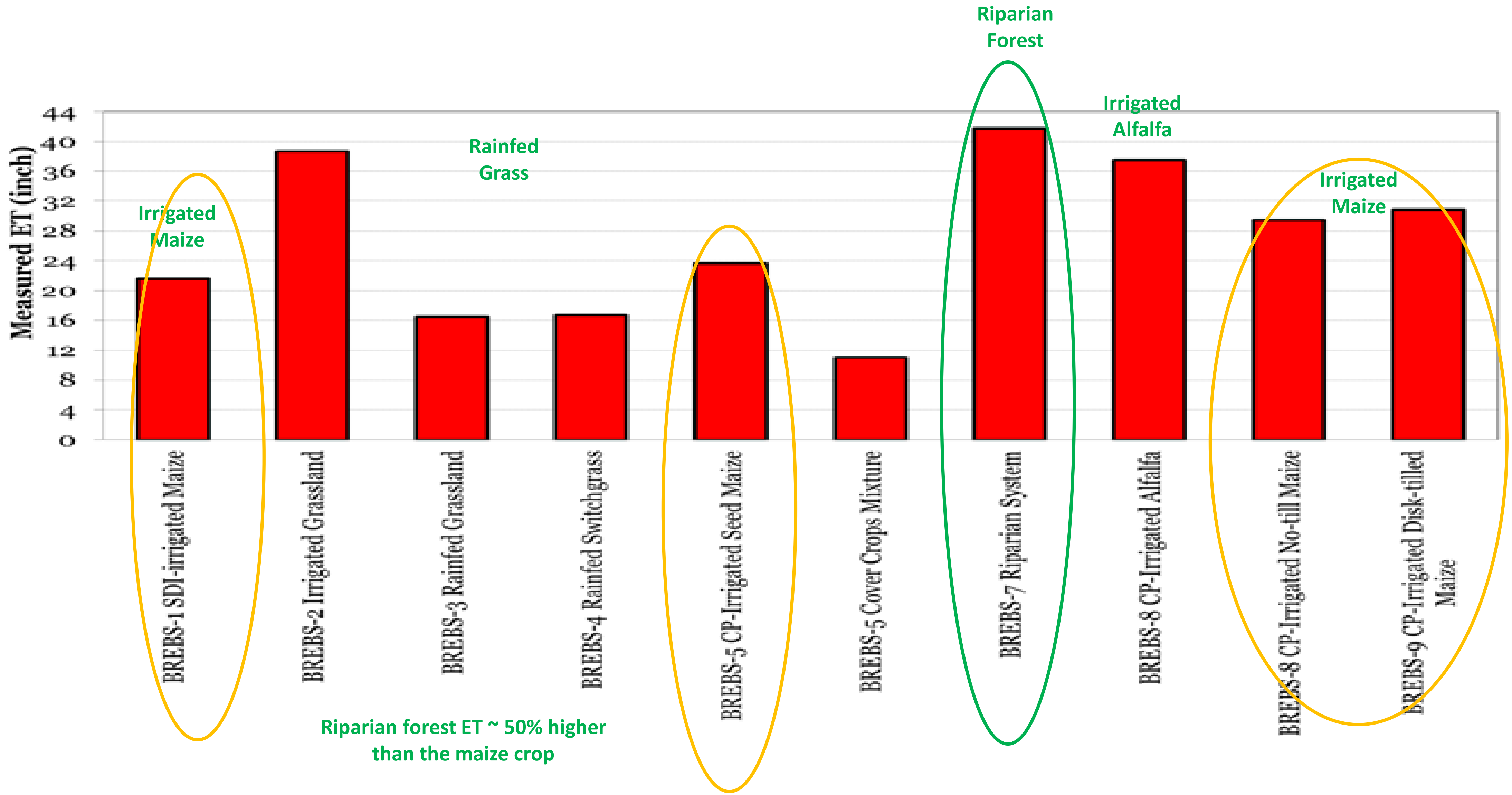


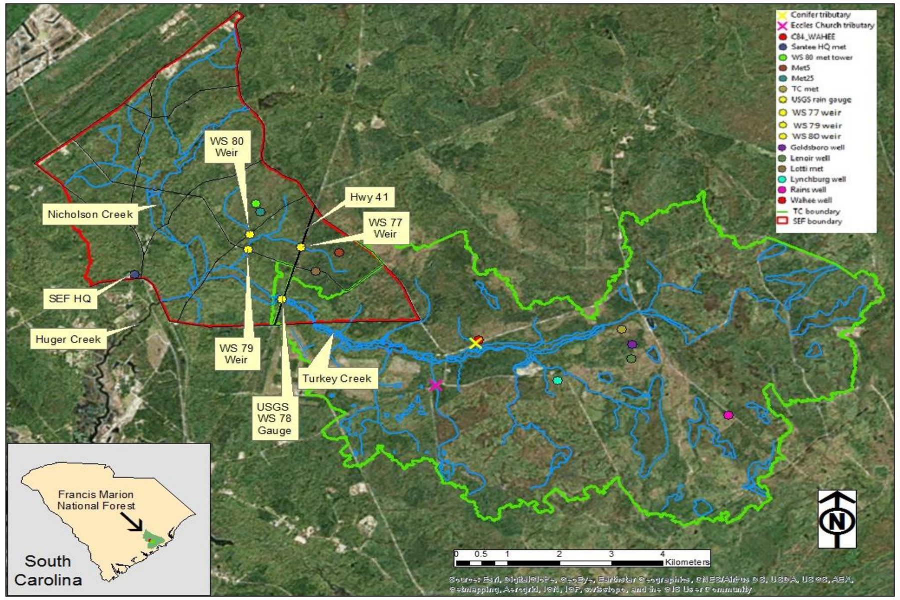
Figure 8. Summary of average annual values predicted for hydrologic components in 50-year simulations for the agricultural site (Ag3) and the forested site (F3).

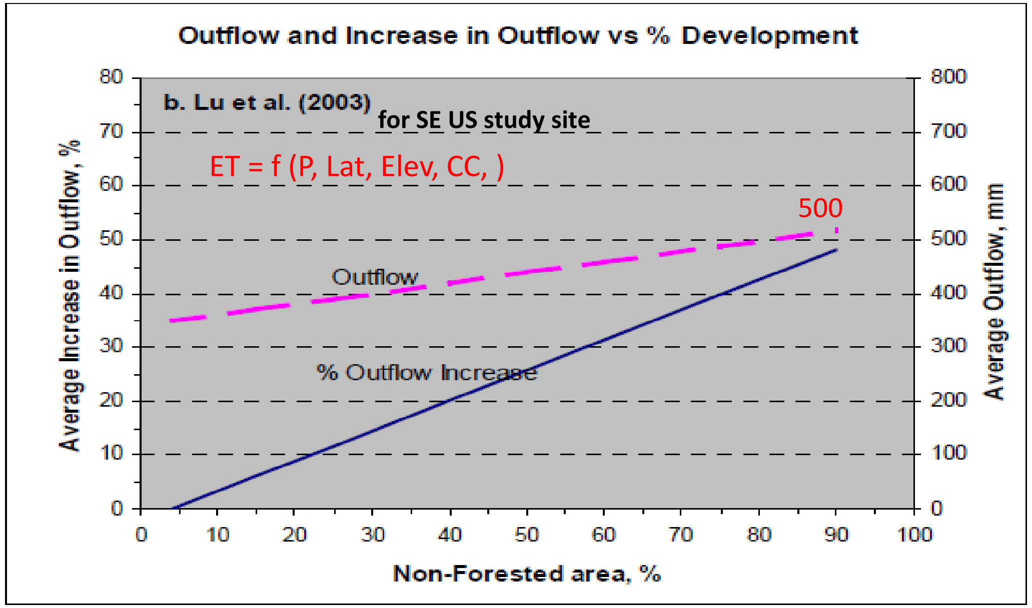
Measured ET for Various Landcovers, Nebraska

Irmak et al., 2015



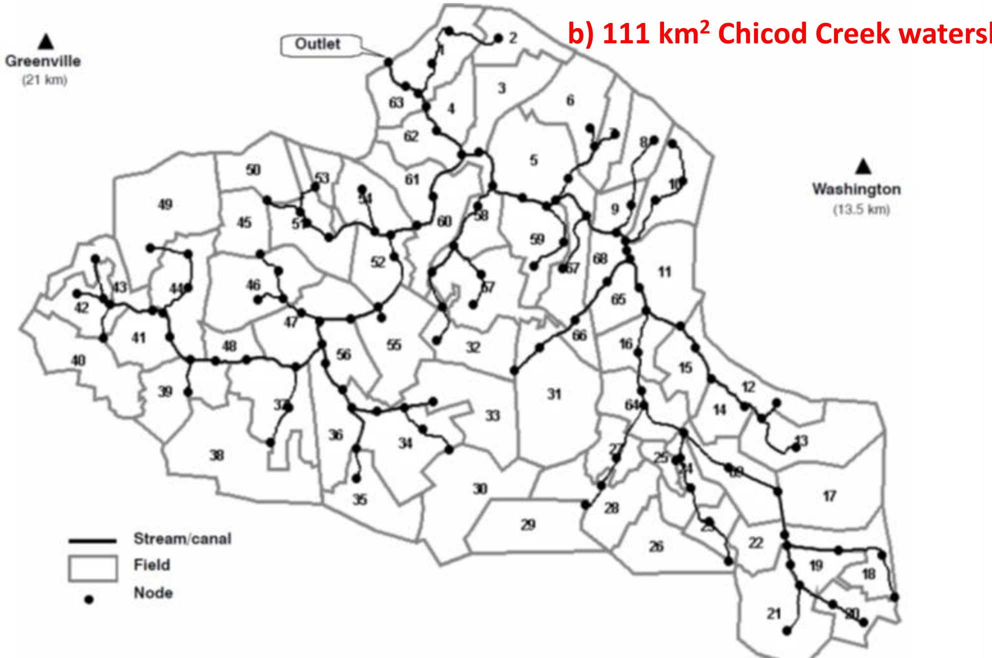
Land Use Change Effect Studies: a) 52 km^2 mostly forested Turkey Ck watershed, SC *(Amatya and Trettin, 2007)*





Outflow

b) 111 km^2 Chicod Creek watershed; 55% Ag-Cropland; 45% Forests (Fernandez et al., 2007)



Outflow

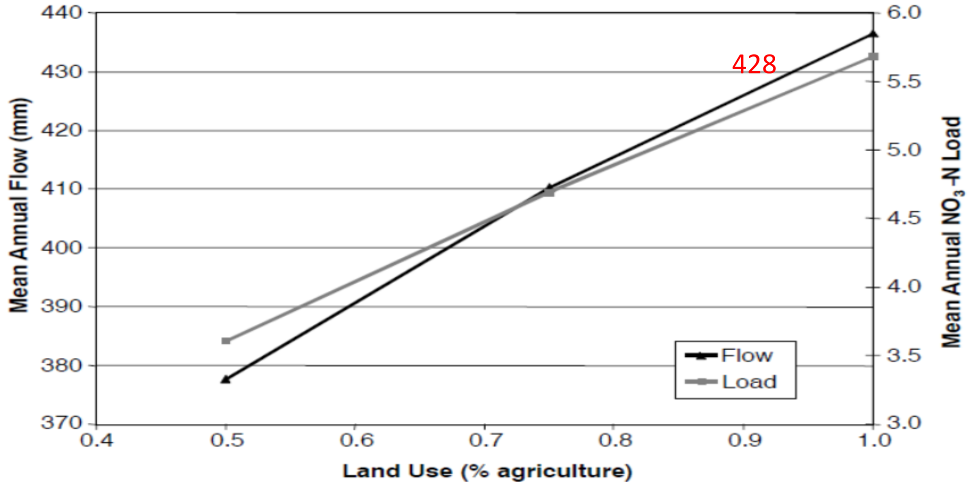


Figure 9. Effects on changing land use on watershed outflow and load.

Some Prelim Simulation Results using WaSSI Model for the ERB

Water Supply Stress Index (WaSSI)

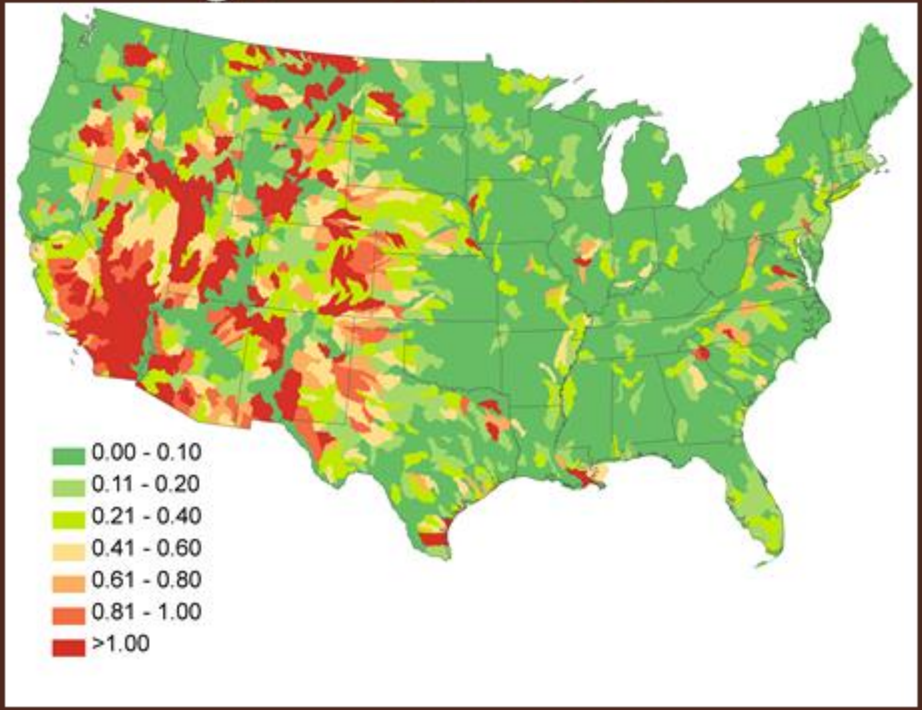
Sun et al. 2011; Caldwell et al., 2012

$$WaSSI = \frac{Demand}{Supply}$$

<u>Sectors</u>

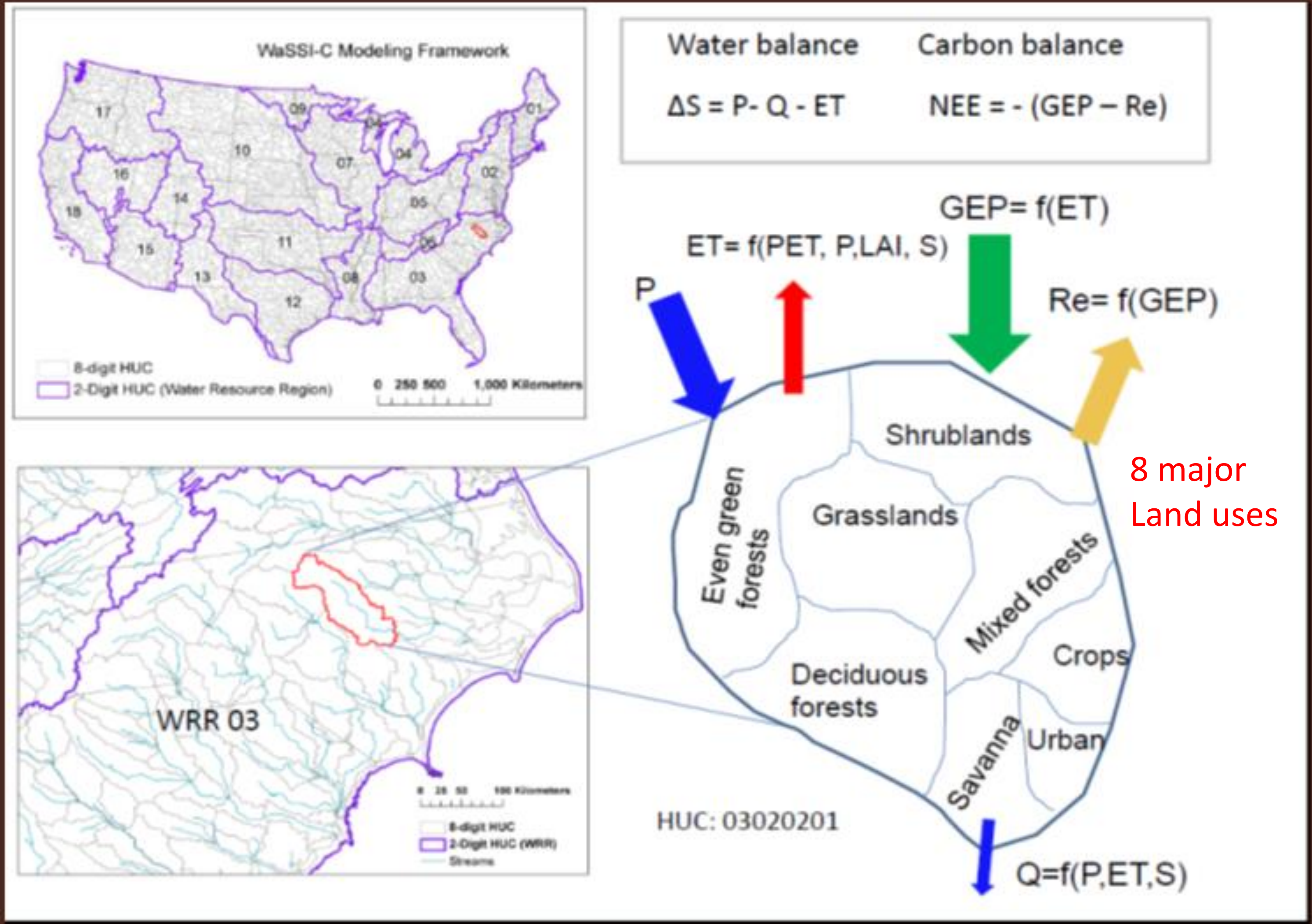
1. Domestic
2. Industrial
3. Irrigation
4. Thermopower
5. Mining
6. Livestock
7. Public Supply
8. Aquaculture

1981-2000 WaSSI



Modeling Framework

(Sun et al. 2011. JGR Vol 116)



Li, Cheng; Sun, Ge; Caldwell, Peter V.; Cohen, Erika; Fang, Yuan; Zhang, Yindan; Oudin, Ludovic; Sanchez, Georgina M.; Meentemeyer, Ross K. 2020. Impacts of urbanization on watershed water balances across the conterminous United States. Water Resources Research. https://doi.org/10.1029/2019WR026574.

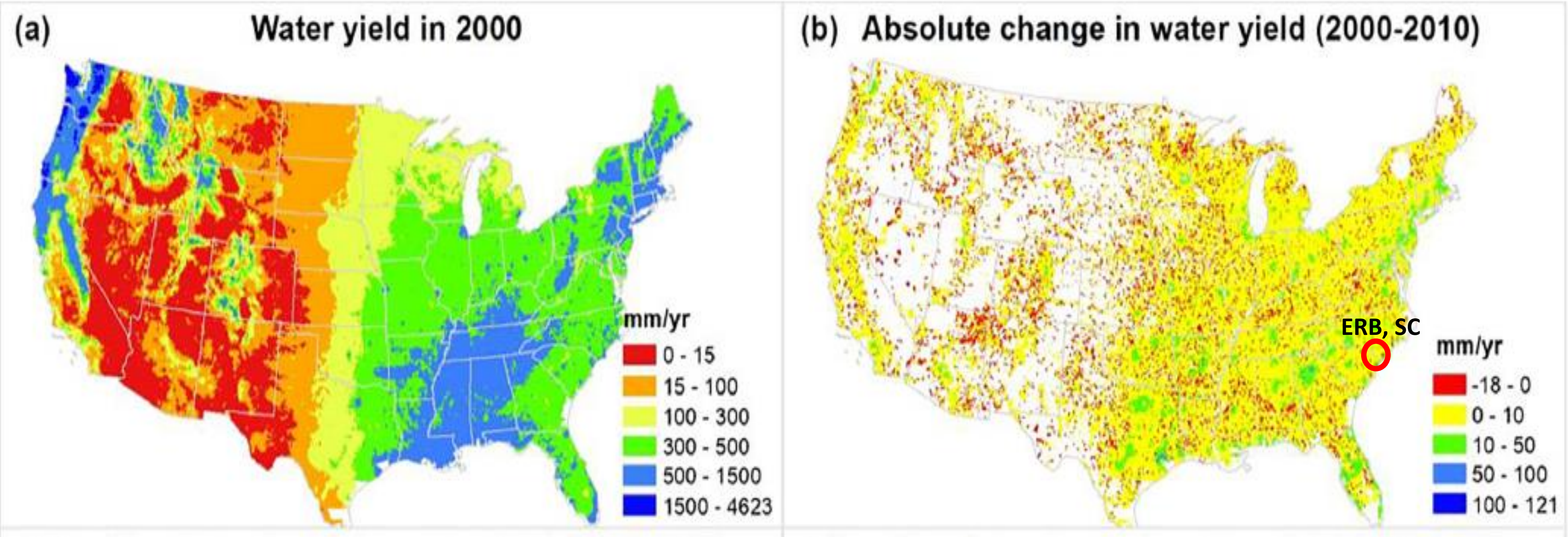


Figure 4. Spatial distribution of water yield in 2000 (a) and the absolute change in water yield during 2000–2010 (b),

Simulation results from here used for preliminary analysis of ET comparison between forest and crop land uses

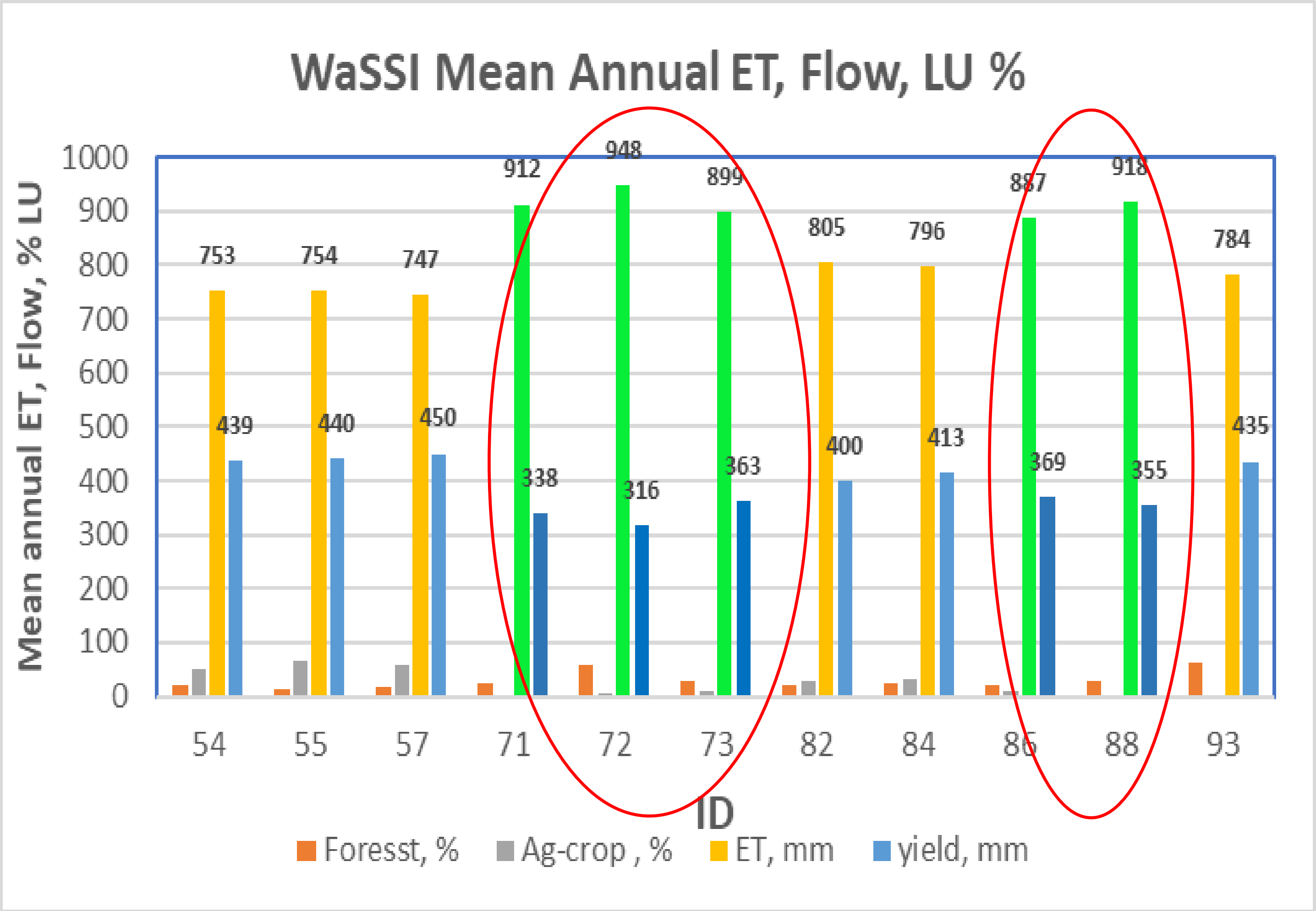
Sample Output from Long-term Hydrologic Simulation using WaSSI model for Edisto River basin, SC (1961-2015)

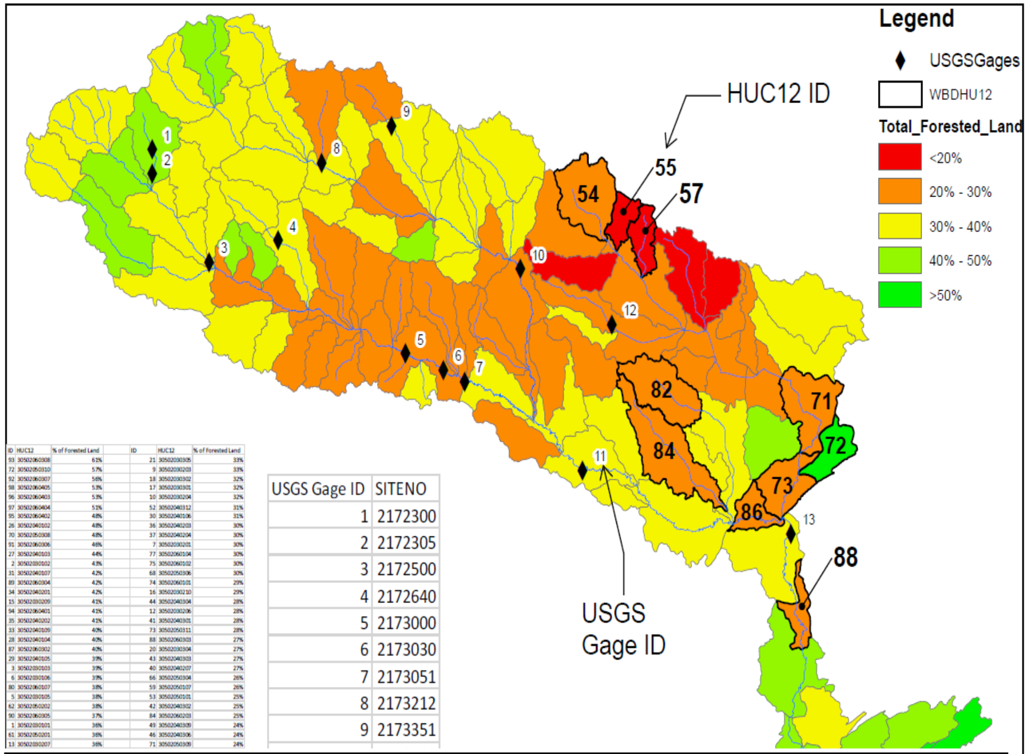
Li et al., 2020

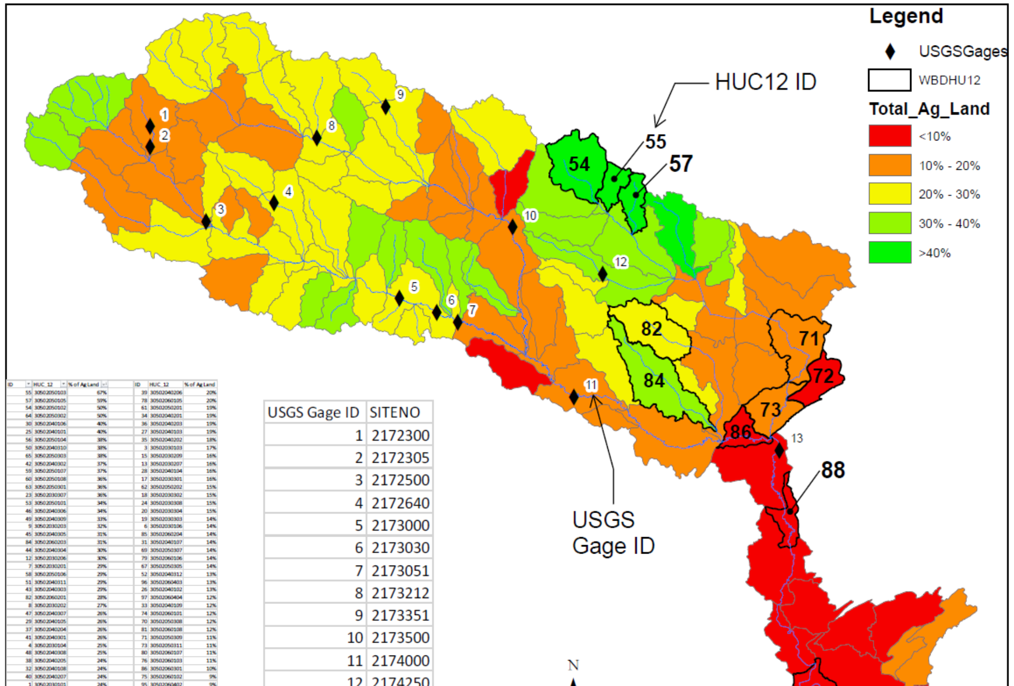
HUC12,	N,	PPT,	TEMP,	PET,	PAET,	AET,	WAT_YLD ("mm")
30502050102.,	55,	1193.4,	17.8,	1032.2,	818.9,	753.5,	438.7
30502050103.,	55,	1195.3,	17.9,	1033.3,	814.2,	754.0,	440.1
30502050104.,	55,	1212.6,	17.9,	1034.9,	817.2,	723.1,	488.3
30502050105.,	55,	1198.0,	17.9,	1033.0,	809.0,	746.5,	450.4
30502050106.,	55,	1203.8,	17.9,	1035.9,	863.7,	776.6,	425.9
30502050107.,	55,	1207.1,	17.9,	1036.7,	857.5,	771.0,	434.8
30502050307.,	55,	1241.1,	18.0,	1039.9,	958.6,	855.8,	383.6
30502050308.,	55,	1245.6,	18.0,	1038.5,	1000.7,	874.6,	370.1
30502050309.,	55,	1251.6,	18.0,	1036.1,	1054.5,	912.2,	338.3
30502050310.,	55,	1266.0,	18.0,	1035.8,	1101.9,	948.0,	316.3
30502050311.,	55,	1263.2,	18.0,	1037.9,	1029.4,	899.3,	362.8
30502060101.,	55,	1197.7,	18.0,	1038.4,	976.2,	829.9,	365.6
30502060102.,	55,	1195.9,	18.0,	1039.1,	982.9,	854.7,	339.7
30502060103.,	55,	1191.0,	18.0,	1040.1,	996.6,	842.0,	347
30502060104.,	55,	1197.5,	18.0,	1037.3,	896.8,	792.8,	403
30502060105.,	55,	1200.4,	18.0,	1040.3,	916.9,	829.1,	369.7
30502060106.,	55,	1199.5,	18.1,	1041.3,	993.1,	861.2,	336.5
30502060107.,	55,	1212.5,	18.1,	1041.0,	1029.5,	886.0,	324.7
30502060108.,	55,	1234.7,	18.1,	1040.4,	1025.4,	893.2,	340.4
30502060201.,	55,	1206.6,	18.0,	1039.6,	886.2,	805.0,	400.2
30502060202.,	55,	1216.7,	18.0,	1040.4,	921.7,	820.0,	395.8
30502060203.,	55,	1211.0,	18.0,	1040.3,	873.4,	796.3,	413.4
30502060204.,	55,	1226.4,	18.0,	1040.3,	1002.4,	883.6,	341.6
30502060301.,	55,	1257.5,	18.0,	1038.7,	1027.4,	887.4,	368.7
30502060302.,	55,	1268.5,	18.1,	1040.6,	1080.9,	916.1,	350.3
30502060303.,	55,	1275.4,	18.1,	1044.1,	1134.6,	918.4,	355.3
30502060304.,	55,	1271.1,	18.2,	1047.6,	1144.9,	924.6,	345.1
30502060305.,	55,	1270.6,	18.4,	1055.4,	1127.9,	945.1,	324.1
30502060306.,	55,	1263.5,	18.4,	1058.5,	1033.5,	881.4,	381.3

HUC12 – 8 Landcover types simulated; WaSSI simulated ET and Water Yield for each landcover on each HUC12

Li et al., 2020







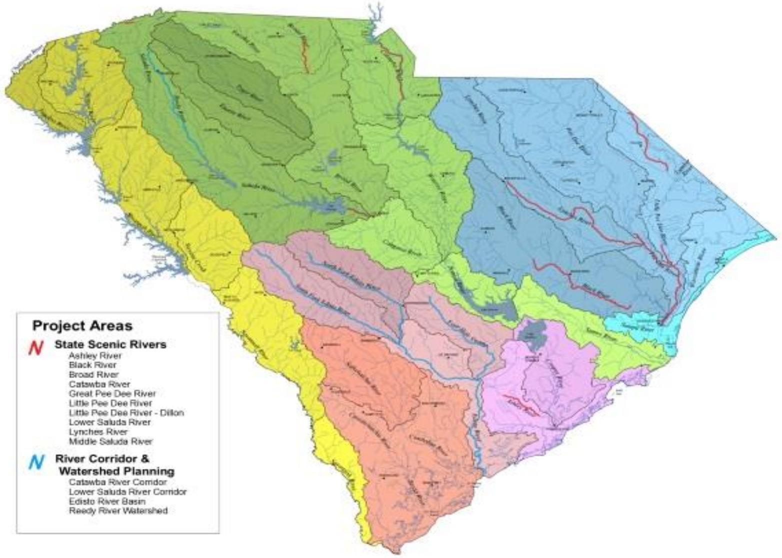
Avg Forest ET = 913 mm
Avg Ag-Crop ET = 771 mm
+ 18.4% more ET from Forest

Avg Forest WY= 348 mm
Avg Ag-Crop WY = 428 mm
18.7% more WY from Ag-crop

SUMMARY

Due to their larger biomass (below and above ground - leaf area index) and deeper roots with greater access to soil water (if and when available) than shorter crops, in addition to potentially somewhat higher PET, ***forest land use yielded 18-24 %, on average, higher ET than agricultural crops*** *that explains their higher ecosystem or gross primary productivity (GPP) and relatively lower streamflow than the agricultural croplands, with a spatial and temporal variability depending upon the climate, vegetation, and location!*

- Long-term (1961-2015) WaSSI water budget simulation results for all the HUC-12 units could be available for river basins in SC.
- Info from PET assessment study for SC by Amatya et al. (2018)
- Water budget can be further partitioned by 8 land use types within each HUC-12 in a river basin
- Additional processing for this needed from a long-term simulation results from 82,774 HUCs of the conterminous US
- Simulations for key land use and climate change scenarios for each of the river basins



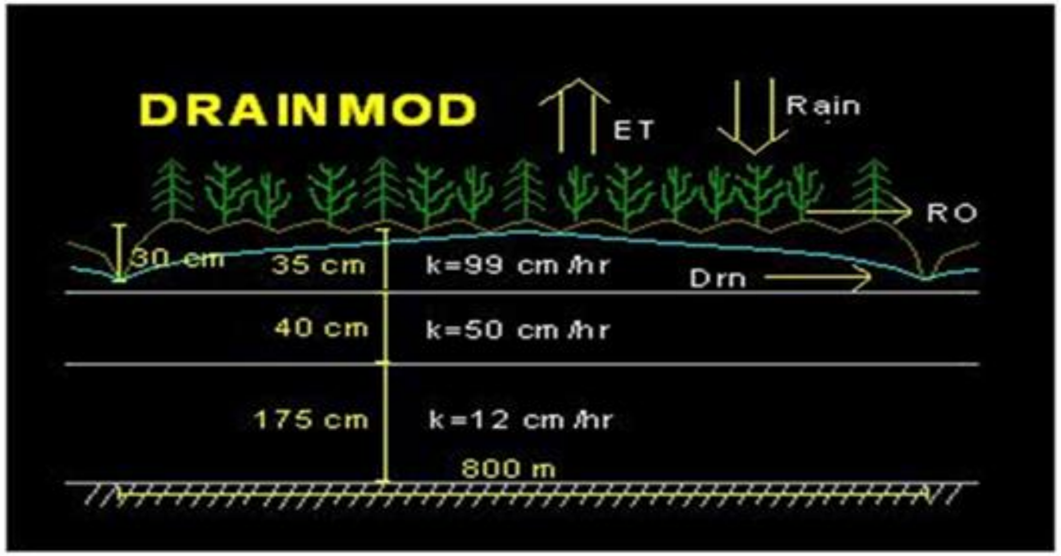
Source: South Carolina Department of Natural Resources - SC.GOV; SCDNR - Scenic Rivers - Water Basins

Some Relevant Literature on Water Yield/ET from Agricultural Crops & Forests

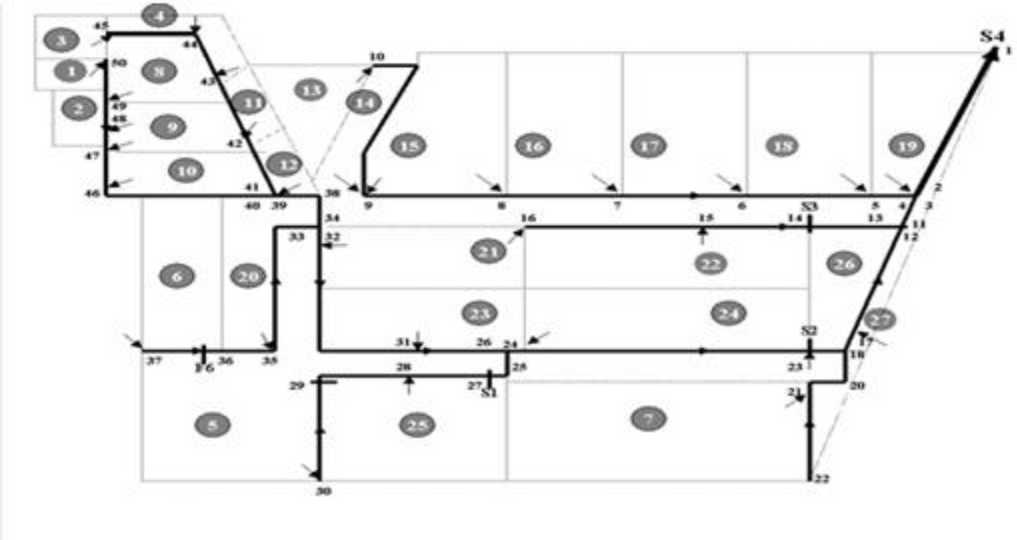
- Ahmed, M.A.A., A.A. Elrahman, F.J. Escobedo, W.P. Cropper, Jr., T.A. Martin, and N. Timilsina. 2017. Spatially-explicit modeling of multi-scale drivers of aboveground forest biomass and water yield in watersheds of the Southeastern United States. Journal of Environmental Management 199 (2017) 158-171.
- Amatya, D.M., G.M. Chescheir, R.W. Skaggs, and G.P. Fernandez. 2002. Hydrology of Poorly Drained Coastal Watersheds in Eastern North Carolina. Paper #022034, St. Joseph, MI: ASAE.
- Li, Cheng; Sun, Ge; Caldwell, Peter V.; Cohen, Erika; Fang, Yuan; Zhang, Yindan; Oudin, Ludovic; Sanchez, Georgina M.; Meentemeyer, Ross K. 2020. Impacts of urbanization on watershed water balances across the conterminous United States. Water Resources Research. https://doi.org/10.1029/2019WR026574.
- Fernandez, G.P., G.M. Chescheir, R.W. Skaggs, and D.M. Amatya. 2007. Application of DRAINMOD-GIS to a Lower Coastal Plain Watershed. Trans. of the ASABE, Vol. 50(2): 439–447.
- Payero, J. O. 2018. An Online Tool for Estimating Evapotranspiration and Irrigation Requirements of Crops in South Carolina. Journal of South Carolina Water Resources, Volume 5, Issue 1, Pages 69–73, 2018.
- Lu, X. and Q. Zhuang. 2010. Evaluating evapotranspiration and water-use efficiency of terrestrial ecosystems in the conterminous United States using MODIS and AmeriFlux data. Remote Sensing of Environment 114 (2010) 1924–1939.
- Sanford, Ward E. and David L. Selnick, 2012. Estimation of Evapotranspiration Across the Conterminous United States Using a Regression with Climate and Land-Cover Data. Journal of the American Water Resources Association (JAWRA) 49(1): 217-230. DOI: 10.1111⁄jawr.12010
- Senay, G.B., S. Bohms, R.K. Singh, P.H. Gowda, N.M. Velpuri, H. Alemu, and J.P. Verdin. (2013). Operational Evapotranspiration Mapping Using Remote Sensing and Weather Datasets: A New Parameterization for the SSEB Approach. J. Amer. Water Resou. Assoc. (JAWRA), 1-15, DOI:10.1111/jawr.12057.
- Skaggs, R.W., G.M. Chescheir, G.P. Fernandez, D.M. Amatya, and J. Diggs. 2011. Effects of Land Use on Soil Properties and Hydrology of Drained Coastal Plain Watersheds. *Trans. of the ASABE, 54(4):*1357-1365.
- Sun, G., S.G. McNulty, J. Lu, D.M. Amatya, Y. Ling, and R.K. Kolka. 2005. Regional Annual Water Yield from Forested Lands and its Response to Potential Deforestation Across the Southeastern Unites States. *J. of Hydrology, 308(2005):258-268*

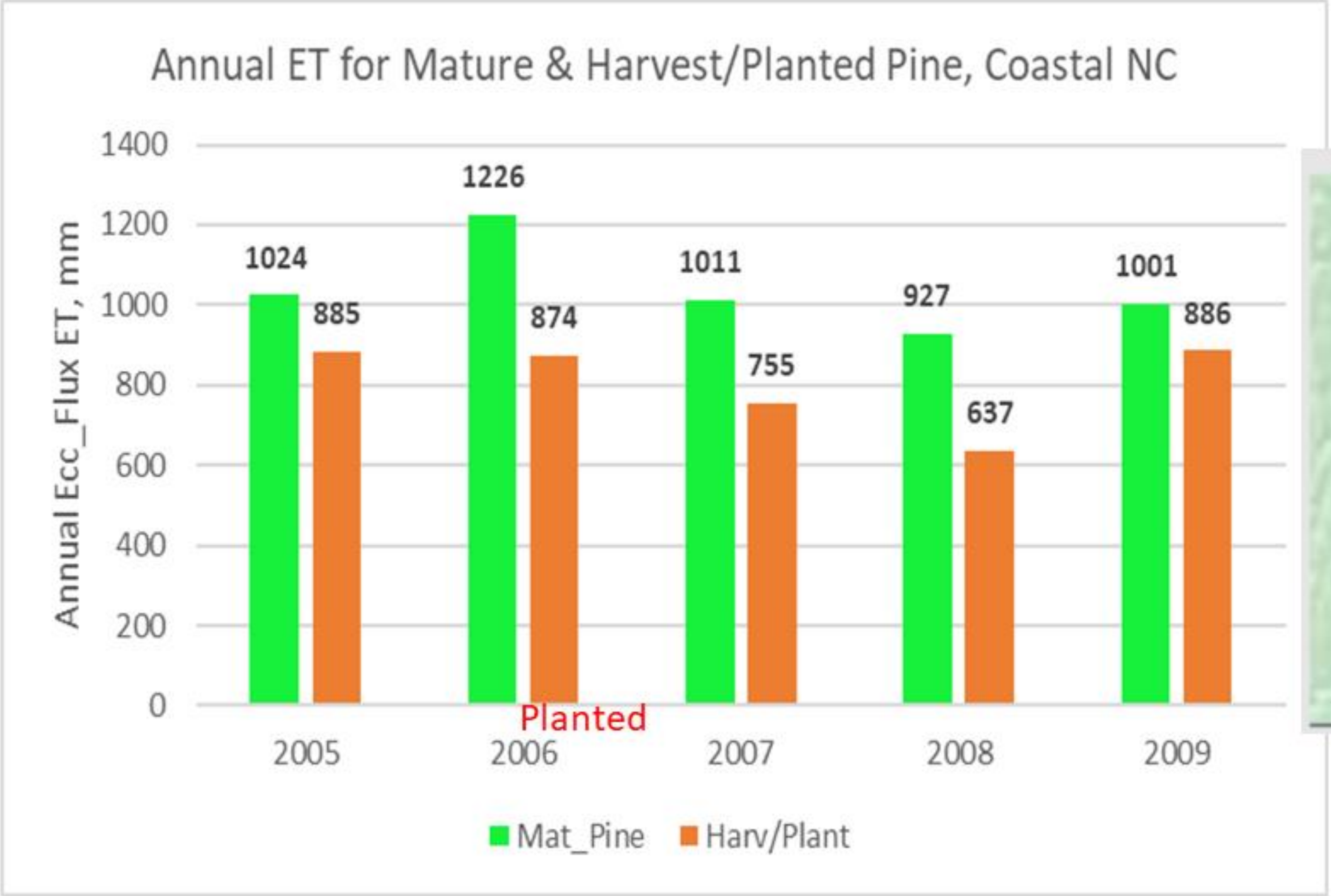
DRAINMOD (Skaggs, 1978) >>> DRAINWAT (Amatya, 1993; 1997); DRAINMOD-WATGIS (Fernandez et al., 2007)

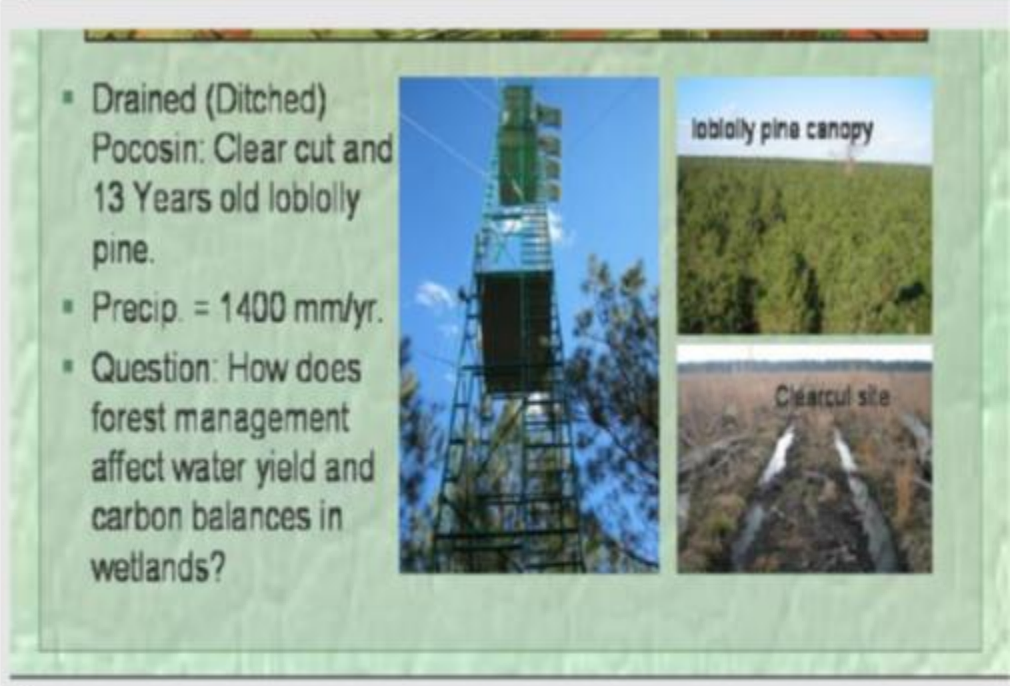
Field-scale Water Balance



Watershed-scale Water Balance w/Field-ditch-canal routing



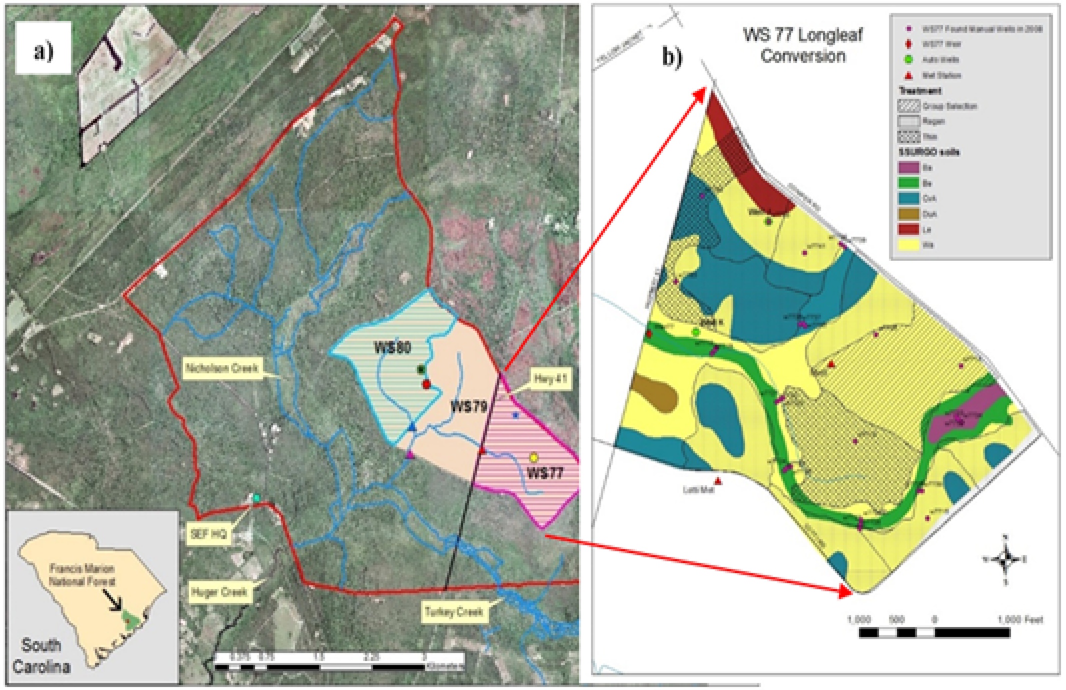


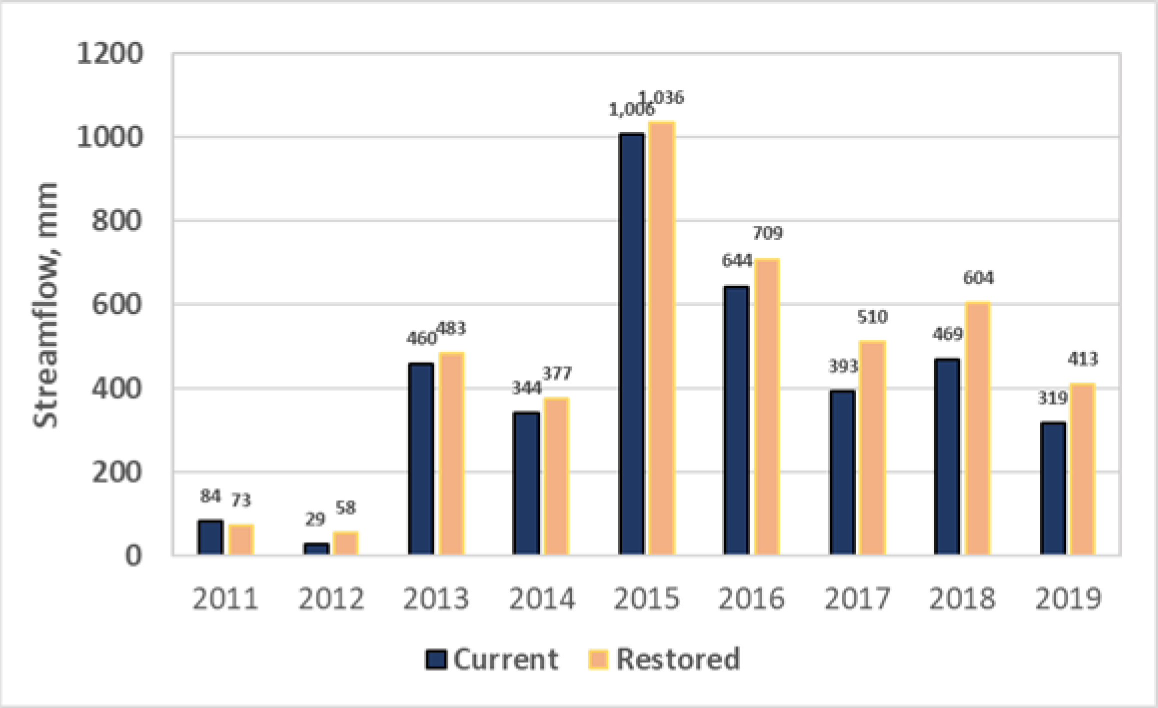


28.5%, on avg, more ET from mature than planted*; Sun et al., (2010); Domec et al. (2012)*

Projected Water Yield converting Loblolly to Longleaf Pine, Coastal SC

Santee Experimental Forest, SC





Mean increase: 57 mm, (22.7 – 135.4, except 2011); 68 mm ET decrease

Mean annual increase =22.3% average; W/out 2012, only 2% average;

Amatya et al. (2022) in Forest Service SRS GTR in Press

Comparative analysis of the actual evapotranspiration of Flemish forest and cropland, using the soil water balance model WAVE. W. W. Verstraeten, B. Muys, J. Feyen, F. Veroustraete, M. Minnaert, L. Meiresonne, A. de Schrijver
Hydrology and Earth System Sciences, 9, 225–241, 2005.

Avg Total ET (Forest) = 491 mm
About 24% more than crops

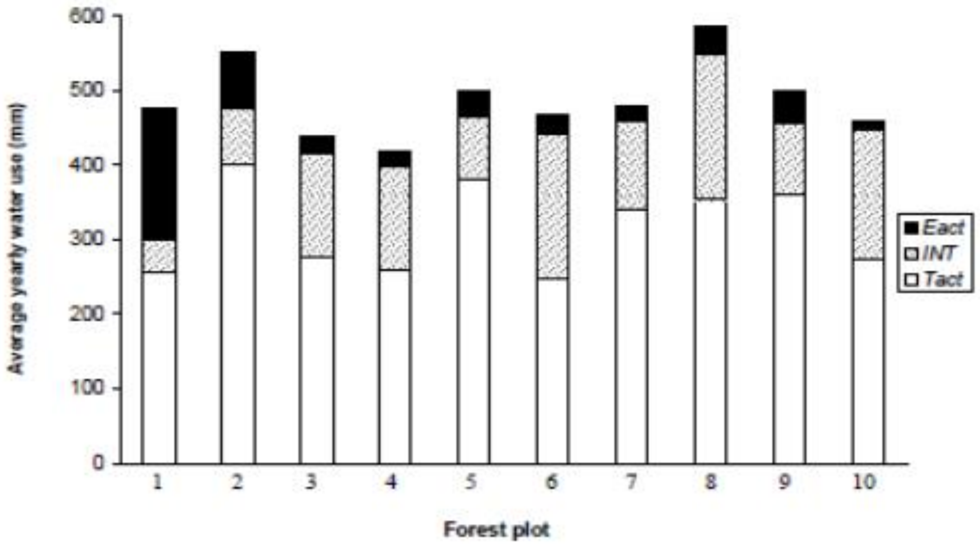


Fig. 3. Average yearly water use components of 10 forest stands in Flanders. ET_{act} is the sum of T_{act}, E_{act} and INT (period: 1971–2000).

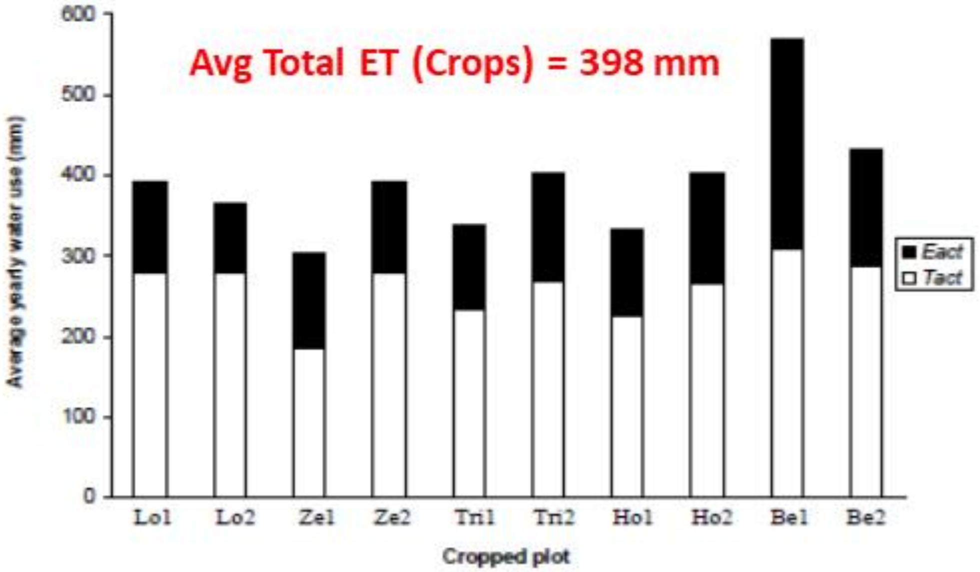
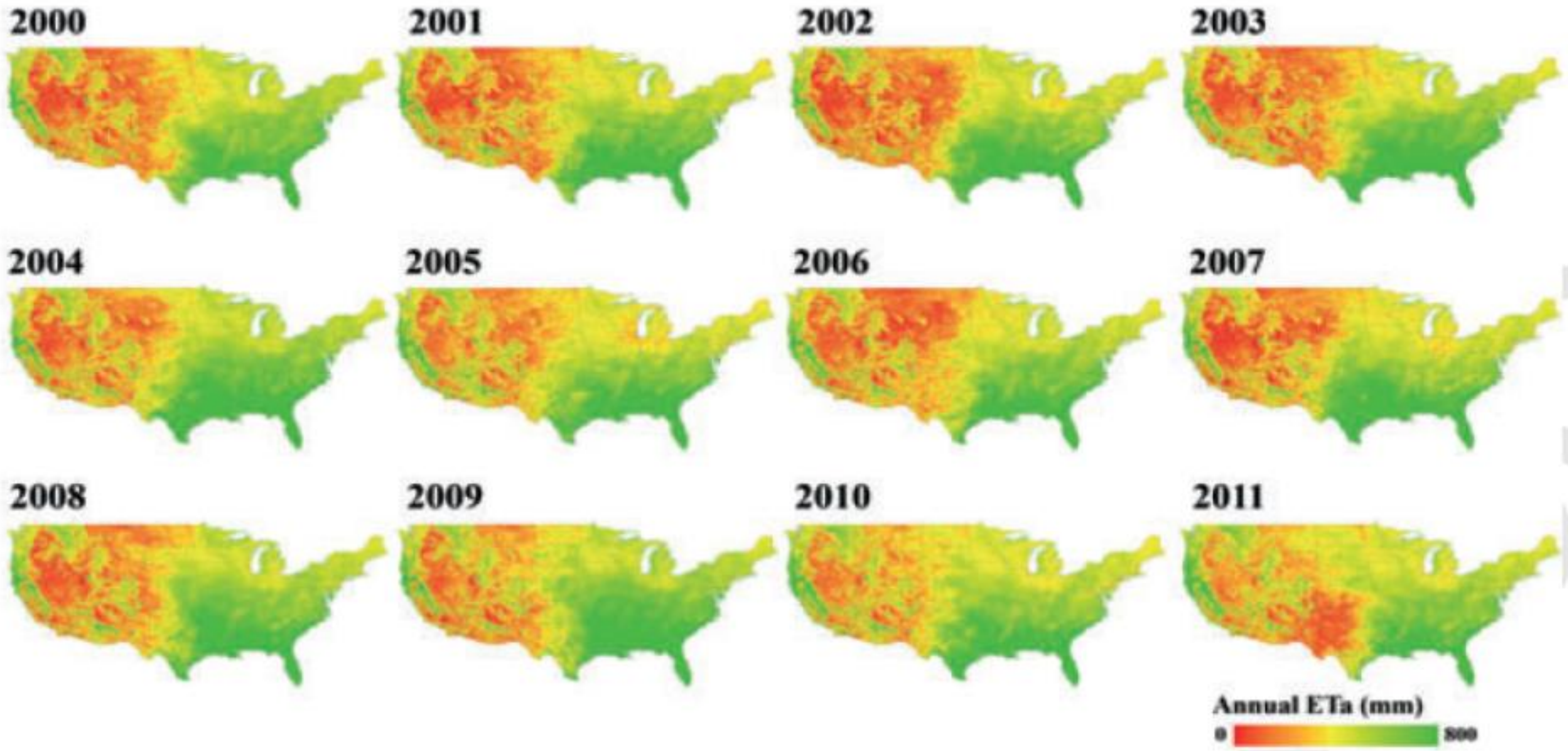


Fig. 4. Averaged yearly water use components of 10 agricultural fields in Flanders (*Lolium perenne* L.: Lo; *Triticim aestivum* L.: Tri; *Zea mays* L.: Ze; *Hordeum vulgare* L.: Ho and *Beta vulgaris* L.: , Be). ET_{act} is the sum of T_{act} and E_{act} (period: 1971–2000).



The maximum value is capped at 800 mm to highlight the ET from agricultural areas that do not exceed 700 mm in most areas. However, the ET from southeast exceeds 1000 mm due to high energy and water availability.

Senay, Gabriel B., Stefanie Bohms, Ramesh K. Singh, Prasanna H. Gowda, Naga M. Velpuri, Henok Alemu, and James P. Verdin, 2013. Operational Evapotranspiration Mapping Using Remote Sensing and Weather Datasets: A New Parameterization for the SSEB Approach. *Journal of the American Water Resources Association* (JAWRA) 1-15. DOI: 10.1111/jawr.12057