2017-2018 TWRI Mills Scholarship Application
2017-2018 USGS Graduate Research Program Application

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Degree Starting Year: Fall 2016

Relating Riparian Health to River Hydrodynamics and Climate Using Dendrochronology and Tree Ring Carbon Isotope Composition

The funds will initiate new research and the findings will subsequently be associated with the Texas Water Observatory (TWO) Project, which is currently in its initial stages. The data collected from the TWO will also contribute towards assessing the findings of this research. This research will reinforce the TWO findings; however, this work is not funded by TWO.

Abstract

Texas is experiencing a steep increase in the frequency and severity of floods and droughts. Under the current situation, the bottomland hardwood forests of Brazos Valley, which are one of the most diverse ecosystems in the state, are hydrologically critical for the region. These extreme hydroclimatic events can have exacerbating effects on the forest health and fundamentally change a wide range of ecosystem processes and services. The ecohydrological impact on these forests will consequently have serious repercussions on the region's water resources. Dendrochronological records of hydroclimatic anomalies and variations in the tree ring carbon isotope composition will be used as a metric to understand the effect of water-related stress on the forests across a time sequence. The study will also provide insights on the role of fossil fuel induced air pollution in intensifying hydrological stress on these forests. Climatic variations, ambient CO_2 levels, seasonal inundation levels and soil parameters will be monitored uniformly over a one-year period and integrated with the historic time series as reinforcement. Modeling future ecohydrological impacts of floods and droughts on these forests will aid in planning mitigation measures as the role of these forests is crucial for improving the overall hydrological condition of the region.

Proposed Research Description

Bottomland hardwood forests and associated habitats occur in significant amounts along the floodplains of the rivers and bayous in coastal counties of Southern Texas. Meandering through coastal Texas, the lower Brazos, San Bernard and Colorado rivers combine to form the Columbia Bottomlands. Trees found in the Columbia bottomland hardwood forests include the bald cypress, pecan, oak, elm, cottonwood and hackberry. These riparian forest stands are subjected to a variety of hydrological stresses as a result of fluctuations in water levels during floods and droughts. Bottomlands also serve as expansive shallow reservoirs that contain floodwaters when rivers overflow. Rivers in the Columbia Bottomlands have a variety of interconnected instream habitat types, all of which help support the ecosystem's hydrology and biodiversity.

This study is a hydroclimatological reconstruction of magnitudes and frequencies of recent or past floods and droughts. The interactions between floodwaters and trees leave datable evidence of past flood activity on the growth-ring record of the trees. Floodplain vegetation will therefore be used

as a natural archive of past floods and droughts, which will be deciphered using dendrogeomorphic techniques. As tree rings are distinguished by their high temporal (annual or sub-annual) and spatial resolution, regional flood chronologies have the potential for being able to identify the full range of natural flooding variability in an area, potentially linking the floods to both climatic drivers and relevant catchment variables. Generally, tree rings are observed to be wider during years of abundant rainfall and narrower during droughts. Sensitivity of tree ring widths to warm temperatures has been attributed to changes in seasonality, decreased amounts of solar radiation due to increased cloudiness, and drought stress. Tree rings not only record growth rates as measured in ring widths, but also provide stable isotope ratios that are directly controlled by a range of hydrological changes in the environment.

Carbon isotope variations primarily relate to plant responses to environmental changes. The measurement of carbon isotope composition in tree rings will help in establishing a temporal relationship of carbon accumulation in trees with the moisture-related stress emanating from hydroclimate changes over a time series. **The study thus addresses the TWRI research priority of investigating impacts of climate variability and drought on water resources and adaptation measures.**

As tree ring stable carbon isotopes are controlled by photosynthetic rate and stomatal conductance, they can provide evidence of physiological moisture stress in response to climatic variations. Enriched tree-ring ^{13}C values usually relate to environmental moisture stress, while depleted values are usually indicative of non-stressful growing conditions. Recent evidence has revealed that increased levels of precipitation can also result in reduced stomatal conductance and/or increased assimilation rates in trees, resulting in relative carbon isotope enrichment. The study will anticipate which pathways are followed by the trees in this region. To avoid desiccation during periods of reduced water availability, plants decrease their transpiration rates by closing a proportion of their leaf stomata. With a greater proportion of its stomata closed, a plant has a reduced ability to replenish internal leaf CO_2 with atmospheric CO_2 and forces the plant to use ^{13}C enriched CO_2 to maintain adequate photosynthetic rates. Therefore, during droughts, the utilization of the relatively heavier ^{13}C is augmented, resulting in a higher ratio of ^{13}C to ^{12}C ($\delta^{13}C$) in the tissue produced. Environmental conditions that control the rate of stomatal conductance and photosynthesis also influence the stable carbon isotope ratios in tree ring cellulose. The climatic factors influencing radial growth can be identified to confirm the expected signals of moisture stress observed in studies of ring width chronologies.

The study site (29°9'44" N, 95°49'15" W) is located in the downwind direction of a prominently large petrochemical refinery and preliminary investigation has indicated the presence of elevated ambient CO_2 levels. In areas where locally-added fossil fuel-derived CO_2 contributes a significant proportion to atmospheric CO_2, plant ^{14}C reflects the proportion of the two sources of CO_2 (natural or anthropogenic) at the time of fixation, and can be used to infer atmospheric CO_2 mixing ratios. The addition of ^{14}C analysis will enable the identification of the carbon source, provide a more accurate estimation and distinction of carbon deposition in the trees and also help in studying the effect of fossil fuel-induced pollution on the ecohydrology of the area.

The primary objectives of the study are: a) Construct a hydroclimatological time series of the region using dendrochronology; b) Correlate carbon isotope ratios in tree-rings with hydrological variability; c) Investigate the impact of fossil fuel-induced air pollution on the ecohydrology of the forest; d) Study the current ecohydrology and microtopography of the forest; and e) Integrate the historic and current records to inform models of vegetation responses to future hydrological anomalies and assist in flood-risk assessment and mitigation.

Ground-based topographic surveys will be conducted by laying 250-m transects perpendicular to the river to develop an elevation model, which will be used to study the seasonal inundation and surface hydrology of the study area. If floods occur during the study period, additional surveys will be conducted to estimate the inundation levels. Tree samples will be collected from plots demarcated along these transects. Dendrochronological sequences will be developed by sampling tree cores with the help of an increment borer and analyzing the annual tree ring widths. For carbon isotopic analysis of the tree rings, α-cellulose will be extracted from the cores by the Jayme-Wise Method (Green, 1953) using a Soxhlet extraction assembly. The α-cellulose samples will be analyzed for ^{13}C using Isotope Ratio Mass Spectrometer and for ^{14}C using Accelerated Mass Spectrometer. Historical precipitation, humidity and temperature data will be acquired from local weather stations. The dendrochronological time sequence, isotope measurements and the historical climate datasets will be comparatively analyzed for correlation. The basal area of the forest stand will also be calculated using a wedge prism relascope to investigate the impacts of hydroclimatic variability on the stand growth. Beginning January 2017, continuous measurements of precipitation, temperature, humidity, soil moisture, soil salinity and atmospheric CO_2 will be collected at a nearby core TWO site in the same forest patch.

The findings are expected to indicate the response of the bottomland hardwood forests to anomalous floods and droughts by altering carbon assimilation. The study will deliver a historic series of the hydroclimatic trends of the region which will act as a baseline for predicting future ecohydrological impacts of floods and droughts on these forests. It will provide fundamental data to plan mitigation measures and more significantly, improve understanding of how hydrology affects riparian forest health of the region. We will also test a new method to use fossil fuel emissions as a tracer for studying temporal growth dynamics in flooded riparian forests.

Budget

Either source of funds would be applicable to my project, with USGS as first choice.

Category	Request	Justification
Laboratory Supplies	$2000	Chemicals and glassware for cellulose extraction
Field Supplies	$500	Soil Samplers, Flagging, Survey Equipment
^{14}C Isotope Pilot Analysis	$1500	KCCAMS Facility at UC, Irvine ($150/sample)
^{13}C Isotope Sample Processing and Analysis	$800	SIBS Lab, TAMU ($6/sample)
Travel	$200	Field visits for sampling and surveying
Total	**$5000**	

Current Assistantship: James M. Carder Graduate Assistantship (Non-Federal) including a stipend of $25,000/year, tuition payment and health insurance benefits (9/1/2016-8/31/2017). Funds for tuition and fees are requested if selected for the TWRI Mills Scholarship and the budgetary breakdown mentioned above is applicable for the USGS Graduate Research Program.

Career Goal

I seek to build a career as a professional researcher in the field of forest ecohydrology with the aim of resolving pertinent problems at the grassroots level. I wish to undertake research work at a global platform, being realistic at the same time and conducting impactful work to target real world water management issues. Dr. Georgianne Moore's superlative expertise in this field has provided me with an ideal platform to achieve my goals. I am eagerly looking forward to contribute to the future success of the efforts to resolve water management issues in Texas. I wish to carry the knowledge and skills that I acquire during my stint, to the developing part of the world, especially the Indian subcontinent, where efficient water resource management is an urgent need to cope up with the rapid development.