Kite-based Aerial Photography (KAP): A Low Cost, Effective Tool for Wetland Research

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The development and utilization of new technologies in wetland research is key for advancing knowledge, conservation, and management of these important ecosystems. While satellite-based remote sensing has proven valuable for understanding mostly regional to continental scale changes in wetlands (Ozesmi and Bauer 2002, Rebelo et al. 2009), the high spatial heterogeneity of wetland plant communities and landscape units has proven challenging to characterize with the use of satellite technologies (e.g., Kim et al. 2012). The use of aerial photography to link or scale plot scale measurements to those made by satellites has long been recognized (e.g., Harris and Bryant 2009). More recently, the increasingly popular use of unmanned aerial vehicles to acquire low altitude high resolution imagery and other data at relatively low cost has reinforced the utility of aerial remote sensing platforms. When most researchers think of UAVs, they think of scaled down airplanes (Rango et al. 2006), blimps (Marzolff and Poesen 2009), and helicopters or quad/octocopters (Rosnell and Honkavaara 2012). Few researchers think of kites as a capable, affordable, and efficient platform for acquiring aerial imagery - kite-based aerial photography (KAP) (Aber et al. 1999, Dandois and Ellis 2010), despite kites being used to acquire among the first airborne imagery ever captured (Beaufort and Dusariez 1995). Furthermore, unlike most of the other UAVs listed above, KAP systems are less restricted by general aviation regulations in most countries. Previous studies have shown the feasibility of KAP as an valuable tool for a wide variety of environmental observations including land degradation (Marzolff et al. 2002), surface hydrology (Andresen and Lougheed in review), high mountain ecosystem research (Wundram and Löffler 2007), biocontrol assessment (Aber et al. 2005), forest ecology (Aber et al. 2002), and bird colony census (Fraser et al. 2010). Given that many wetland landscapes typically experience windy conditions, KAP represents a suitable platform for acquiring high spatial resolution aerial imagery of these ecosystems. This article introduces kite-based aerial photography to the wetland scientific community as an inexpensive, user-friendly remote sensing technique that has numerous applications in wetlands research.

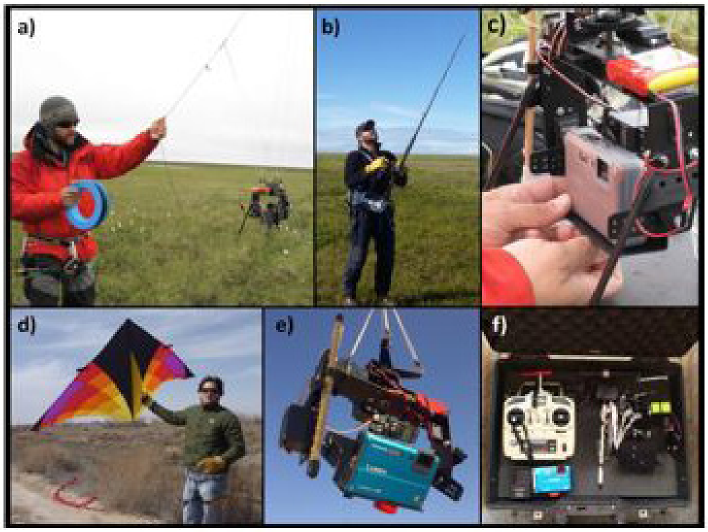

Figure 1. KAP equipment used for the studies featured in this article. a) Deployment of KAP rig with hand reel and waist harness for line attachment, b) Rod and reel for high altitude image acquisition (>200m), c) Camera setup on KAP rig, d) Delta style kite (9ft), e) KAP rig and picavet auto-levelling system, f) and carry case with the KAP radio control, camera, rig, tools, and spare parts.

Methodology and Equipment

A typical KAP system consists of a kite, a kite line and a camera rig suspended from the kite line (Aber et al. 1999). For the case studies presented in this article, a relatively simple light-weight single-camera rig system lifted by a delta style kite was utilized (Figure 1). The rig allows users to pan, tilt and trigger the camera via a remote transmitter that is typically used by model airplane enthusiasts (4 channel R/C system). This system permits users to acquire images of a given region of interest from various perspectives. Cameras included relatively standard point-and-shoot and small DSLR models. For low altitude flights, a 100-250 lb-test Dacron or braided line was used, while for high altitude flights (>200m), a large-line capacity (500-1000m) fishing reel and rod was used to make line control more efficient and comfortable for the user. It is advice to always wear heavy-duty gloves for hand protection from line.

Prior to flying it is important to know the size of the area of interest in order to calculate the desirable flying

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height. Optimal flying heights can be estimated based on the viewing angle of the camera using basic trigonometry and users are advised to conduct pre-flight calculations of line length vs flying angle. Several websites also facilitate the calculation of optimal flying heights given camera specifications (e.g., http://www.aerogis.de/eng/gsdcalculator.html; http://www.grc.nasa.gov/WWW/k-12/airplane/kitehigh.html). During high altitude flights, considerable bow can persist in the kite line and we have found that attaching a transmitting GPS to the KAP rig aids in calculating both the horizontal distance the KAP rig is away from the user and if the KAP rig is positioned optimally over the region of interest (ROI). When combined with measurement of flying angles of the kite relative to the observer using a clinometer, flying height can easily be calculated using formulae in the links provided above. It should be noted that fluctuations in wind speed and turbulence can alter camera rig height rapidly so it is wise to be conservative in the calculations of the camera footprint and either oversample the ROI and/or fly at a higher altitude to ensure a larger sampling footprint.

Image Processing

In recent years, advances in photogrammetric and digital image processing software have substantially improved capacities for deriving environmental characteristics from photographs. Images can be incorporated into Geographical Information System (GIS) software using geometric corrections based on ground control points (GCPs) distributed throughout the site or by image to image rectification with existing high resolution satellite or aerial imagery. When study sites are larger than the camera's footprint, images can be mosaicked and color balanced in a range of image processing software (e.g. ERDAS Imagine, ENVI, Agisoft, PhotoScan, etc.). After geometric correction and/or mosaicking, images can be used for multiple purposes including delineation of features of interest, production of land cover maps, estimation of area or distance, and calculating vegetation greenness indices that are proxies for vegetation productivity (Richardson et al. 2009, Migliavacca et al. 2011). In addition, recent advances in digital photogrammetry, image processing, and computing has allowed for 3D spatial data to be derived for ROIs captured with multiview imagery that is suitable for the production of digital elevation and hydrographic surface models (e.g., Snavely et al. 2010). Below, we present two case studies that showcase the potential of KAP in wetlands research.

KAP Case Studies

The Rio Bosque Wetlands Park is a 372-acre mitigation site near El Paso, TX that includes a seasonally waste-water irrigated wetland (Rodriguez and Lougheed 2010). Management of invasive species such as tumbleweed (*Salsola* spp.) and saltcedar (*Tamarix* spp.) can be aided by the production of detailed land-cover classifications using ENVI

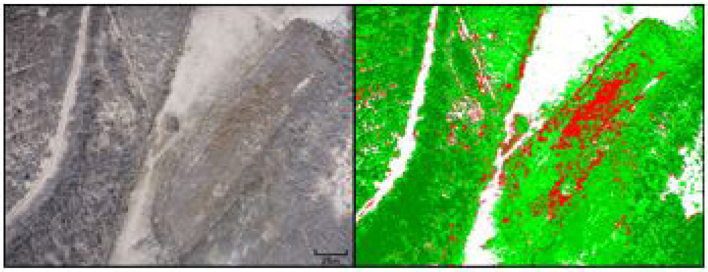

Figure 2. Winter KAP image of Rio Bosque Wetland Park (left) and supervised land-cover classification (right) depicting invasive species in red (mostly tumbleweed), and native plant communities (green).

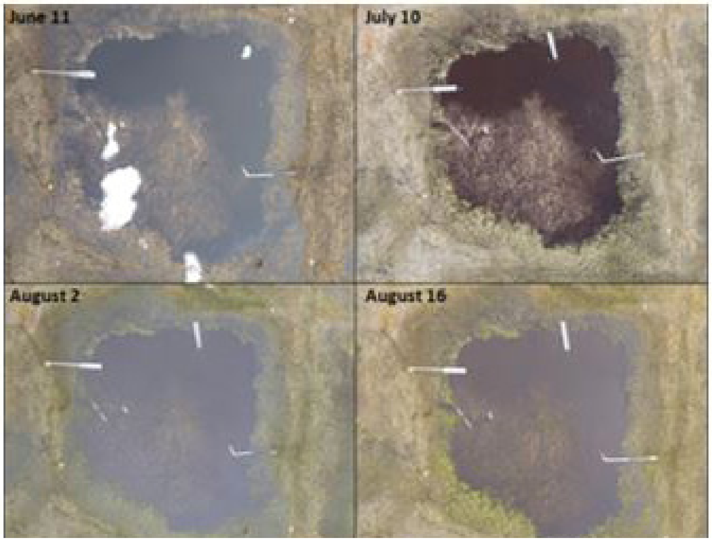

Figure 3. Kite-based aerial imagery of an Arctic tundra pond showing seasonal changes in pond water depth and plant cover during the growing season in 2011 (Site: IBP-J 71.293626N, -156.70144W). Infrastructure for accessing the ponds can be seen in all photographs and snow/ice can be seen in the image acquired on June 11th. Imagery was acquired with a point and shoot camera at an approximate height of 80m.

Figure 4. KAP panoramic image composite of the International Biological Program wetland ponds near Barrow, Alaska acquired with a DSLR camera at an approximate height of 100m.

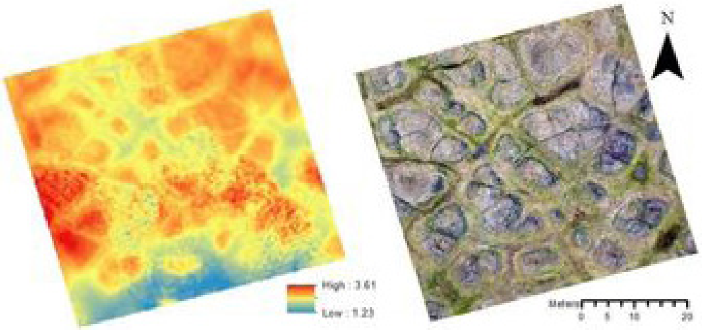

Figure 5. Interpolated DEM surface model (left, meters above sea level) and corresponding georeferenced kite aerial image (right) for polygonal tundra near Barrow, Alaska. DEM derived from 200 multi-view angle images at a height of 50m approximately.

and KAP imagery acquired with a point and shoot camera flown at approximately 80m (Figure 2). Ground surveys suggest that the classification given in Figure 2 allows for the identification of tumbleweed plants that are as small as 15cm in diameter.

For Arctic Tundra Wetland research on the North Slope of Alaska (Lougheed et al. 2011), the KAP system was used to document seasonal landscape-level changes and spatial and temporal greening trends of small tundra ponds, generally less than 40m across (Figure 3). In addition, the KAP was used to obtain composite image mosaics for larger wetlands, oblique-view panoramas (Figure 4) and digital elevation models (DEMs) (Figure 5). Greening trends can then be calculated using georeferenced repeat photography and greenness indices that are proxies for plant phenology and carbon fluxes (e.g. Richardson et al. 2009; Migliavacca et al. 2011). DEMs were derived from multi-view imagery that were processed with Agisoft PhotoScan.

KAP Advantages and Challenges

We tested the KAP system in a variety of wetlands situated in extreme environments such as the Arctic tundra and the Chihuahuan desert. This low-cost remote sensing system has proven to be a cost effective and reliable tool for acquiring high-spatial resolution aerial imagery of research sites. The advantages of KAP over other small format aerial photography platforms such as the UAVs listed above, include lower cost, longer flight times (including sustained stationary acquisitions), ease of operation and few legal constraints. The relatively low cost of a KAP system is one of the major advantages over remote sensing platforms. The systems we typically deploy cost $500 - $1,000 US depending on the camera and altitude we are flying. One of the major limitations of drones is their short flight time, which is directly related to the battery life, design, and payload. In contrast, KAP systems can be flown for a couple of hours depending mainly on wind strength and battery life of the camera and servos on the KAP rig. In addition, the simplicity of KAP over drones and other systems makes it a better option for inexperienced or infrequent users and/or users deploying systems in remote areas where there is limited access to specialist components. Piloting drones is technically demanding and usually requires extensive maintenance in comparison with KAP systems. We typically 'fly blind' in that we do not usually telemet video footage from the KAP rig to the user on the ground. As a result, the user and, where possible, observers position the KAP rig over a given ROI by careful judgment. We have found that experience improves target accuracy and that it is only for high altitude KAP that the need for a real time video feed would be useful. Nonetheless, following a flight, we always carefully view images on site and repeat the flight if we are dissatisfied with initial results.

As with most aerial remote sensing platforms, there are challenges to KAP. Although kites of varying sizes and multi-kite configurations can be used to sustain flight during varying wind conditions, including turbulent conditions downwind of ridgelines and infrastructure, winds of less than 7mph typically prevent flight. When flying a 1kg KAP rig, small delta kites (8-12ft) are well suited to strong winds (15+ mph) and bigger kites (12-16ft) for lighter winds (7-15 mph). In some cases, wind direction can be problematic if obstacles prevent overflight of a target downwind of the user. Forests and vegetation can be problematic especially with canopy taller than 10m. It is advice to launch the kite in open areas free of obstacles such as power lines and large trees. Flying the kite at higher altitude helps gain kite stability by avoiding canopy and terrain wind turbulence. A preflight analysis of the research site is highly encouraged to address questions of wind speed and direction as well as launching area and potential obstacles. In addition, several bad experiences hasten us to caution users that weather conditions can change quickly at times and that appropriate scenarios for responding to such adversity should be planned before any flight. We also encourage users to fly responsibly and abide by flight restrictions enforced by local and general aviation authorities. ■

Acknowledgements

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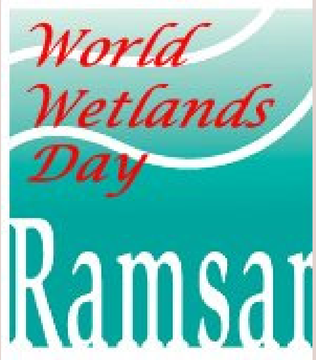
World Wetlands Day Coming



Every year the international community celebrates wetlands around the globe on February 2. This day marks the anniversary of the signing of the Convention on Wetlands of International Importance in Ramsar, Iran in 1971 (see the article by Rob McInnes in this issue of Wetland Science and Practice for more information on the treaty). On World Wetlands Day, governments and non-government organizations sponsor events (e.g., nature walks and lectures) to increase public awareness of wetland values and benefits and promote wetland conservation. For a list of U.S. Ramsar sites where events may be happening, check out the website of the U.S. National Ramsar Committee: http://usnrc.net/.

WETLAND SCIENCE RESEARCH NEWS

This section is intended to inform readers about ongoing wetland research by various universities, government agencies, NGOs and others. When studies are completed, WSP invites short articles that address key findings, while more technical papers are submitted to Wetlands or other peer-reviewed journals. Researchers interested in posting short or more detailed summaries of their investigations are encouraged to contact the WSP editor (please include "WSP Research News" in the email subject box).

Carlos Troche has shared summaries of two ongoing wetland research projects in Mexico that he is involved with. One of them at CONABIO (a government agency) and the other one at the Centro de Investigaciones en Geografía Ambiental of the Universidad Nacional Autonoma de Mexico.

Mexican Wetlands: Assessment and Spatial Monitoring

Study by the National Commission for Knowledge and Use of Biodiversity (CONABIO)

Objectives:
1. develop a remote sensing method to identify, delimit and characterize four
4. mexican wetlands;
2. generate land use / land cover maps;
3. examine seasonal changes in waterbodies in wetlands; and
4. explore the relationship between wetland vegetation (biomass) and passive/active optical sensing data.

Expected completion: December 2015
Contacts: Dr. Rainer Ressl (rressl@conabio.gob.mx) and Carlos Troche (ctroche@conabio.gob.mx)

Geo-ecological Assessment of Coastal Wetlands as Carbon Sinks

Research at the Centro de Investigaciones en Geografía Ambiental *of the Universidad Nacional Autonoma de Mexico*

Objectives:
1. determine the composition, structure, distribution and differences in coastal wetland landscapes at 1:250000 and 1:50000 scales;
2. examine the relationship between the heterogeneity of landscapes of coastal wetlands in the Gulf of Mexico, their vertical structure and storage capacity of soil carbon; and
3. establish the relationship of landscapes and biomass estimated from geographic object-based Image analysis.

Expected completion: August 2018
Contacts: Carlos Troche (ctroche@pmip.unam.mx) and Dr. Ángel Priego Santander (apriego@ciga.unam.mx) ■

STUDENT RESEARCH PROFILE

This is a new subsection of the Wetland Science section of WSP that allows students to provide a little background on themselves and highlight their ongoing projects. The first contribution comes from Wes Hudson a Ph. D candidate at the Virginia Institute of Marine Sciences, College of William & Mary, Gloucester Point, VA, USA. Other students interested in summarizing their work should send their profiles to the WSP Editor (rtiner@eco.umass.edu).

Seeking Improvements in Forested Wetland Restoration

Herman W. Hudson III

My current research is an outgrowth of my master's thesis that focused on the drivers of natural tree colonization into post agricultural restored wetlands in southeastern Virginia (Christopher Newport University under Dr. Robert Atkinson). Heavy colonization (>90,000 stems/ha) by pioneer species decreased exponentially as distance from the forest edge increased and stem density was also positively correlated with the size of the trees in the surrounding forest. When tree planting is necessary for the success of a restoration project, deciding what species and stocktype[1] to plant can be a challenge and little information is available to guide practitioners. Few studies have investigated how species and stocktype choice can influence the development of ecosystem functions in forested wetlands. This gap in knowledge drove my interest in forested wetland restoration and is the basis for my dissertation for the Doctorate in Marine Science with Dr. James Perry at the Virginia Institute of Marine Science (VIMS).

My dissertation is a large-scale field experiment that was planted with 2,772 trees in 2009. Seven species were planted: *Betula nigra* (river birch), *Liquidambar styraciflua* (sweetgum), *Platanus occidentalis* (American sycamore), *Quercus bicolor* (swamp white oak), *Quercus palustris* (pin oak), *Quercus phellos* (willow oak) and *Salix nigra* (black willow). Three stocktypes of each species were used: bare-root, tubeling, and 1-gallon containers. The trees were planted in three cells where the hydrology was manipulated using an aboveground irrigation system to include: (1) an ambient cell (a minimum 2.5cm irrigation or rain per week), (2) a saturated cell (kept saturated at a minimum of 90% of the growing season within the root-zone), and (3) a flooded cell (inundated above the root collar at least 90% of year). The environmental conditions in the wettest treatment (flooded cell) represented conditions that could exist in a recently restored forested wetland. They

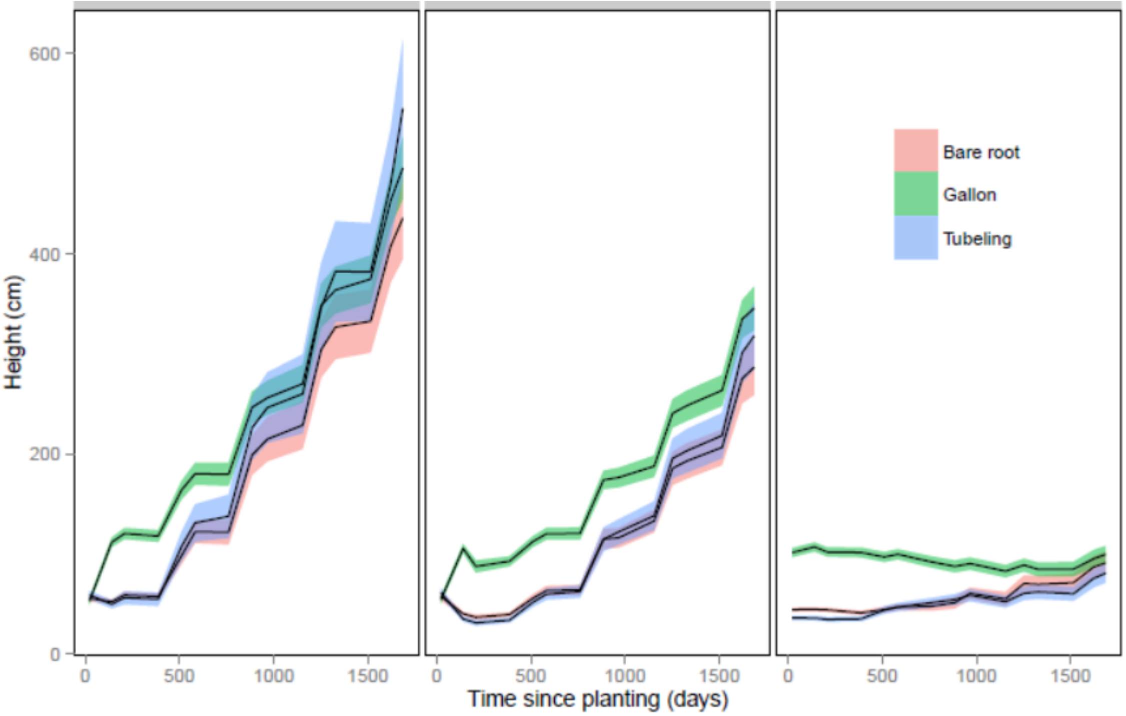


Figure 1. Height of stocktypes in 3 cells over 5 years. Solid line represents mean and colored ribbons represent 95% confidence interval.

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[1] Stocktype is a loose term that refers to the culmination of various nursery production techniques.

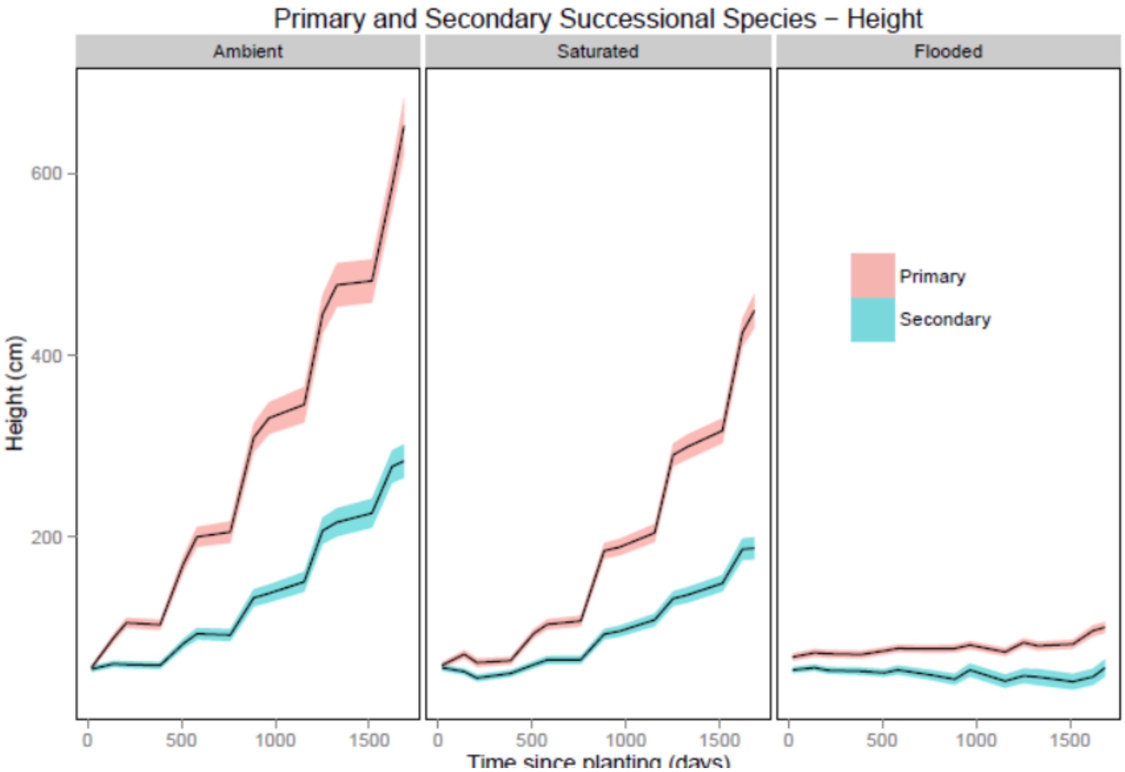

Figure 2. Height of primary and secondary successional species in 3 cells over 5 years. Solid line represents mean and colored ribbons represent 95% confidence interval.

were more stressful than those of the ambient and saturated cells due to uncontrolled herbaceous vegetation competition, higher soil bulk density, lower soil nutrient content, and higher clay content. More than 200 citizen volunteers helped monitor the survival and growth (stem diameter, height, and canopy diameter) of the planted trees for five years. Above- and below-ground biomass of 560 trees were harvested and measured to develop equations relating the biomass to morphological traits, which will quantify biomass accumulation and carbon sequestration functions.

The preliminary results suggest that under stressed conditions (flooded cell) similar to those found in recently restored forested wetlands, stocktypes with larger initial size survive, grow and accumulate biomass more that the smaller stocktypes (Figure 1). Primary successional species (especially *S. nigra*) exhibited greater survival than secondary successional species (*Quercus*) in stressed environmental conditions while the survival of the secondary species equaled or exceed the survival of the primary species in less stressful conditions. The growth and biomass accumulation of the primary successional species was greater than secondary species under all environmental conditions (Figure 2).

These preliminary findings suggest that species and stocktypes need to be selected to match the conditions present at the restoration site or, failing that, primary successional species should be planted using larger stocktypes to ensure the return of ecosystem functions (habitat, productivity, carbon sequestration, etc.). Where the environmental conditions are less stressed, small stocktypes could be used to reduce the cost associated with planting and both primary and secondary species could be used to enhance biodiversity and return gradients of ecosystem functions.

The future goals for this research are to quantify the amount of carbon sequestered by these species and to investigate the role competition/facilitation may have on tree survival and growth. Other research has shown that early successional species could facilitate natural colonization or survival and growth of planted late successional species. My hope is that this research will help improve the practice and ecological understanding of forested wetland restoration.

For additional information on the research, please contact Wes at: hwhudson@vims.edu or via Twitter: @hwhudson3. ■