Coweeta's Influences Reach Beyond its Watershed Boundary

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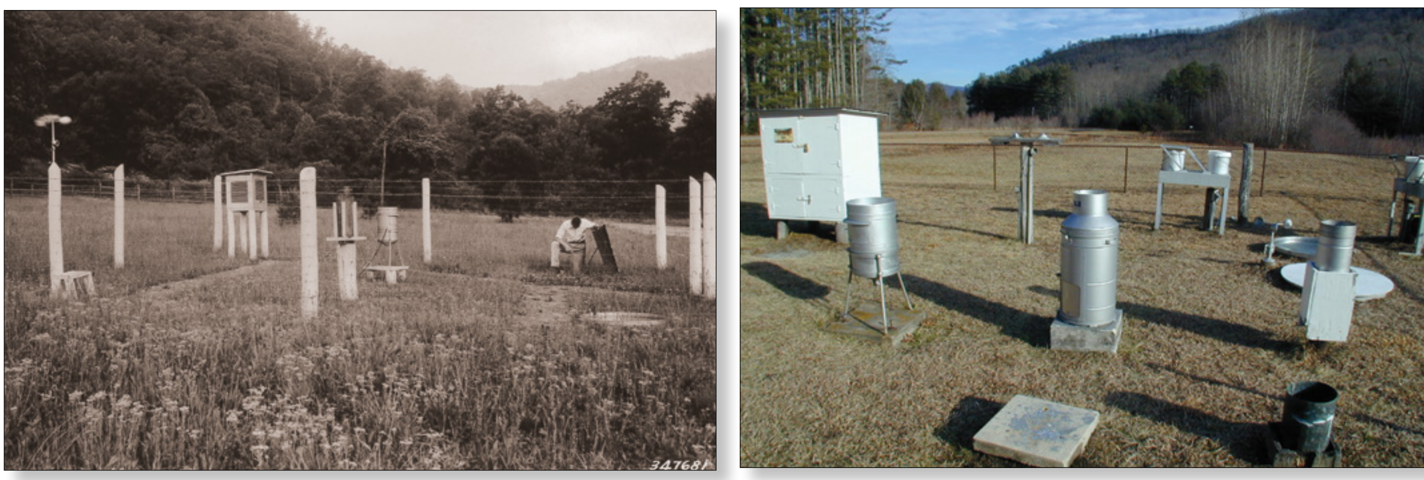

Meteorological data have been collected continuously at the same location by the Coweeta Hydrologic Laboratory since 1934. Left: circa 1934; Right: circa 1999.

In 1934, near the small town of Otto, NC, the Appalachian Forest Experiment Station, U.S. Department of Agriculture Forest Service, established the Coweeta Experimental Forest (later renamed the Coweeta Hydrologic Laboratory) (Ice and Stednick 2004, Lehman 2009). Much of the early scientific knowledge about how forests influence watershed water cycles was produced from studies at Coweeta. Indeed, much of today's forest hydrology science—the study of water movement in forests—originated from the research at Coweeta and other experimental forests across the United States (Ice and Stednick 2004).

As one of the world's oldest forest hydrological stations with the longest hydrologic records, Coweeta is regarded as a special "holy" place to visit and study for many international forest hydrologists—a once in a lifetime opportunity. For this reason, I take great pride to have done research at Coweeta and to be associated with its people.

Indeed, Coweeta's influences on my academic career have been profound, tracing all the way to the 1980s when I was a graduate student in Beijing, China. At that time, I never thought that I would professionally and personally become part of Coweeta's story! Collaborative work with Coweeta during the past 25 years has been the most rewarding part of my dream job with the Forest Service. Fully accounting for all the influences that Coweeta has had on me is a challenge, but one I would regret if I did not share my story during this occasion of the centennial celebration of the Southern Research Station (SRS).

A group photo of Coweeta's 75th anniversary celebration, November 4, 2009, Otto, NC.

This essay extends an invited presentation at Coweeta's 75th anniversary celebration symposium in which I reviewed the international influences of the science and scientists of Coweeta. Hosted by then-Project Leader Jim Vose, this 2009 event allowed pioneering scientists—and my academic heroes such as Wayne Swank, Lloyd Swift, Peter Black, John Stednick, and Tim Burt, just to name a few—to celebrate their great achievements and legacy at Coweeta.

THE COWEETA CONNECTIONS FROM AFAR

In 1981, there was an unusually open debate on the true hydrological effects of forests among two well-known academics in China (Huang 1981, Wang and Huang 1981). This controversial discussion centered around "correctly understanding the role of forests" and was led by Professor Bingwei Huang, a geographer and the director of the Institute of Geographical Sciences of the Chinese Academy of Sciences, and Professor Zhenru Wang, a tree physiologist and Duke University graduate teaching at my alma mater, Beijing Forestry University. Huang warned that a forest's hydrologic benefits should not be exaggerated while Wang stressed the large ecological functions of forests in precipitation formation and erosion controls.

This debate was triggered by the 1981 flood in the upper Yangtze River, a river with a similar length to the Mississippi River, which killed 1,369 people and left over 20 million homeless. Like many undeveloped countries, soil erosion problems were rampant throughout China in the 1980s due to years of deforestation and land exploitation. In particular, the Yellow River Basin, "the cradle of Chinese civilization," was known to have chronic sedimentation and flooding problems. In fact, the former USDA assistant chief of Soil Conservation Service W.C. Lowdermilk visited China in the 1920s, and his famous book *Conquest of the Land through Seven Thousand Years* describes the Yellow River as "China's Sorrow" (Lowdermilk 1948). Since the 1970s, foresters and soil conservationists in China recognized the problems and called for large-scale tree planting, aimed at slowing down the trend of land degradation and floods at the national scale (Sun and others 2006).

Unfortunately, the debate between Huang and Wang was inconclusive because there were few rigorous forest hydrologic studies in China at that time. Huang and Wang's arguments were mostly based on limited Western literature outside of China, including work done at Coweeta. The debate was later dubbed as "Fighting Civil War with Foreign Weapons" (Wei and others 2008). In retrospect, the controversy was not unique to China, because forest-water relations are complex and have been the subject of considerable speculation since at least the French Revolution (Andréassian 2004), and even today there remains globally many unknowns (Vose 2019).

The release of the book *Forest Hydrology and Ecology at Coweeta* (Swank and Crossley 1988) proved to be a milestone. This synthesis comprehensively documented the long-term forest hydrology and ecosystem-scale research conducted at Coweeta since the 1930s. Unfortunately, back in the middle 1980s, I had very limited access to Coweeta research before this "green book" was published. The "bible" that I used as a graduate student was the lengthy "Proceedings of Forest Hydrology Symposium" (Sopper and Lull 1967). There was perhaps one single copy in China and this book could only be read in the National Library in downtown Beijing. I was so happy that the library had such an important document published in the late 1960s when the "Cultural Revolution" (1966–1976) was at its height and most higher education and academic activities were halted.

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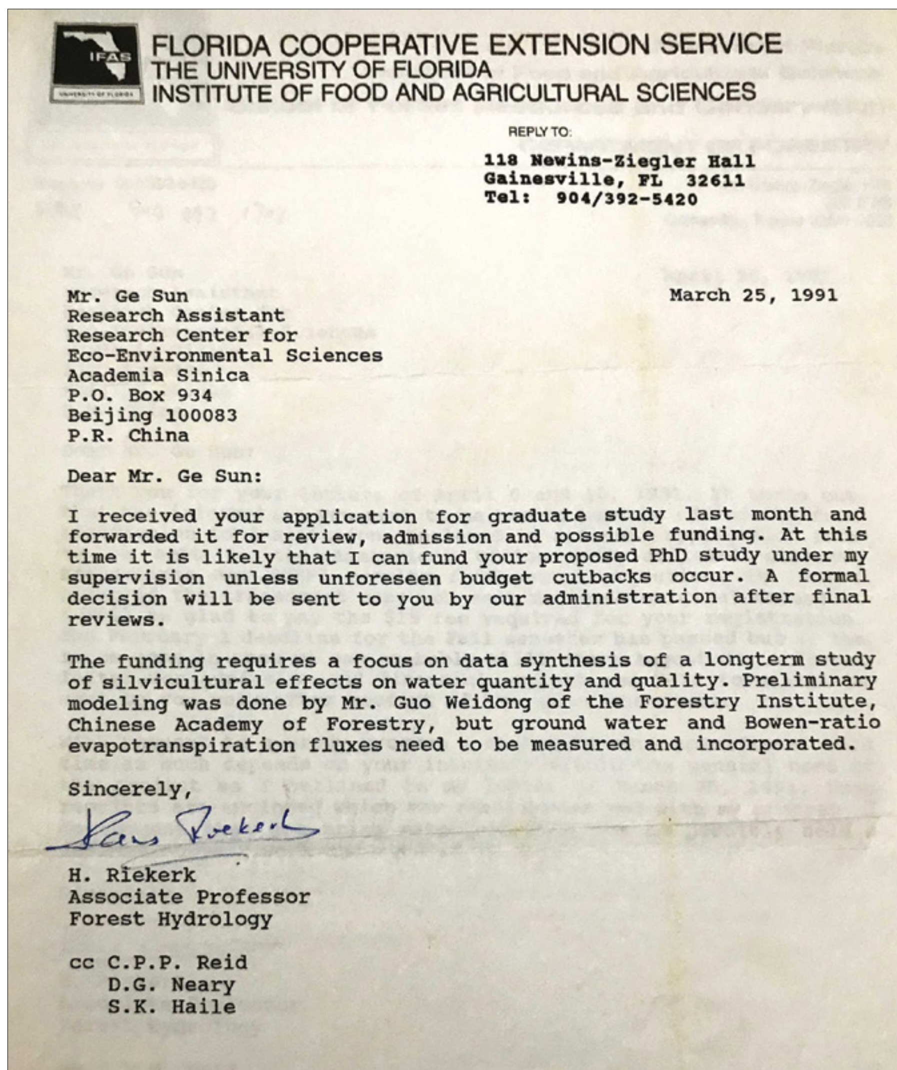
As one of a handful of graduate students focusing on forest hydrology in China in the late 1980s, I was amazed by the contradictions between limited Western forest hydrology literature (mostly from the United States and Australia) and what I was taught. Our rudimentary college textbooks were heavily weighted towards Russian and Japanese literature and our "traditional wisdoms" that view forests as benefiting water resources. The popular view was that since forests are like sponges, forests can "*Han Yang Shui Yuan*," meaning "forests retain flood water and release it slowly," and so planting trees will "gain" and store water like "green reservoirs." The zeal to use trees to solve water problems still exists today in many parts of the world and many lessons have been learned, especially in arid regions in China. However, even well-intentioned afforestation or reforestation programs can go wrong when our understanding of basic hydrologic science is not used to inform decisionmaking.

My master's thesis research in 1987 aimed at quantifying the hydrological functions of Chinese fir (*Cunninghamia lanceolata*) forests in southern China. To get more reading materials about hydrograph separation methods and to understand the Variable Source Areas theory that explains streamflow generation in humid regions, I sent Dr. John Hewlett a handwritten letter—the first one in English in my life. Hewlett was stationed at Coweeta during 1956–1964 and served as project leader during 1959–1964, before joining the faculty of University of Georgia where he retired in 1984. He was regarded by many as "the Godfather" of forest hydrology (Jackson and others 2005). To my delight, a month later I received a large yellow envelope from Hewlett. Inside were several reprints of Coweeta publications including a report of their famous soil moisture model (Hewlett and Hibbert 1963) and the *Science* paper on the effects of converting deciduous hardwoods to eastern white pine (*Pinus strobus*) (Swank and Douglass 1974). Hewlett also provided a copy of the cover page of his book *Principles* *of Forest Hydrology* (1982) published in Chinese (in Taiwan), writing me that he understood "… it might be difficult for you to get a copy of the translated one…". Since then, the relationships between China and the world certainly have changed, thanks to China's "open door" policy implemented in the early 1980s.

THE FLORIDA IMPAC

My life changed forever in the fall of 1991. I was fortunate to have the opportunity to start a doctoral program in forest hydrology and watershed management under Hans Riekerk and Dan Neary in the School of Forest Resources and Conservation at the University of Florida. My financial support was provided by the Intensive Management Practices Assessment Center (IMPAC), established in Gainesville in 1976 to assess various southern forest management practices for maximizing tree growth and to determine if these practices were ecologically, environmentally, and economically feasible (Comerford and others 1985). Neary worked as a soil scientist at Coweeta for several years before moving in 1981 to Gainesville as the project leader of IMPAC.


FLORIDA COOPERATIVE EXTENSION SERVICE
THE UNIVERSITY OF FLORIDA
INSTITUTE OF FOOD AND AGRICULTURAL SCIENCES

REPLY TO:
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March 25, 1991

Mr. Ge Sun
Research Assistant
Research Center for
Eco-Environmental Sciences
Academia Sinica
P.O. Box 934
Beijing 100083
P.R. China

Dear Mr. Ge Sun:

I received your application for graduate study last month and forwarded it for review, admission and possible funding. At this time it is likely that I can fund your proposed PhD study under my supervision unless unforeseen budget cutbacks occur. A formal decision will be sent to you by our administration after final reviews.

The funding requires a focus on data synthesis of a longterm study of silvicultural effects on water quantity and quality. Preliminary modeling was done by Mr. Guo Weidong of the Forestry Institute, Chinese Academy of Forestry, but ground water and Bowen-ratio evapotranspiration fluxes need to be measured and incorporated.

Sincerely,

Hans Riekerk

H. Riekerk
Associate Professor
Forest Hydrology

cc C.P.P. Reid
D.G. Neary
S.K. Haile

Admission letter from Dr. Hans Riekerk to the author to start his doctoral program in forest hydrology in the School of Forest Resources and Conservation at the University of Florida.

My dissertation research synthesized the 2-decade-long accumulated hydrological data on the effects of various forest harvesting practices on pine flatwoods watershed hydrology. The Florida watershed study design followed the standard paired watershed methods developed at Coweeta. Measuring flow from small, poorly drained, flat watersheds in Florida proved to be more challenging than in the mountainous Coweeta watersheds. The first-order streams in these headwater watersheds are ephemeral and often stagnant, but the watersheds are periodically flooded by tropical systems. Furthermore, the water samples for chemical analysis needed to be refrigerated under the Florida heat (Ice and Stednick 2004).

Modeling the watershed hydrology was another goal of my graduate research. Initially, I was advised to investigate VASA, a computer simulator developed by Hewlett's group at the University of Georgia based on the Variable Source Area Concept (Bernier 1982, Troendle 1979). The model did well for the Piedmont landscape to model stormflow generation processes and had previously been tested with some success in Florida (Guo 1989). However, I ended up using a different modeling scheme to simulate the variably saturated areas on the heterogenous flatwoods landscape dominated by cypress (*Taxodium distichum*) swamps and slash pine (*P. elliotii*) plantations by explicitly tracking the shallow water table using a spatially distributed approach (Sun and others 1998a, 1988b). The shallow ground water table, rather than hillslope, controls surface and fast flow generation in the lower Coastal Plain. The shallow ground water table in pine flatwoods fluctuates appreciably on a subhourly basis in response to forest evapotranspiration (ET) or rainfall. My own studies on ground water table dynamics on Watershed 2 at Coweeta confirmed the saturated area in the hilly watersheds was rather small and the stormflow was generated from fast subsurface flow in the hilly watersheds (Sun and others 2008b). In comparison, the extent of the variable source area to explain stormflow generation in the lower Coastal Plain can be rather large (Sun and others 2002, 2008b).

FROM THE MOUNTAINS TO THE SEA

Knowledge gained at Coweeta has been widely used in modern watershed management both regionally and globally. While Coweeta's research has provided considerable knowledge, hydrologic processes in the Southern Appalachians may not be representative of other physiographic regions. Fortunately, the SRS also installed similar sites across the South, such as the Calhoun Experimental Forest in South Carolina in the Piedmont and the Santee Experimental Forest on the lower Coastal Plain in the 1960s. Both the Santee and Calhoun sites have significantly contributed to our understanding of water movement from the "Mountains to the Sea" and characterize the critical zones in the Southeast (Sun and others 2008a, 2008b). Most recently, SRS established the Experimental Forest and Range Network (EFN) by bringing together 19 field-based research sites under one umbrella. The goal of the EFN is to facilitate cross-site collaboration, leverage resources, and share data and expertise. The EFN also looks to answer emerging large-scale environmental challenges such as climate change, urbanization, and invasive species. Such a network-based, top-down approach allows scientists to work across traditional SRS work units and disciplinary boundaries to develop more powerful modeling systems and answer management questions that more limited studies cannot.

The studies at Coweeta were some of the earliest to consider the interactions between hydrology and ecological processes. Using this field of ecohydrology, we have learned much about how water moves through the forests in the Appalachian Mountains.

My own research has benefited greatly from SRS-wide collaborations. Over the decades, I have helped build various simulation models, including the Water Supply Stress Index hydrological model (WaSSI), as tools to estimate watershed water and carbon balances in the Southeastern United States and beyond (Sun and others 2011). The core of the WaSSI model is an ET submodel that provides a straight coupling of the water and carbon fluxes. The ET model development was the direct result of a close collaboration with former and current Coweeta scientists including Steve McNulty, Jim Vose, Chelcy Miniat, and Peter Caldwell. The generalized monthly scale empirical ET model was derived from field measurements of tree sapflow at Coweeta and eddy fluxes on the lower Coastal Plain of North Carolina led by research partners John King and Asko Noormets. These datasets covered a large climatic gradient from Coweeta's subtropical forests to semi-arid woodlands in Australia and grasslands on the Mongolia Plateau in northern China.

CONCLUSIONS

Today, Coweeta represents one of the crown jewels of the Forest Service's long-term research installations. Thanks to those early visionaries such as Charles R. Hursh, who set up the first weather station and built the first weir at Coweeta, continuous, often high-temporal-resolution weather and streamflow data for the past 9 decades have been recorded. The studies at Coweeta were some of the earliest to consider the interactions between hydrology and ecological processes. Using this field of ecohydrology, we have learned much about how water moves through the forests in the Appalachian Mountains. Over the years, in response to the public needs, the mission of this outdoor hydrological lab has shifted from research on the effects of forest cutting on flood and sedimentation to developing a process-based understanding of ecosystem functions and services at much broader scales. Furthermore, Coweeta has played a prominent role in advancing ecosystem sciences, developing sound watershed management practices, and helping to address global environmental issues such as climate change.

Coweeta's contribution and impacts extend far beyond its watershed boundaries, and it continues to inspire and shape forest science, scientists, and public policies. For instance, Chinese institutions and scientists have benefited tremendously from all of the exchange opportunities with Coweeta (and vice versa), such as the Chinese language textbook, *Watershed Ecosystem Process and Management* (Wei and Sun 2009), developed using many materials from Coweeta. The long-term integrated place-based approach exemplified by Coweeta remains relevant for contemporary watershed sciences in a human-dominated world. Solving many of the global challenges and problems facing sustainable development requires a clear understanding of the basic science of water—the foundation of the work at Coweeta.

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