13th Southern Forestry and Natural Resource Management GIS Conference

December 6-7 2021

University of Georgia
Georgia Center
for Continuing
Education & Hotel

Editors:
Krista Merry, Pete Bettinger,
Chris Cieszewski, Michael Crosby,
Alba Rocio Gutierrez Garzon, Jacek Siry,
Bo Song, Zennure Ucar, Joshua Uzu

SOFOR GIS

ATHENS, GA

2021

13th Southern Forestry and Natural Resource Management GIS Conference

Conference Date:
December 6-7, 2021
University of Georgia
Center for Continuing Education & Hotel
Athens, GA

Conference Proceedings Published:
July 2022

Overall Conference Sponsors:

Orbis

F4 TECH

Additional Sponsors:

Landmark Spatial Solutions, LLC.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference

■ ■ ■ ■ ■ ■ ■ ■

Editors:
Krista Merry
Pete Bettinger
Chris Cieszewski
Michael Crosby
Alba Rocio Gutierrez Garzon
Jacek Siry
Bo Song
Zennure Ucar
Joshua Uzu

Warnell School of Forestry and Natural Resources
University of Georgia
Athens, GA
June 2022

Preface

The University of Georgia in Athens, GA was host to the 13th Southern Forestry and Natural Resource Management GIS Conference. Over 150 natural resource professionals attended the 2021 conference with the majority attending in person while 34% were remote. Attendees came from different organizations including private industry, non-profit groups, universities, and state and federal government. Attendees traveled or connected remotely from across the United States including a large presence from the U.S South along with attendees from Oregon, Washington, West Virginia, Pennsylvania, Maine, and Vermont.

The 2021 conference again included scientific presentations and technical demonstrations following the format of the last two conferences. This year's conference included three keynote speakers: Elizabeth Martinez of Forestland Group, Clarence Neese of Orbis, Inc., and Max Nova of NCX. Topics for conference presentations included technology in forest management, data analysis, forest inventory, natural resource conservation, remote sensing including LiDAR and UAVs, and landscape management technologies. Best Student Presentation awards were awarded to Nisham Thapa for the presentation entitled "Impact assessment of invasive plants on wetlands, coastal prairies, and forests to evaluate the effectiveness of monitoring and control measures" and Anthony Mesa for the presentation entitled "Evaluation of vegetation success on reclaimed natural gap pipelines." Additionally, Anthony's paper by the same title won the Best Student Paper award. We also awarded the Best Poster award to Schyler Brown for the poster entitled "Using airborne and spaceborne LiDAR to estimate forest inventory parameters: A case study over forests in the southeastern U.S."

The conference was supported by the Warnell School of Forestry and Natural Resources and held at the University of Georgia Center for Continuing Education & Hotel. This conference would not have been possible without the expertise and time of members of our planning committee who volunteered their time. Pete Bettinger served as the conference chair, Michael Crosby as the program chair, and Krista Merry as the proceedings chair. Krista Merry, Pete Bettinger, Chris Cieszewski, Michael Crosby, Alba Rocio Gutierrez Garzon, Jacek Siry, Bo Song, Zennure Ucar, and Joshua Uzu served as editors for this conference proceedings.

Finally, we would like to thank our sponsors, F4 Tech, Orbis, Inc., and Landmark Spatial Solutions, LLC. for their support of the 13th Southern Forestry and Natural Resource Management GIS Conference.

K.M.

Proceedings of the 13th Southern Forestry and Natural Resource Management and GIS Conference

Table of Contents

Proceedings Papers

Keynote Address Abstracts

Presentation Abstracts

Poster Abstracts

Papers

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar, and J. Uzu, eds. 2022. pp. 1-8.

Proceedings Paper

Virtually exhausted: Experiences in hybrid conference management during the pandemic

Pete Bettinger
Warnell School of Forestry and Natural Resources, University of Georgia
Athens, GA, 30602, pbettinger@warnell.uga.edu

Krista Merry
Warnell School of Forestry and Natural Resources, University of Georgia
Athens, GA, 30602, kmerry@uga.edu

Abstract

The *Southern Forestry and Natural Resource Management GIS* Conference is generally held once every two years and provides attendees with the latest knowledge and advances in the use of geographic information systems (GIS) and other technology to support forestry and natural resource management. In December 2021, the 13th conference was held in Athens, Georgia, using a hybrid approach that welcomed unlimited in-person attendance while accommodating remote attendance (and delivery of presentations). This paper describes some of the more interesting challenges associated with the hosting and delivery of the conference.

Keywords: Remote attendance, remote presentations, Zoom

Introduction

The 2021 *Southern Forestry and Natural Resource Management GIS Conference* was the 13th conference in a series extending back to 1996, when it was formerly called the Southern Forestry Geographic Information Systems Conference (Arthaud and Hubbard, 1996). Currently, the conference is held once every two years, often in December, and often (since 2009) in Athens, Georgia, at the Georgia Center for Continuing Education and Hotel (Georgia Center).

The last seven *Southern Forestry and Natural Resource Management GIS Conferences* have been managed using a consistent framework. In early January of the conference year, a Planning Committee is formed, and a conference call is held. The organization of the conference is discussed during this meeting, and potential keynote speakers are proposed. A formal theme for the conference is avoided with the aim to attract presentations of any type and from any potential speakers. The call for presentations and the call for posters are designed and provided to the planning committee in February and the calls are released to the general public in March. The call for presentations generally closes in mid-May, and a decision regarding the acceptance of proposed presentations is made by mid-June.

As a result of the outbreak of Covid-19, the ability of people to travel and interact through conference events was restricted, and many conferences were cancelled, shortened, delayed, or offered virtually or in a hybrid format (Ha et al., 2021). During the planning of the 13th Southern Forestry and Natural Resource Management Conference, we followed the guidelines of the Georgia Center, which were aimed at ensuring the safety of conference participants through potential limits on the number of in-person attendees and the spacing of these within the conference venue. Therefore, although our intent was to host an in-person conference in December 2021, we modified our planning processes accordingly to offer for the first time a hybrid experience. Although the lower cost and carbon footprint of the virtual model have been hailed, along with increased accessibility for those who cannot travel, there are still challenges related to planning such events including the use of technology to deliver the hybrid event and limitations on personal interaction and immersion amongst conference attendees (Dua et al., 2021).

Pre-conference experience

Our intent in early 2021 was to host a traditional, in-person conference at the Georgia Center. It became apparent in our early discussions with the Georgia Center event planners that the conditions (number of people allowed, spacing, etc.) would likely change between the early part of 2021 and December 2021. The Georgia Center followed the guidance of the University of Georgia, which followed the guidance of the State of Georgia, which was further consistent with guidance from the U.S. Centers for Disease Control. We therefore decided that a hybrid format would be most appropriate, as early indications were that only about 60 people would be allowed to attend the conference in person, given the size of the facilities at the Georgia Center. In late May 2021, we received notice that the limitations placed on number of attendees were lifted, that face masks were no longer required, and that the Georgia Center was planning to operate with no social distancing in the fall. However, this policy could have changed again prior to the date of the conference in December so we decided to keep the hybrid format of the conference. Fortunately, no other policy changes were enacted, even as the omicron variant of Covid-19 began to spread throughout the world.

Due to the hybrid nature of the conference, we decided that a single track of speakers would be more manageable than multiple tracks. In past conferences, we usually accommodated two simultaneous tracks of speakers in different conference rooms, and thus prior conferences included around ten more speakers than the 2021 conference. We were unsure whether enough people would be interested in attending the conference during the Covid-19 pandemic but were pleasantly surprised that the

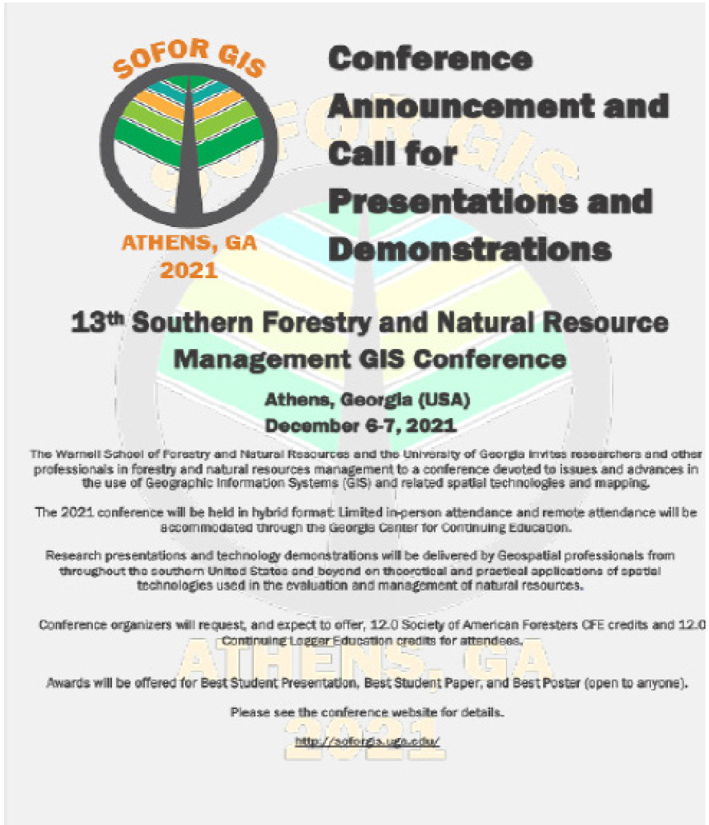

Figure 1. The face page of the call for presentations for the 13th Southern Forestry and Natural Resource Management GIS conference.

program was not difficult to fill. In prior conferences, we may have included presentations from the planning committee members to fill minor holes in the multi-track schedule; however, that was not necessary this time. Through the call for presentations (Figure 1) in early 2021, we asked each potential speaker to indicate whether they would desire to deliver their presentation in person or remotely. Of the 27 presentations we ultimately placed on the conference program, five speakers chose to deliver their presentations remotely and one presentation included a mix of in-person and remote presenters.

During the pre-conference period, some potential conference attendees wondered why the hybrid portion of the conference was not free of charge. Certainly, anyone who spends more than a few minutes developing a conference such as this knows that accommodating remote speakers and attendees comes with a cost (time, effort, equipment, technology, and training associated with online conference software, etc.). We were not willing to subsidize this cost through the registration fees paid by the in-person attendees, nor by our normal School or personal accounts. However, if one were to value the amount of time spent addressing the concerns and issues brought forward by online attendees, one would likely have found that the Warnell School of Forestry and Natural Resources at the University of Georgia did indeed subsidize their registration costs. Fortunately, the cost of registration for the online attendees did not need to accommodate meals and refreshments, and further, the attendees themselves did not need to arrange travel and hotel accommodations (Pedaste and Kasemets, 2021). Hopefully, the remote attendees found value in receiving the wisdom, knowledge, and advice of the conference speakers.

Although there are a number of platforms available for hosting the virtual portion of the conference, we utilized the system (Zoom) that was preferred by the Georgia Center for Continuing Education. As previously noted, a few presenters indicated that they would deliver their presentations remotely, and in these limited cases we allowed the presenter full control over their presentation, which seemed appropriate for this type of setting (Seery and Flaherty, 2020). As has been suggested by others (Rekawek et al., 2020), online speakers were encouraged to participate in a trial run of their presentation one week before the conference date, to reduce anxiety and potentially avoid errors. Only 2 online speakers took advantage of this opportunity prior to the conference. Presentations delivered in person required speakers to give their PowerPoint presentations to the conference organizers so that they could be shared with attendees online. This was managed from the back of the conference room, rather than from the front of the room in usual circumstances.

In addition to the actions needed to accommodate online attendees and speakers, the normal conference pre-planning tasks were attended to. These included planning the reception, choosing the meals, developing signage for sponsors, developing conference brochures, acquiring conference gifts and SWAG (stuff we all get), arranging for exhibitor space, acquiring approval for continuing education credit for foresters and GIS professionals and logger education credit, and then developing the materials related to earning these (sign-in sheets, certificates, etc.).

Live event experience

The conference attracted 159 participants from across the continental portion of the United States. Conference attendees traveled from, or connected remotely from, 12 southern states and 7 other states from Maine to California. As in other hybrid conferences during the Covid-19 pandemic (Patel et al., 2021), the majority (65.4%) of conference participants preferred the in-person attendance option (Figure 2). During the conference experience, hand sanitizer was available to in-person attendees, and only a few people wore masks. Regardless, the in-person experience was comfortable and as lively as always.

There were a few difficulties associated with remote attendees. Some adjustments were required in the days, hours, and minutes leading up to (and including the time of) the conference. For example, a few remote attendees lost the e-mail message from the Georgia Center that provided the Zoom link to the conference. These people requested immediate assistance as the conference was getting underway. A few other people who registered for the in-person experience changed their minds, and subsequently

Figure 2. A portion (about one-third) of the live audience attending the 13th Southern Forestry and Natural Resource Management GIS Conference (Photo courtesy Joshua Uzu).

requested remote attendance access in real time. There may have been some differences in time zones that prevented further remote engagement from people connecting from other states (Pedaste and Kasemets, 2021), and there may have been difficulties in engaging those people who attend online (Pedaste and Kasemets, 2021), but none were documented. Further, no lags in video and audio streaming were brought to our attention, as have been noticed to a lesser extent in other virtual conferences (Wang et al., 2021).

Two remote speakers cancelled their presentations: one 8 hours before the conference began, and one during the middle of the first day of the conference. Although with each conference we offer we expect one or two speakers to cancel several weeks before the conference (which was also true in 2021), we had never before had speakers cancel with such immediacy.

There were still other interesting issues that required attention during the live event. In association with offering continuing education and logger education credits, someone needed to monitor the remote attendance and develop a list of the people who connected. So that the remote attendees could hear presentations, speakers were instructed to talk directly into a microphone, which may not have been a normal course of action for some. Further, anyone in the live audience who posed a question was asked to offer those questions through the microphones. Anyone online who had a question to ask submitted these through the chat function in Zoom. These questions were then offered to speakers from a person monitoring the chat. One other side effect of the virtual delivery of the conference was the tendency of online attendees to place sometimes irrelevant comments in the chat, which were sometimes then viewed by the live audience. Perhaps some members of the online group viewed the content in the chat in a manner similar to whispered comments of people seated near each other. Only in this case, everyone may have become aware of their comments.

Post-event experience

As with prior *Southern Forestry and Natural Resource Management GIS Conferences*, we intend to produce a proceedings. The outcome will be both a printed version (mailed to conference registrants and several university libraries) and a digital version (PDF) that can be accessed from the conference website (sofordis.uga.edu). We allowed conference speakers about 6 weeks after the conference to develop and submit their conference papers. An editing team then reviewed each paper for clarity, content, and condition.

A positive side effect of the real-time delivery of presentations (through Zoom) to remote attendees was the ability to record the entire conference. Regardless of whether a presentation was delivered remotely or in person, they were all recorded. Knowing this, several people requested the video of their presentation, even though it was never offered as a benefit of the conference prior to the date of the conference. These requests were of two kinds: 1) from attendees who wanted to review all of the presentations at their leisure, and 2) from speakers who wanted a personal copy of their presentation. Ultimately, we decided to offer the recorded presentations free of charge through the conference website. This results in the need for speakers and conference organizers to negotiate the rights to the content, and how the content may be shared (Rekawek et al., 2020). Therefore, we developed a release for each presentation, to provide us with permission to offer the presentations online. We found that not everyone wanted their presentations to be offered in this manner. Therefore, some recorded presentations from this conference are not available. Further, as we had not made a promise to offer recorded presentations online, this work was not considered urgent to us (yet seemed urgent to others). These additional work processes had an associated cost that may not have been evident to those requesting their (or other's) recorded presentations.

Discussion

Regardless of how easy it seems to facilitate a conference through Zoom or some other platform, to deliver a professionally managed conference does require more effort than one might expect. In addition, as we have noted throughout this paper, several side-effects were encountered in association with our decision to offer the conference in a hybrid manner. Contrary to what others have suggested - that virtual conferences are relatively easy to organize and that they may be more inclusive than the case of in-person meetings (Veldhuizen et al., 2020) - our experiences point to several weaknesses of the virtual conferencing model. For example, it seems that people who do not attend in person may feel that it is easy to cancel their remotely-delivered presentation shortly before their appointed time slot. Further, the looseness with which comments can be placed into the chat area of the Zoom platform by remote attendees indicates a lack of professional conduct that may normally not be on display in a traditional conference program format. Further, a number of live event accommodations were made (several in real time) to increase the accessibility of remote attendees, who represented about 34% of the audience.

While there continues to be a risk for spreading Covid-19 and variants through in-person interaction, the in-person conference model still seems to be preferred by conference attendees, perhaps because of the ability for people to network face-to-face rather than through social media and other means (Patel et al., 2021). Certainly, there is a need for improving how people interact when they are solely online (Kim et al., 2022), and particularly how in-person attendees might interact with online attendees. To mixed success, the International Union of Forest Research Organizations (IUFRO) offered a *Tearoom* during the IUFRO World Day (September 28-29, 2021) in an attempt to have online attendees move to a virtual room and engage with groups of people in a manner similar to a real room (IUFRO, 2021). While we do not agree, some have suggested that the in-person traditional conference model may be dead (Dua et al., 2021). Others have suggested that the virtual conference model should continue to be integrated with the traditional conference model, due to savings in time and cost for some attendees (Ha et al., 2021). For better or worse, from our perspective as conference organizers, given the number of accommodations needed and issues that arose with the remote connection option, it is unlikely the Southern Forestry and Natural Resource Management Conference will continue to pursue the hybrid option.

References

Arthaud, G.J., and W.C. Hubbard (eds.). 1996. SoFor GIS ‘96. Proceedings of the Southern Forestry Geographic Information Systems Conference. Daniel B. Warnell School of Forest Resources, University of Georgia, Athens, GA. 416 p.

Dua, N., M. Fyrenius, D.L. Johnson, and W.H. Moos. 2021. Are in-person scientific conferences dead or alive? FASEB BioAdvances. 3(6): 420-427.

Ha, E.S., J.Y. Hong, S.S. Lim, H.P. Soyer, and J.-H. Mun. 2021. The impact of SARS-CoV-2 (Covid-19) pandemic on international dermatology conferences in 2020. Frontiers in Medicine. 8: Article 726037.

IUFRO. 2021. IUFRO World Day Tearoom. International Union of Forest Research Organizations, Vienna, Austria. Available at: https://www.iufroworldday.org/tearoom. Accessed 2 February 2021.

Kim, K.-J., S.R. Kim, J. Lee, J.-Y. Moon, S.-H. Lee, and S.J. Shin. 2022. Virtual conference participant’s perceptions of its effectiveness and future projections. BMC Medical Education. 22: Article 10.

Patel, M.H., J. Akhtar, S.M.R.H. Taqvi, and T. Batool. 2021. Analysis of challenges faced and the scientific content of a hybrid pediatric surgical conference arranged during the COVID-19 pandemic. Annals of Pediatric Surgery. 17: Article 67.

Pedaste, M., and M. Kasemets. 2021. Challenges in organizing online conferences: Lessons of the Covid-19 era. Education Technology & Society. 24(1): 92-104.

Rekawek, P., P. Rice, and N. Panchal. 2020. The impact of COVID-19: Considerations for future dental conferences. Journal of Dental Education. 84(11): 1188-1191.

Seery, M.K., and A.A. Flaherty. 2020. Ten tips for running an online conference. Journal of Chemical Education. 97(9): 2779-2782.

Veldhuizen, L.J.L., M. Slingerland, L. Barredo, and K.E. Giller. 2020. Carbon-free conferencing in the age of Covid-19. Outlook on Agriculture. 49(4): 321-329.

Wang, M.H., B. Liao, Z. Jian, X. Jin, L. Xiang, C. Yuan, H. Li, and K. Wang. 2021. Participation in virtual urology conferences during the Covid-19 pandemic: Cross-sectional survey study. Journal of Medical Internet Research. 23(4): Article e24369.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 9-14.

Proceedings Paper

Woody residue biomass availability and transport costs to supply a biofuel production facility

Michael K. Crosby
School of Agricultural Sciences and Forestry, Louisiana Tech University
Ruston, LA, 71270, mcrosby@latech.edu

Eric McConnell
Department of Forestry, Mississippi State University
Mississippi State, MS, 39762, eric.mcconnell@msstate.edu

Jason J. Holderieath
School of Agricultural Sciences and Forestry, Louisiana Tech University
Ruston, LA, 71270, jjhold@latech.edu

Abstract

As biofuel production continues to gain traction, producers will search out ways to source material for fuel conversion. Pine forests in the southeastern United States provide an excellent source for harvest residues that can be converted into, for example, biodiesel. Using a proposed site for a biofuel production facility in Louisiana as an example, Forest Inventory Analysis (FIA) data were queried for harvest residue estimates (i.e., tops and limbs) within the State. Subsequent to this, the proposed facility location was buffered at distances of 5-, 15-, 30-, 50-, and 100-mile radii to provide a parish-level estimate of residue availability and scenarios for transportation to the facility. There are between 3,900 lbs/ac - 137,000 lbs/ac, between 5- and 100-miles of the facility. Varying transportation costs from $0.10/ton/mile to $0.20/ton/mile, moisture content of residues between 45%-55%, and load limits from 20 to 28 tons, we calculated estimates for green ton costs of residue brought to the facility. The maximum payable fiber price ranges from $5.25/ton to $32.06/ton delivered. This provides a method of estimation for other potential sites/markets for wood residues. Further, the methodology could be expanded to include workforce needs, etc., related to facility establishment in other areas.

Keywords: Cost estimation, facility location, harvest residuals

Introduction

In the continual development of alternative energy sources, biofuel production from forest residues continues to gain traction. Transportation is the second-greatest greenhouse gas emitting sector in the United States, leading some areas actively seeking to understand the potential forest biomass availability for conversion to biofuel/biodiesel (Mitchell et al., 2015). More than 15 million acres of Louisiana is forested and greater than one-third of that is pine species (Oswalt, 2014). Pine forest residues have been found to be a viable source for energy production (Nurek et al., 2019). Louisiana has selected a site for a biofuel production facility in the state, reported to be carbon negative (Louisiana Economic Development, 2021).

Considering the acreage of pine forest in the southeast, if residues are a viable source for fuel production, there will be an effort to determine quantities available and costs of transport from harvest sites. Resource availability is also an important consideration in the determination of where such facilities will be sited. Additionally, transportation costs are among the greatest for a logging operation (McConnell, 2020). Given the pine acreage and pending production facility in Louisiana, this study seeks to determine the availability of source materials from potential harvest slash in Louisiana forests. The objectives of are to 1) determine parish-level estimates of residue in pine forests and 2) estimate hauling costs at various intervals from the proposed location. This will provide a rough estimation of feedstock availability and costs that may be improved upon and expanded to other areas.

Methods

Forest Inventory Analysis (FIA) data were acquired for Louisiana from 2013-2017. The data were queried for all plots containing pine species with quantifiable harvest residue estimates (i.e., tops and limbs/DRYBIO_TOP field). The biomass was estimated by expanding the weight of tops by trees per acre for each plot; this plot-level estimate was expanded by the area represented by each plot (6,000 acres). This resulted in 997 plots throughout forest area of Louisiana (Figure 1a). The biomass plots were displayed in ArcGIS Pro, summarized at the parish level, and divided by forested acres in each parish to calculate total biomass (lbs/ac) for each parish within the State. Subsequent to this, a proposed facility location coming to Louisiana was established (Louisiana Economic Development, 2021) and the site buffered at distances of 5-, 15-, 30-, 50-, and 100-miles around the location (Figure 1b) to provide an estimate of residue availability as a source of raw material at varying distances from the plant. A transportation cost estimation tool was utilized to estimate load costs. The tool accounts for the cost per mile, load weight, moisture content, and distance hauled. For these scenarios the buffer distances were used as an absolute distance estimate “as the crow flies” as opposed to distances computed using a road network. Transportation cost scenarios varied between $0.10/ton/mile to $0.20/ton/mile with loads limits between 20 and 28 tons and moisture content of the wood between 45%-55%.

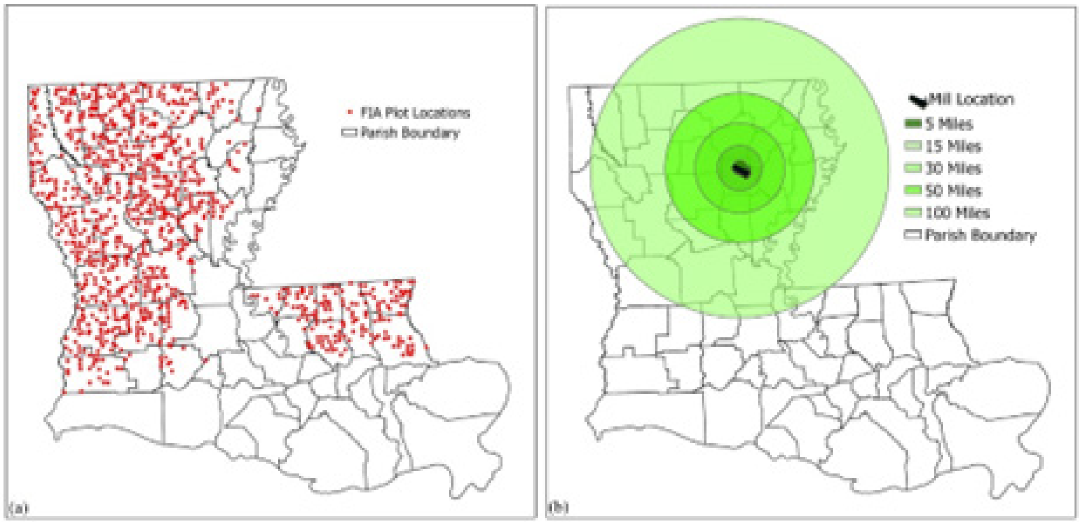

Figure 1. Plot locations (a) containing pine residues and (b) buffer distances for potential source areas around a proposed biofuel conversion plant in Louisiana.

Results and Discussion

Parish-level estimates of residues range from zero (0) in parishes bordering the Mississippi River and coastal parishes to greater than 7,500 lbs/ac throughout the central portion of the State (Figure 2). If the plant location were to be supplied by residues from nearby areas, there is a total estimated biomass of 3,900 lbs/ac – 137,000 lbs/ac between five and 100 miles of the facility (Table 1). The maximum payable delivery cost to the mill would range from $5.25/ton to $32.06/ton, depending on distance, moisture content, and cost of transportation per mile, using the buffered distance as absolute distance travelled.

While this analysis used a relatively coarse dataset (FIA) and estimates were made based upon forested acreage within a parish, it does provide a means of assessing residue availability as tops and limbs are estimated separately in FIA data. Another method of approach would be to query plots within buffered zones and expand those by forest are estimates from classified datasets (like a forest cover dataset or classification obtained from remotely-sensed data). Analysis considering resources beyond the 50-mile radius of the proposed location would also need to include biomass from neighboring states (e.g., Arkansas and Mississippi), necessitating an efficient plan to remove traditional timber and residues (Mendell et al., 2006). Incorporating network analysis using road networks would also allow for an accurate representation of road miles to be traveled to a potential mill site, minimizing stops along the route as much as possible (Parsakhoo and Mostafa, 2015). This would also be useful for other potential (i.e., non-residue) feedstock used in biofuel conversion. The methodology presented here provides a means of estimation for other potential sites/markets for wood residues although more information and a finer resolution estimate of availability would be warranted. Further, the methodology could be expanded to include workforce needs,

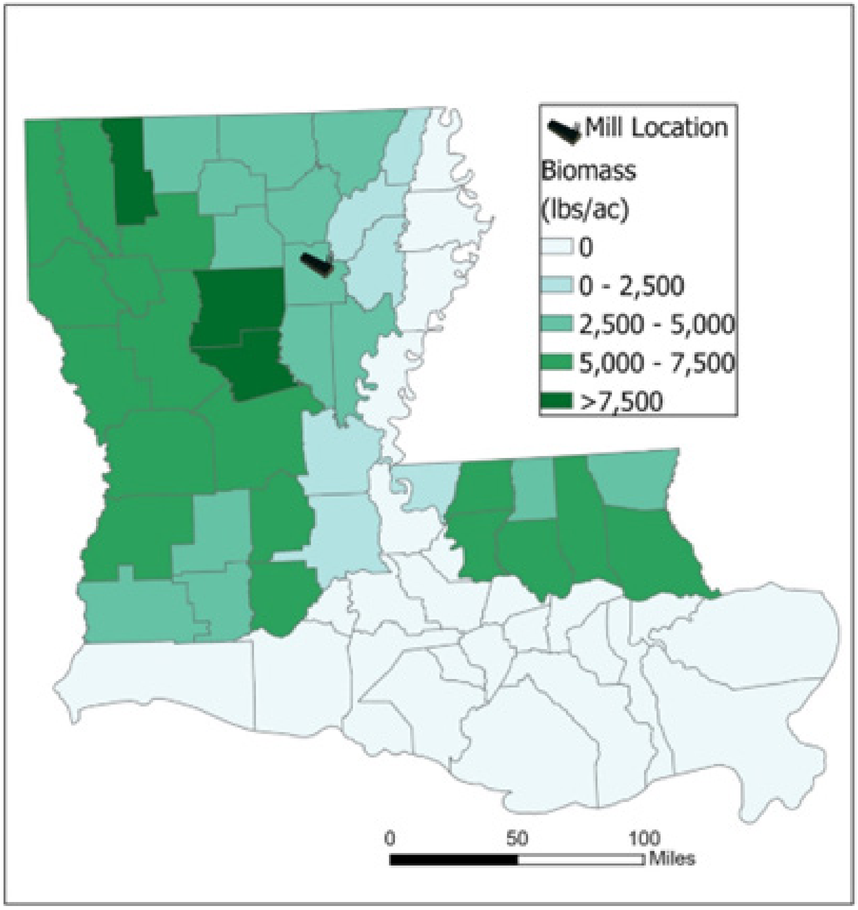

Figure 2. Biomass availability (lbs/ac) by parish and within each buffered distance around the proposed plant location in Louisiana.

Table 1. Buffer distances and available residues within each buffer.

Distance (miles)	Total Residue (lbs/ac)
5	3,913
15	22,338
30	41,621
50	69,523
100	136,039

etc., related to facility establishment or feasibility in other areas.

The analysis here does not evaluate stand age or density that may indicate the likelihood of harvest. More accurate estimates should consider the average area harvested and perform a more localized analysis. Another important consideration is willingness to sell residues as Sinton et al. (2021) suggest slightly more than half of forest managers in Wisconsin and Michigan would support residue removal. There may also be a demand consideration for plants that may produce biofuel and those that use the residues as fuel sources in other processing facilities (e.g., pellet production, OSB plants, etc.).

Conclusions

This study provides estimates of potential harvest residues and transportation costs for a proposed production facility in Louisiana. This approach was at the parish level given the resolution of the inventory data utilized. The approach is generic but provides a first approximation and subsequent studies should attempt to obtain higher resolution dataset and an accurate road network to better estimate availability and transportation costs. Other important considerations are workforce needs, harvest cycles, and competing interests for harvest residues which may exist in different markets. Understanding biomass availability and transportation costs associated with moving biomass to a production facility are important considerations if biofuel production from harvest residues are to be sustainable.

References

Louisiana Economic Development. 2021. Louisiana green fuels plans $700 million renewable diesel refinery in Caldwell Parish. Opportunity Louisiana. Available at: https://www.opportunitylouisiana.com/led-news/news-releases/news/2021/04/23/louisiana-green-fuels-plans-$700-million-renewable-diesel-refinery-in-caldwell-parish. Accessed 1 November 2021.

McConnell, T.E. 2020. Unit costs and trends within Louisiana's logging contract rate. Forest Products Journal. 70: 50-59.

Mendell, B.C., J.A. Haber, and T. Sydor. 2006. Evaluating the potential for shared log truck resources in Middle Georgia. Southern Journal of Applied Forestry. 30: 86-91.

Mitchell, K.A., N.C. Parker, B. Sharma, and S. Kaffka. 2015. Draft Report: Potential for biofuel production from forest woody biomass. California Biomass Collaborative. Available at: https://biomass.ucdavis.edu/wp-content/uploads/Forestry-Biomass-Fuel-Potential-6_24_2015-web-version.pdf. Accessed 1 November 2021.

Nurek, T., A. Gendek, and K. Roman. 2019. Forest residues as a renewable source of energy: elemental composition and physical properties. BioResources 14: 6-20.

Oswalt, S.N. 2017. Forests of Louisiana, 2014. Resource Update FS–117. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station. 4 p.

Parsakhoo, A., and M. Mostafa. 2015. Road network analysis for timber transportation from a harvesting site to mills (Case study: Gorgan county – Iran). Journal of Forest Science. 61: 520-525.

Sinton, S.M., F. Dulys, and S.S.H. Klammer. 2021. Why biomass residue is not as plentiful as it looks: case study on economic supply of logging residues. Applied Economic Perspectives and Policy 43: 1003-1025.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 15-30.

Proceedings Paper

Evaluation of vegetation success on reclaimed natural gas pipelines

Anthony Mesa
Davis College of Agriculture, Natural Resources & Design, West Virginia University
Morgantown, WV, 26506, Anm0041@mix.wvu.edu

Shawn Grushecky
Davis College of Agriculture, Natural Resources & Design, West Virginia University
Morgantown, WV, 26506, Shawn.Grushecky@mail.wvu.edu

Michael Strager
Davis College of Agriculture, Natural Resources & Design, West Virginia University
Morgantown, WV, 26506, Mstrager@wvu.edu

Paul Kinder
Davis College of Agriculture, Natural Resources & Design, West Virginia University
Morgantown, WV, 26506, Paul.Kinder@mail.wvu.edu

Abstract

The infrastructure needed for unconventional oil and gas wells creates disturbances across the landscape during both the drilling and transportation stages of development. The midstream, or transportation stage, can disturb much more land area than the drilling stage of production. One such disturbance during midstream development is the destabilization of surface soils, which can lead to increased sediment runoff. Sediment transported into streams can be detrimental to aquatic ecosystems, and regulations have been implemented to minimize its introduction. Inspectors travel across the midstream portion of the infrastructure to monitor the reestablishment of surface vegetation cover and identify failing areas for future management. The topographically challenging terrain of West Virginia makes these inspections difficult, and the subjective nature of the evaluation leaves a gap in precision. We evaluated the use of an unmanned aerial vehicle equipped with a multispectral sensor as a complementary tool to be used in the inspection process. A forest-based classification and regression analysis was conducted on the collections using derived NDVI values and the single light bands of red, green, blue in different arrangements. Our research found the most accurate model to be guided only by NDVI values. Using this model, we were able to determine the proportion of vegetative cover across the entire study area. This technique appears to be capable at augmenting the current inspection process,

though it is likely that the model can be improved, and regulations will need to be shifted to better reference this new capability.

Keywords: NDVI, drones, UAV, revegetation, forest-based classification and regression

Introduction

The United States has surpassed all other countries in the production of natural gas (Doman and Kahan, 2018). Of all the natural gas development regions in the U.S., the Appalachian basin has risen to become the largest producer, contributing 33% of the national output of the resource (U.S. Department of Energy, 2020; U.S. Energy Information Administration, 2021). Two shale plays lay under this region, identified as the Marcellus and Utica shales, extend across 298,000 km^2 and 240,000 km^2 respectively (Kargbo et al., 2010; Popova, 2017a; Popova, 2017b). The implementation of modern drilling and hydraulic fracturing (fracking) techniques have led to the large growth seen in this region, which is projected to have natural gas productivity double by 2050 (U.S. Department of Energy, 2020).

Unconventional drilling includes a vertical well bore descending upwards of 2.4 km in depth with a lateral leg that can extend over 6 km (Marcellus Drilling News, 2021). The initial stages of drilling require the surface creation of a well pad. Once the gas is produced from the shale, it flows to the surface through the well casing (U.S. Energy Information Administration, 2021). At the surface the natural gas is directed into a gathering pipeline, through which it travels to the fuel's final users. Throughout this pipeline, midstream compressor stations are established to ensure the pressure of the pipeline is maintained (Messersmith et al., 2015). Compressor stations also require the building of a pad where the above ground equipment is located. The installation of these pads, along with the midstream land alterations needed for the installation of the gathering pipelines, create large disturbance events across the landscape.

Preparing a site for natural gas infrastructure requires the removal of all standing timber and reprofiling of the soil surface throughout the entire right-of-way. Development of gas wells has been found to contribute significant impact to surface water flow (Warner et al., 2013) and total suspended solids (TSS) quantities in associated watersheds (Olmstead et al., 2013). Increased sediment in freshwater ecosystems has led to significant ecologic impacts. Lower-level trophic species have decreased populations after the introduction of significant sediment (Richards and Bacon, 1994), while primary producers at this level have been found to have their productivity significantly reduced (Cederholm and Lestelle, 1974). Larger freshwater vertebrates have been found to have organ damage and recruitment loss in sediment rich waterways (Kemp et al., 2011).

Unconventional development is regulated by both state and federal programs. The U.S. Environmental Protection Agency, Clean Water Act (CWA) Section 404, prohibits companies from discharging sediments and establishes a specific permitting process. In West Virginia (WV), the Department of Environmental Protection (DEP) advises several means of sediment control through their best management practice manual (West Virginia Department of Environmental Protection, 2016). Specifically, the WV DEP manual instructs that establishing vegetative cover is the most important practice in preventing erosion and sediment. The importance of revegetation is reinforced in the General Water Pollution Control Permit (GWPCP) given to natural gas development companies (West Virginia Department of Environmental Protection, 2013). The permit outlines the inspection schedule to be conducted on the site and directs a minimum threshold of 70% vegetation be present at a site for a company's bond to be released.

Within the WV GWPCP, there are two types of inspections. The first and most frequent is conducted by the permit holder on a defined schedule. An individual certified in site inspections is tasked with performing weekly on-foot checks of the entire pipeline. Typically, the pipeline is broken into sections and the inspector will walk an assigned section looking for failures in the vegetation establishment, the soil surface structure, or the erosion control structures of a site. Upon finding any of these permit violations, the inspector submits a report to the permit holder, who must immediately address the issues. The second type of inspection is conducted by the WV DEP and is focused on the closing of the permit. During a closing inspection, the WV DEP representative will walk the length of the pipeline, inspecting the integrity of the permanent erosion control measures to determine whether the site has reached a state of final stabilization. A declaration of this state closes the standing permit and returns the withheld bond to the permitee. Specifically, this state inspection requires the permanent surface vegetation within all non-permeable grounds in the permit area be at least 70% vegetated, as outlined in the GWPCP. This threshold is usually determined with a surface sampling ring, approximately 1 m^2 in area, which is randomly cast by the state inspector several times throughout the permit area. Wherever the ring lands, the inspector will make an ocular estimation to determine whether the vegetation contained within the sample covers at least 70% of the area. The 70% standard is not further defined in the GWPCP, and often a single sample judged to be below 70% will generate a failing report from the state inspector, keeping the permit open.

Internationally, unmanned aerial vehicles (UAVs or drones) have been implemented into the operations of various industries. This trend is due to the UAV's ability to either offer new functionality or augment and enhance existing techniques. Industrial facilities containing dangerous or inaccessible structures have been able to include UAVs in their safety inspection process to minimize risk and maintain coverage (Nikolic et al., 2013). Civil engineers needing to inspect large structures for minor faults have found both the speed and precision capabilities of drones to be a valuable toolset (Hallermann and Morgenthal, 2014). Agricultural operations utilize UAVs equipped with multispectral sensors in their decision-making process, allowing the optimization of fertilizer application and harvest (Kim et al., 2019). The remote sensing of geospatial data by UAVs has improved the efficiency, accuracy, and safety of data capture.

The process of multispectral analysis involves the examination of emitted, refracted, or reflectedor reflected light from targets of interest in specific electromagnetic bands.

Land cover classification commonly uses this multispectral analysis, with many federal agencies such as the National Aeronautics and Space Administration (NASA) and the United States Geological Survey (USGS) using the process in the development and distribution of a wide variety of geospatial or mapping products. The normalized difference vegetation index (NDVI) is one such form of multispectral analysis used to answer questions of target vegetation (Tucker, 1979). This index is structured through the comparison of the reflectance values of the red and near-infrared (NIR) bands of light and is designed to detect stages of photosynthesis in land cover. As light comes into contact with a plant, red light is absorbed by the chlorophyll of the vegetation while the unusable NIR light is reflected or scattered by the mesophyll layer (Campbell and Wynne, 2011). The interaction of these bands with healthy vegetation results in disparity between their reflectance intensity, with unhealthy or failed vegetation producing a noticeably different relationship. NDVI values range from -1 to 1, with higher scores associated with healthier vegetation, and lower scores being associated with artificial objects. This index has served as the primary multispectral analysis conducted by the agricultural industry through UAV collection.

Though UAVs have been used to answer the questions of various industries, the use of multispectral capable UAVs in assessing the vegetation ground cover of oil and gas pipelines has not yet been evaluated to the best of our knowledge. This study attempts to address two primary questions: 1) can UAV-based multispectral remote sensing replace on-the-ground inspections by constructing a model from NDVI, RGB, or a combination of these reflections; and 2) does a UAV-based process for vegetative cover quantification provide a more objective and extensive solution than mere on-the-ground inspection. As the agricultural industry has found great usefulness of NDVI collection, the best performing model in accuracy and quantification will likely incorporate this index.

Methods

Study area

An industry partner provided access to a recently completed pipeline in northern West Virginia for the execution of this project. This area was comprised of two branches of a continuous pipeline separated by a natural gas well pad (Figure 1). The combined length of the two branches was 2.3 km, which provided approximately 10 ha of managed and monitored pipeline area for analysis. The southern branch was approved for release several years ago and is bordered by forested lands. The northern branch completed construction and installation in early 2021 and runs through lands used for livestock grazing. There is no physical barrier barring animals from grazing upon the pipeline area. The elevation in the study area ranges from about 326 m-414 m MSL, with greatest slopes being around 57%. Flow interruption angled water bars are created along all straight areas with significant length and slope. Additional erosion control features on the test site include the surface application of hay, coir mats, hydro-seed, silt socks, and silt fences.

Figure 1. Approximately 2.3 km of natural gas pipeline used as study area for the UAV based evaluation of vegetation success in Northern West Virginia, USA. a) The full extent collected along the pipeline, with the area of vegetation assessment marked with red crosshatch. b) An expanded view of area enclosed in a) to enable a detailed view of the surface at the site. Note the surface variance in vegetation and disturbance in the linear pipeline area as compared to the surrounding agricultural field.

Test plots and classification

The industry partner managing the study area allowed 30 small testing plots for vegetation analysis to be established. A field technician was tasked with the selection and creation of plots while equipped with a handheld Garmin GPS unit to monitor approximate distances as necessary. Across the two branches, 20 sites representing either passing or failing vegetation were selected. Passing sites were defined as those where greater than 70% of the internal plot area was vegetated, while failing sites contained less than 70% vegetation. To avoid over-selection from a single area, no two test plots of the same category were to be within 25 m of each other. Additionally, all failing plots were established on areas which were intended to be vegetated, as there were several maintained gravel roads within the study area which would provide inaccurate representations of the local soil.

After recording the numbers associated to the passing and failing plots, a third reflected were randomly established to provide reference plots for subsequent analysis. Starting from a random point, the technician walked along the center of the pipeline and created

Figure 2. Example of training plot established to denote areas on pipeline that failed vegetative cover threshold. Plot is approximately 1 m square and used a 2-digit identifier outside the bottom right corner.

a reference plot at 25 m intervals. If the new plot was within 25 m of a plot of another class, the technician moved perpendicular to the pipeline until distance between all previously established plots was greater than or equal to 25 m.

Each plot was created using high-visibility survey marking spray to create the 4 corners of an area of approximately 1.44 m^2 (1.2 m × 1.2 m) (Figure 2). This size was selected to allow the extraction of approximately 1 m^2 of internal pixels unaltered by the survey spray for each test plot. To create continuity between foot and drone imagery, the top of each test plot was indicated by a solid line connecting the two respective corners, and a two-digit number was created just outside and beneath the bottom right corner. Numbers ranged from 00-29. Upon completion of the marking of each test plot, a ground image was captured using a hand-held 12-megapixel camera, to create a high-resolution collection of the vegetation contained within each test plot.

Official vegetation classification for each of the test plots was achieved through coordination with an environmental inspection subject matter expert (SME). The SME for this review had approximately 20 years' experience conducting environmental inspections in the field throughout the central Appalachian region. During the last 5 years, the SME focused on oil and gas revegetation and erosion compliance inspections in the state of West Virginia. The SME was shown the captured ground images in a random order and asked to provide a classification judgment based on the image. Most plots produced several images capturing the plot surface from different angles. Images could be enlarged and scrolled through as requested. If the SME's judgment throughout all images of a single plot was uniform, a plot was classified as either passing or failing. If the SME indicated that they were unsure of a plot's category, we recorded their initial assignment, but added a sub-category of mixed to indicate the borderline nature of the plot.

Multispectral collection

Once all test plots were established, a DJI Matrice 200 quad-propeller drone with a direct interfacing Sentera 6x Multispectral sensor conjoined with an apex oriented solar sensor was used for remote data collection. The 6x Multispectral sensor simultaneously collects from 5 individual wavelengths: blue (475 nm), green (550 nm), red (670 nm), red edge (715 nm), and near infrared (NIR, 840 nm). Additionally, the 6x sensor is equipped with a 20MP RGB camera. This sensor performs a simultaneous capture from all 6 sensors on a preset trigger period. For our collection, we set the trigger to occur every 2 seconds. Flight planning and execution was achieved with the UgCS Client. Through this software we could load in elevation maps, break each branch into transects, generate a flight path at a fixed distance above the terrain. The height above terrain used was 91.44 m (300 ft), and the sensor was oriented at nadir. Both flights occurred on the same day between 1130 and 1330 EST to minimize light variance and shadows. Immediately prior to collection, the multispectral sensor captured a series ofcalibration images of a Sentera Reflectance Panel for future radiometric correction.

Reflectance map creation

The Sentera 6x Multispectral sensor does perform some on-the-fly collection alteration based on changes in detected solar intensity; however, radiometric calibration is only achieved through a post-processing technique provided to the end user by Sentera. The basis of this technique is a program guided identification of reflectance from the captured calibration images and correcting the reflectance values of every image to the atmospheric conditions at the time of flight. These corrected images were then loaded into Pix4Dmapper Version 4.6.4 to create total reflectance maps for the site.

Pix4Dmapper aligns the images according to the GPS data recorded in the EXIF portion of each image and begins to identify tie-points between neighboring images. These tie-points guide the final orientation and transformation of each image. This process creates the RGB orthomosaic map of the site and the reflectance maps of individual bands. Pix4Dmapper is also capable of conducting index calculations between generated reflectance maps, enabling the generation of an NDVI map for the site. The specific equation used by Pix4Dmapper for the NDVI map is:

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

where the values for *NIR* and *Red* are the recorded wavelength intensity for an individual pixel.

Analysis

The RGB orthomosaic and NDVI map for each branch was then loaded into Esri's ArcGIS Pro (Esri, 2020) for final extraction and analysis. Due to the approximation of the geolocation for each image in the previous step, the orthomosaic and reflectance map for each branch were misaligned. Fixed permanent objects visible in both layers were used as georeferenced points to reduce alignment issues. Objects included fence posts, downed timber, and permanent surface structures such as rocks. Manually performing this step allowed the test plots visible in the RGB orthomosaic to accurately overlay the associated NDVI values in the reflectance maps.

As the final method of analysis cannot analyze separate bands of composite rasters, the RGB orthomosaics were copied and split into their three-color individual bands of red, blue, and green. There was variation in pixel size between layers, so a standardization was created through a resampling process. The largest pixel size of the layers (0.047 m) was selected as the new size using a nearest-neighbor sampling scheme to address any slight misalignment between pixel edges. As the mission flight height provided a complete capture of the target study area, data were captured for land outside of the area of interest. This surrounding data can skew the final vegetation analysis, necessitating the removal of the excess data. The RGB orthomosaics were used to create an inclusive polygon over the study area of interest. All raster data from all layers being used for analysis had their relevant data extracted by this study area mask.

The combination of high visibility marking paint and the high resolution of the RGB orthomosaics (0.016 m) allowed the accurate identification of all 30 test plots. Polygons were created inside of each of these test plots, with form priority being the exclusion of areas near the paint, so that the artificial reflectance of the foreign coating was not included in the training and evaluation data. This prioritization coupled with the natural variance in presentation caused by slope, created a polygon set with a mean area coverage of 0.9 m^2. These polygons were placed into two data layers, one for the training plots, and a separate layer containing the test plots. The training layer polygons were given a class number according to the SME scoring for the associated plot.

Random forest algorithm classification was selected for final modeling in this study due to its noted high accuracy in the classification of multispectral data (Akar and Güngör, 2012). This analysis was conducted with the ArcGIS Pro Forest-Based Classification and Regression (FBCR) tool from the Spatial Statistics Toolbox's Modeling Spatial Relationships toolset (Esri, n.d.a). Using the classified training plots, decision trees were created from a random combination of selected explanatory variable layers for each tested model. A majority vote from the decision algorithm outcome was ascribed to a predicted classification value. The FBCR tool also provides an output of metrics based on the training data. These values guide the parameter settings used in final analysis (Esri, n.d.b). The optimal settings determined through this process were 125 trees with 100% of the data available to each tree's creation. The default value of 10% of the training data were assigned to be used to preliminarily test the accuracy of the model.

After the appropriate parameters of the FBCR tool were determined, the operation was switched to predict a surface raster. The process was conducted 3 times using different explanatory layers in the model; RGB, NDVI, and a combined model. All output rasters had a resolution of 0.047 m. Within each testing plot, the proportion of passing to total cells was calculated. Using the WV DEP inspection standard of 70% passing cover as a categorizing threshold, the category of each test plot was determined. Model accuracy was determined across the testing plots by building confusion matrices between the machine categorized plots and their SME classification. Plots identified as mixed were omitted from this step. Using the model with the highest accuracy, the proportion of surface cover categorized as passing was determined for the whole site.

Results

The image viewing by the SME of training plots resulted in 10 passing and 10 failing, aligning with the field technician's predicted classification for these sites. The 10 reference testing plots were assessed as containing 3 passing samples and 7 failing samples. This limited testing pool was further reduced as one of the passing test plots and 2 of the failing test plots classified as mixed by the SME. Training plots had a mean NDVI value of 0.42 and 0.67 for failing and passing plots, respectively (Table 1). Both passing and failing training plots contained similar minimum (0.17) and maximum (0.81-0.89) NDVI values. The reflectance values of red, green, and blue also had disparities in mean with failing class training plots having higher means in all bands (221.73, 199.47, and 167.53 for red, green, and blue respectively).

The model predicted by the FBCR tool to perform the best based off of the training data evaluation used the three RGB derived layers as explanatory variables. For Out-of-Bag (OOB) errors, the model had a mean squared error (MSE) of 7.51, with a 95% classification accuracy of the validation data (Table 2). The resultant decision tree forest for this RGB model found all three layers of equal importance for classification (33%-34% importance for each layer). This model also had the lowest mean tree depth across

Table 1. Statistical summary of the training plots' NDVI values by classification. NDVI values can range from -1 to 1, with higher values being associated with more vegetative activity.

Classification	Mean Area (m^2)	NDVI Min	NDVI Max	NDVI Range	NDVI Mean	NDVI Std Dev	NDVI Median
Failing	0.95	0.17	0.81	0.64	0.42	0.19	0.35
Passing	0.84	0.18	0.89	0.71	0.67	0.16	0.68

Table 2. Model statistics from the built-in evaluation metrics of the Forest-based Classification and Regression tool. The combined model used the red, green, blue, and NDVI layers. Tree depth is a measure of decisions made per tree, with lower numbers for easier decisions. OOB MSE is the average error across classes when using a random selection of data from within the training plots. Layer importance is determined by its effectiveness when included in a decision tree. Predicted accuracy is assessed from the training data only.

Model	No. Layers	Mean Tree Depth	OOB MSE	Most Important Layer	% Importance	Predicted Accuracy
Combined	4	436	7.511	NDVI	33%	93%
RGB	3	341	6.508	Green Reflectance	34%	95%
NDVI	1	1029	17.161	NDVI	100%	82%

Table 3. Model accuracy assessment using the testing plots. Accuracy measurements were made from confusion matrices between model and inspector classification of the same plot. The combined model used the red, green, blue, and NDVI layers.

Model	Classification Accuracy	Type 2 Error
Combined	57.14%	28.57%
RGB	42.86%	42.86%
NDVI	71.43%	14.29%

the decision forest at 341 decisions per tree. The NDVI only model produced the lowest training validation accuracy at 82% with an OOB MSE of 17.16. The mean tree depth was also the highest at 1029. The combined model's predicted validation accuracy and OOB MSE tracked closer to the RGB model at 93% and 7.511 respectively. Interestingly, in the combined model, the NDVI layer was weighted as higher importance (33%) in classification than any of the RGB layers (21%-24%).

Despite having the highest predicted accuracy, analysis of the test plots revealed the RGB model to have the lowest accuracy at 43% (Table 3). Beyond being inaccurate, this model also had the highest type 2 error of any model at 42.86%. The model which used only NDVI in its prediction had the highest accuracy of 71%, while also having the lowest amount of type 2 errors of 14.29%. The combination model yielded a lower accuracy than the NDVI model, accurately identifying test plots only 57% of the time. As the NDVI model was the most accurate at determining the classification of the test plots, it was selected for the whole site classification process (Figure 3). For the entire site, the NDVI guided prediction identified 72.37% as passing (Table 4).

Discussion

The Marcellus and Utica shale plays in the U.S. have seen large growth in the

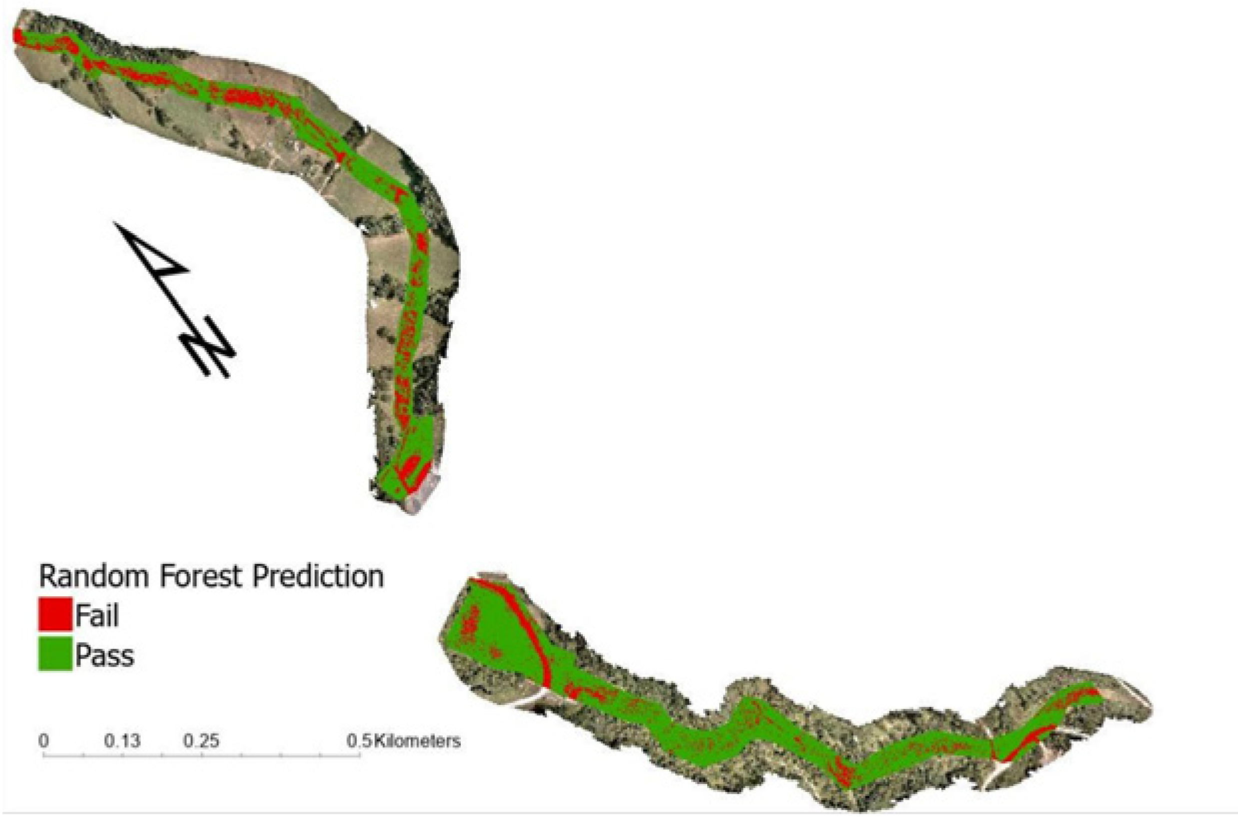

Figure 3. Prediction of vegetative cover threshold on a natural gas pipeline in Northern West Virginia sampled using UAV-based sensors. Areas in red are those that did not meet the 70% vegetative cover threshold. Areas in green met the 70% vegetative cover threshold.

Table 4. Quantification of the whole site's vegetation cover using the NDVI model. Cell size is 0.047 m^2.

Passing Cells	34,708,182
Failing Cells	13,249,536
Sum	47,957,718
% Pass	72.37%

production of unconventional resources. If not managed appropriately, the installation of the infrastructure required for these operations can cause the destabilization of surface soils. Regulations have been implemented to address these damages, and permits require the re-establishment of surface vegetation across pipeline sites. Tracking the progress of the stabilizing actions is labor intensive and often requires subjective evaluations of on-the-ground conditions. Many other industries have found the use of UAVs to be an appropriate solution to inspection needs, especially in dangerous or difficult to reach areas. This study set out to evaluate the effectiveness in using UAVs to match current inspection classification and determine whether this technology could be used for whole site quantification.

From categorized training plots, a FBCR model was able to be formed from UAV collected multispectral data which provided a relatively accurate prediction of the proportion of surface vegetation coverage on a midstream site. The NDVI model was the most accurate model in identifying test plot classification. Analyzing the predicted classification for the entire site with this NDVI model, we were able to determine that the site was above the 70% vegetative cover necessary to be declared stabilized. The findings of this study have implications in future multispectral detection of vegetation from UAVs, pipeline inspection practices, and regulation definitions.

The models chosen in this study had noticeable differences in accuracy between their predicted and actual performance. This discrepancy was most noticeable in the RGB model. The handicap of this model seemed to carry-over into the combined model, as it performed worse than the NDVI exclusive model. This disparity has several explanations. The first is the non-homogenous nature of the samples. Training sites of different classes displayed similar range in minimum and maximum values due to their heterogenous form. Establishing samples over uniform ground cover will likely lead to more accurate depictions of true passing and failing vegetation, and not incorporate that variance into the model's formation. Another option is the creation of more training plots. Future studies should work with industry partners to establish more plots.

Due to land access limitations, all training plots were established over a relatively small area, covering approximately 15% of the length of the study area. The layout of the training plots leaves large amounts of variance in the site uncaptured. According to the Natural Resources Conservation Service (NRCS) Web Soil Survey, the region surrounding this study area as 21 different soil units (Natural Resource Conservation Service, 2019). Past research has found unique spectral signatures in different soil types, which will likely impact the multispectral returns in this analysis (Meerdink et al., 2019; Baldridge et al., 2009). Additionally, different species of vegetation have also been found to have different spectral signatures (Kokaly et al., 2017). Future studies would benefit from increased capture of these natural variances across the whole site.

Current quantification of the entire site is based on the best approximation of the permit area as determined by the research team. During the establishment of the permit, land surveys are conducted, and GIS datasets are created which lay out the specific boundaries of responsibility. Additionally, land features that are inappropriate to include in vegetation analysis, like roads, paths, pads, and other structures, are given hard boundaries in these files. Access to the files can aid future researchers in providing more accurate quantification of the areas of concern, while appropriately excluding areas which are not subject to vegetation assessment and management, such as the site's roads and pads.

This study suggests that any future multispectral vegetation modeling for quantification would benefit with the inclusion of NDVI data; however, due to FBCR's ability to incorporate multiple layers of explanatory variables, it may be beneficial to alternate multispectral layers in future analysis. Comparative analysis in previous studies has found that alternate indices perform better at identifying certain landcover features (Joshi, 2011). Future research should evaluate the effectiveness of including alternate indices alongside NDVI to determine whether the model can be enhanced through their inclusion.

Our study suggests that whole site vegetation quantification through UAV collection is possible and can lead to many benefits if implemented in this industry. By using UAVs across the permit site, worker safety is increased and time on site is reduced. Once researchers are able to determine the best combination of explanatory variables, models can be produced in shorter periods of time than was required for our research. Temporal analysis between collections can effectively display vegetative changes. This, in turn, may aid in the evaluation of various revegetation techniques. Additionally, temporal analysis should be able to shorten the period necessary to identify failing vegetation, allowing corrective action to be taken sooner, benefitting site stabilization and downstream ecosystems. This increase in directed management and potential for accurate whole site quantification can lead to reduced time until bonds are released to the permitee.

The final vegetation quantification at this site also suggests that regulations will need to change if this technique is implemented in final stabilization inspections. The northern branch of the site was constructed several months before collection, and through the SMEs categorization it can be expected that the site would not yet meet the threshold for release. Despite these factors, the quantification found that the whole site surpassed the current regulation standard of 70% minimum vegetative cover. The ability to produce accurate measurements of cover suggests that regulators will need to alter the modern threshold to have it more appropriately align with the desired outcome.

Conclusions

In this study, the effectiveness of UAV-based multispectral analysis of vegetation cover on a midstream site was evaluated. Of the models tested, a model based on NDVI greatest accuracy at replicating the classification of the current inspection processes. The speed and capabilities of this method should be considered as an augmented technique in monitoring the regeneration of vegetation on sites similar to the one sampled.

Acknowledgements

Special acknowledgement to Sam Bearinger and Lucas Kinder of the WVU Natural Resource Analysis Center who helped to fly and process the UAV imagery. This project was supported by funding from the United States Department of Transportation Pipeline and Hazardous Materials Safety Administration. And lastly, this work was also supported by the USDA National Institute of Food and Agriculture, Hatch project accession number 1015648, and the West Virginia Agricultural and Forestry Experiment Station.

References

Akar, Ö., and O. Güngör. 2012. Classification of multispectral images using Random Forest algorithm. Journal of Geodesy and Geoinformation. 1(2): 105-112.

Baldridge, A.M., S.J. Hook, C.I. Grove, and G. Rivera. 2009. The ASTER Spectral Library Version 2.0. Remote Sensing of Environment. 113: 711-715.

Campbell, J.B., and R.H. Wynne. 2011. Introduction to Remote Sensing. 5th ed. New York, NY: Guilford Press.

Cederholm, C.J., and L.C. Lestelle. 1974. Observations on the effects of landslide siltation on salmon and trout resources of the Clearwater River, Jefferson County, WA, 1972-73, Final Report. University of Washington.

Doman, L., and A. Kahan. 2018. United States remains the world's top producer of petroleum and natural gas hydrocarbons. U.S. Energy Information Administration, 21. Available at: https://www.eia.gov/todayinenergy/detail.php?id=36292. Accessed 12 April 2022.

Esri. n.da. Forest-based classification and regression (spatial statistics). Available at: https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/forestbasedclassificationregression.htm. Accessed 14 January 2022.

Esri. n.db. How forest-based classification and regression works. Available at: https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-statistics/how-forest-works.htm. Accessed 14 January 2022

Esri. 2020. ArcGIS Pro 2.9.0. Redlands, California.

Hallermann, N., and G. Morgenthal. 2014. Visual inspection strategies for large bridges using Unmanned Aerial Vehicles (UAV). In Proceedings of the 7th International Conference on Bridge Maintenance, Safety and Management (IABMAS). pp. 661-667.

Joshi, P.C. 2011. Performance evaluation of vegetation indices using remotely sensed data. International Journal of Geomatics and Geosciences. 2: 231.

Kargbo, D.M., R.G. Wilhelm, and D.J. Campbell. 2010. Natural gas plays in the Marcellus shale: Challenges and potential opportunities. Environmental Science and Technology. 44: 5679–5684.

Kemp, P., D. Sear, A. Collins, P. Naden, and I. Jones. 2011. The impacts of fine sediment on riverine fish. Hydrological Processes. 25: 1800-1821.

Kim, J., S. Kim, C. Ju, and H.I. Son. 2019. Unmanned aerial vehicles in agriculture: A review of perspective of platform, control, and applications. IEEE Access. 7: 105100-105115.

Kokaly, R.F., R.N. Clark, G.A. Swayze, K.E. Livo, T.M. Hoefen, N.C. Pearson, R.A. Wise, W.M. Benzel, H.A. Lowers, R.L Driscoll, and A.J. Klein. 2017. USGS Spectral Library Version 7: U.S. Geological Survey Data Series. 1035: 61.

Marcellus Drilling News. 2021. SWPA Olympus Well Becomes Longest Marcellus Onshore Lateral. Available at: https://marcellusdrilling.com/2020/12/swpa-olympus-well-becomes-longest-marcellus-onshore-lateral/. Accessed 12 January 2022.

Meerdink, S.K., S.J. Hook, D.A. Roberts, and E.A. Abbott. 2019. The ECOSTRESS spectral library version 1.0. Remote Sensing of Environment. 230: 1-8.

Messersmith, D., D. Brockett, and C. Loveland. 2015. Understanding natural gas compressor stations. Penn State Extension. Available at: https://extension.psu.edu/understanding-natural-gas-compressor-stations. Accessed 05 January 2022.

Natural Resources Conservation Service. 2019. Web Soil Survey. Available at: http://websoilsurvey.sc.egov.usda.gov/. Accessed 14 January 2022.

Nikolic, J., M. Burri, J. Rehder, S. Leutenegger, C. Huerzeler, and R. Siegwart. 2013. A UAV system for inspection of industrial facilities. In 2013 IEEE Conference on Aerospace Conference, 1-8. Big Sky, MT: IEEE.

Olmstead, S.M., L.A. Muehlenbachs, J.S. Shih, Z. Chu, and A.J. Krupnick. 2013. Shale gas development impacts on surface water quality in Pennsylvania. Proceedings of the National Academy of Sciences of the United States of America. 110: 4962-4967.

Popova, O. 2017a. Marcellus Shale Play: Geology Review. U.S. Energy Information Administration. Available at: https://www.eia.gov/maps/pdf/MarcellusPlayUpdate_Jan2017.pdf. Accessed 03 January 2022.

Popova, O. 2017b. Utica Shale Play: Geology Review. U.S. Energy Information Administration. Available at: https://www.eia.gov/maps/pdf/UticaShalePlayReport_April2017.pdf. Accessed 03 January 2022.

Richards, C., and K.L. Bacon. 1994. Influence of fine sediment on macroinvertebrate colonization of surface and hyporheic stream substrates. The Great Basin Naturalist, 106-113. Available at: http://www.jstor.org/stable/41712819. Accessed 12 April 2022.

Tucker, C.J. 1979. Red and photographic infrared linear combinations for monitoring vegetation. Remote Sensing of Environment. 8: 127-150.

U.S. Department of Energy. 2020. The Appalachian Energy and Petrochemical

Renaissance: An Examination of Economic Progress and Opportunities. Available at: https://www.energy.gov/sites/prod/files/2020/06/f76/Appalachian%20Energy%20and%20Petrochemical%20Report_063020_v3.pdf. Accessed 03 January 2022.

U.S. Energy Information Administration. 2021. Natural gas explained. Available at: https://www.eia.gov/energyexplained/natural-gas/. Accessed 03 January 2022.

Warner, N., C. Christie, R.B. Jackson, and A. Vengosh. 2013. Impacts of shale gas wastewater disposal on water quality in western Pennsylvania. Environmental Science Technologies. 47: 11849-11857.

West Virginia Department of Environmental Protection. 2013. General Water Pollution Control Permit. Available at: https://dep.wv.gov/WWE/Programs/stormwater/csw/Documents/OG%20stormwater%20GP%203_10_15.pdf. Accessed 12 April 2022.

West Virginia Department of Environmental Protection. 2016. Erosion and Sediment Control Best Management Practice Manual. Available at: https://dep.wv.gov/WWE/Programs/stormwater/csw/Documents/E%20and%20S_BMP_2006.pdf. Accessed 12 April 2022.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar, and J. Uzu, eds. 2022. pp. 31-40.

Proceedings Paper

Use of a standalone virtual reality headset in hurricane river flood modelling

Brian J. Williams
Baruch Institute of Forest Science and Coastal Ecology, Clemson University
Georgetown, SC, 29442, bwilli8@clemson.edu

Bo S. Song
Baruch Institute of Forest Science and Coastal Ecology, Clemson University
Georgetown, SC, 29442, bosong@clemson.edu

Thomas M. Williams
Baruch Institute of Forest Science and Coastal Ecology, Clemson University
Georgetown, SC, 29442, tmwllms@clemson.edu

Daniel Hitchcock
Baruch Institute of Forest Science and Coastal Ecology, Clemson University
Georgetown, SC, 29442, dhitchc@clemson.edu

Abstract

Advancements in computer technology have allowed for development of high fidelity simulations of real-world phenomena. However, visualization of those simulations has been limited by two-dimensional screens used to view simulated three-dimensional environments. Different viewpoints are often prerendered, limiting the user from moving freely through the visualization. First developed in 1968, virtual reality (VR) headsets have traditionally relied on sophisticated, very expensive computer systems to create a three-dimensional environment. The expense limited VR systems to large research universities or private corporations. By the mid-1990s, the video game industry began introducing VR technology (Nintendo Virtual Boy, Sega VR, Virtuality pods) with limited success. Most of these systems were discontinued within a year because of the limited development of VR compatible games. In the mid-2000s, Google developed Street View in Google Earth, allowing anyone with a computer and eventually a cellphone to view 3D scenes across the globe. In 2012, Oculus released the Rift which was one of the first VR headsets affordably available to the public. However, the Rift and competitors, such as the HTC Vive and Valve Index, still required a dedicated computer system to drive the VR environment. Oculus released the Quest in 2019 which uses a mobile chipset and was the first standalone VR headset. The Quest can display VR without the aid of a

computer.

Due to demands on processing power, VR environments are often on a smaller scale and limited scope, such as scenes of house interior or X-ray tomography. Large scale and complex scenes are often more difficult to make. In this paper we will discuss constructing a landscape level VR environment for the Oculus Quest. We show how GIS data hydraulic modeling, and high-resolution photography were used to recreate flooding in a five-mile section of the Pee Dee River Valley. We discuss how hardware limitations impacted the realism of the scene, the way the flood model was displayed, and use of complex three-dimensional models.

Keywords: 3D visualization, water hydraulics, HEC-RAS modelling, simulation

Introduction

Coastal regions are subject to flooding by three separate mechanisms: flash flooding, tidal flooding, and river flooding. Flash flooding occurs when rainfall occurs faster than runoff channels can carry water away. It occurs during periods of high rainfall intensity such as thunderstorms or tropical storms. Tidal flooding is associated with exceptionally high tides and is often also associated with tropical storm. River flooding is the result of heavy rainfall in the watersheds of larger coastal rivers. River flooding is caused by rainfall over the entire watershed and may be only marginally related to rainfall at a particular downstream site as well as being delayed. Tropical storms may cause all three types of flooding in a coastal part of a county: a tidal surge as the storm approaches, intense rain during landfall, and river flooding several days after the storm.

Georgetown County, South Carolina (SC) is particularly susceptible to all three types of flooding. Low relief in much of the county limits the ability of drainage systems to rapidly making areas susceptible to flash flooding. The Atlantic Ocean forms the eastern border of the county creating many tidal wetlands. River flooding occurs along the Santee River on the southern border. The Pee Dee River Basin terminates in Winyah Bay at Georgetown SC (33°22’ N, 79°16’ W) with a total watershed area of 26,000 km^2 (U.S. Geological Survey, 2021). The Pee Dee forms part of the northern border of the county and flows through the entire center of the county. River flooding in the Pee Dee basin is a major contributor to flooding hazard in Georgetown County.

Hurricane Florence resulted in large scale evacuations in Georgetown County following record rainfall in the Pee Dee Basin (Griffen et al., 2019). Much of the evacuation proved unnecessary, prompting a study of flooding in the Lower Pee Dee Basin funded by the South Carolina Water Resources Center. That study resulted in a series of applied papers explaining the behavior of flooding following tropical storms in the Winyah Bay estuary/tidal river system (Williams et al., 2019; Williams et al. 2020a; Williams et al., 2020b). In addition to the development of research papers, the goal of the project was also to inform interested stakeholders about flooding hazards. This paper describes an effort to communicate river flooding relationships to the public using the flood following Hurricane Florence as an example.

Methods

HEC-RAS modelling

Two gauging stations on the Great Pee Dee River, USGS 02131000 - Pee Dee River at Pee Dee, SC, and USGS 02131010 - Pee Dee River Below Pee Dee, SC, provided an ideal section to create a calibrated HEC-RAS (Hydraulic Engineering Center-River Analysis System) (Brunner, 2016) model of the Hurricane Florence flood. Each station had a complete record of both stage and discharge for the entire flood and the entire section is above tidal influence.

Development of the HEC-RAS model generally followed the procedures outlined in Williams (2008) but was modified to include new GIS capability of version 5.0.7 of the HEC RAS software. The latest version of HEC-RAS includes a GIS package (RASMAPPER) that incorporates the functions that were formerly contained in an ArcGIS 9.x extension.

LiDAR DEM and county hydrography data were obtained from the South Carolina Department of Natural Resources (SCDNR) (South Carolina Department of Natural Resources, 2018) for Florence, Georgetown, Horry, Marion, and Williamsburg Counties, SC. These data were converted to Esri grid format and clipped to exact county boundaries. Since the individual county DEMs included a buffer of data from an adjoining county, the lines used to clip adjoining counties were drawn to be within the buffer of both counties. However, where a river of interest was the county line, the arbitrary line was either the right or left bank line from hydrography layer. The bank used depended on which county DEM was created at the lowest river stage. The mosaic of the clipped DEMs then contained the lowest water level and, thereby, the greatest amount of data about the profile of the river channel.

Between the U.S. Geological Survey (USGS) gauge stations, the Great Pee Dee River is the boundary between Florence and Marion counties. The LiDAR mission for Marion County was flown when the river was at the lowest level and the data for each county was clipped by the eastern bank line to create a mosaic grid. That grid was then clipped with an area of interest between the USGS gaging stations, that included an upstream and downstream buffer and extended beyond the sides of the valley on the eastern and western edges. The clipped area of interest was then imported into RASMAPPER for creation of river cross sections. The distance between the stations was 4.2 miles (6.76 km) and 45 cross sections were chosen with an average spacing of roughly 500 feet (152 m), with closer spacing around bends and wider spacing along straight sections. Cross sections were drawn to be at 90° to the estimated flow direction and extended from the western to eastern valley edge (elevation > 100 ft (30 m)).

Since the project budget did not provide funds for survey of the river bottom, as was done on the Santee (Williams, 2008), an arbitrary channel cross section was used. Creating of the arbitrary channel was a multi-step process. The LiDAR-derived water level was determined at Station 02131000, a rating curve for that station was created from observed data downloaded from the USGS gauging station data (Williams et al. 2020b), and the flow was estimated to have been 4040 ft^3 per second (cfs) (114.4 m^3/s) when the Marion County LiDAR was flown. At each cross section the water surface width was determined in the HEC-RAS cross section editor. A Manning's *n* value of 0.025 was used for all channel modeling. A trapezoidal channel was estimated, with depth and bottom width as fitted variables, to obtain a modeled flow of 4040 ±100 cfs (114.4 ± 2.8 m^3/s). At each cross section the arbitrary trapezoidal channel was then entered as the channel bottom in the HEC-RAS cross section editor. Floodplain land use (primarily bottomland hardwood forest, clearcut forest, agricultural fields, and a wildlife impoundment) was determined from Google Earth images of the area of interest. Elevation of roads, dikes, and the natural levees were used to estimate non-flow elevations on each cross section. Once all the geometry was established floodplain Manning's *n* values were adjusted to mimic the observed maximum stage and discharge at the downstream station, 02131010 Pee Dee below Pee Dee.

Once the model was considered satisfactory, the results were exported to the RASMAPPER software, and a 2-D model output was displayed. At each 1-hour time step, for the 30-day period, a 2-D display of the modelled region was captured. These displays were then combined into a runtime movie of the model region. This movie was used as the "ground truth" for the 3D simulation.

Virtual reality 3D simulation

Creating the VR environment of the Great Pee Dee River was accomplished using the Unity (2021) programming platform. Unity is an ideal platform for development due to being compatible with the Quest and free for educational institutions. The program has included prefabricated (prefabs) assets for use in VR. Likewise, there is a marketplace where numerous free and professional paid assets can be obtained.

To recreate the landscape, the LiDAR DEM of the study area was imported into the Blender graphical program. The DEM was used to create a 3D surface model of the landscape. High-resolution photography obtained from the NAIP (National Agriculture Imagery Program) (U.S. Department of Agriculture, 2021) was wrapped over this model to show the landscape vegetation and surface features. This model was exported from Blender as a FBX (Filmbox format commonly used for 3D digital objects) file and imported into Unity. A custom flight script was used for movement to allow the user to fly above this surface and view it in 3D.

Included water prefabs were used to recreate the river and water flooding. These prefabs consisted of textures and animations to give the appearance of water within Unity. A single prefab was laid out along the course of the river. To recreate the cross sections used for the HEC-RAS model, planes of water were laid out over the floodplain.

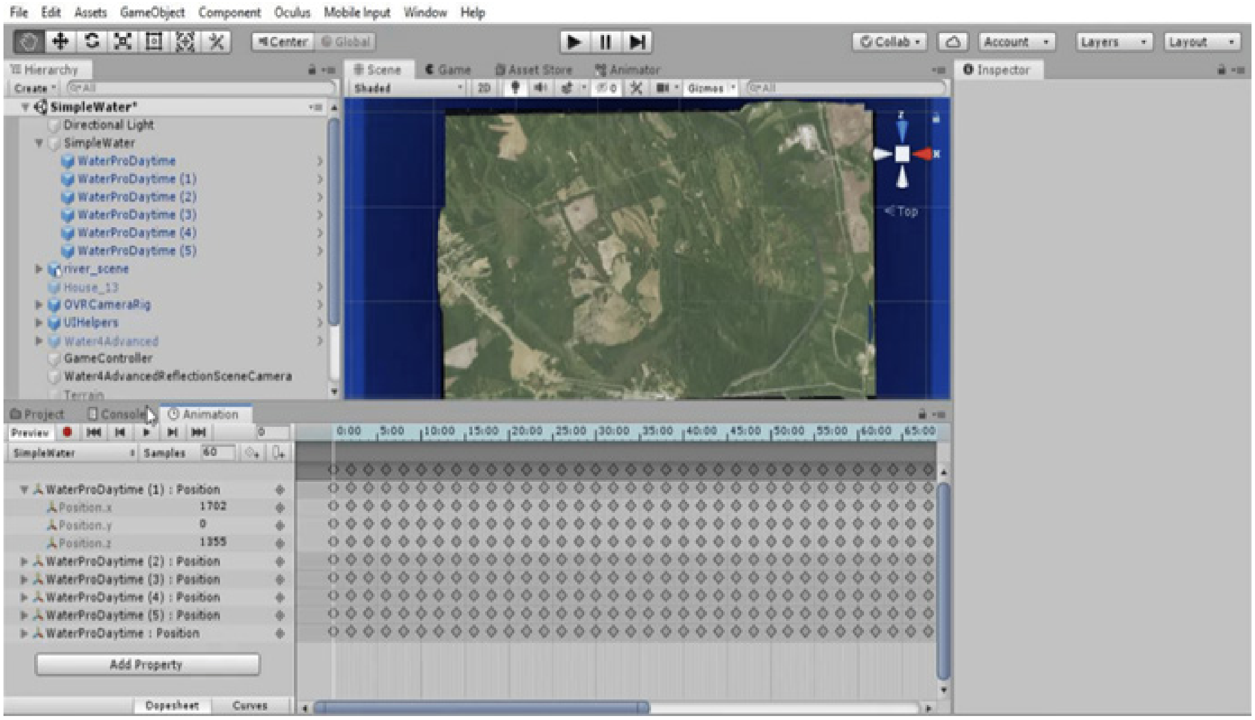

Figure 1. Timeline showing the heights of the different water prefabs for making the flooding animation.

Instead of the 45 cross sections used for HEC-RAS, five planes were used for modelling efficiency. To represent the rising and receding flood waters, the heights for river and each of the water prefabs were raised or lowered along the flooding timeline (Figure 1). When the timelines for each of these prefabs were combined, it produced an animation showing the rise and ebb of the flood water. The animation was compared to the two-dimensional output of the HEC-RAS model to confirm accuracy of the 3D recreation.

A custom menu was constructed using Unity's included features allowing the user to control the flooding animation. This menu was included in the user's viewpoint so it would always be visible and follow their location. It allowed the user to start and stop the animation along with exiting the simulation.

Results

During the construction of the flood animation, it was discovered that the same water prefab could not be used for different purposes; thus, the river water and flooding water had to use different prefabs. This led to an investigation into the other water prefabs included with Unity. Two different prefabs were discovered, a "simple" and more "advanced" water model. Each of these prefabs had highly different characteristics (Figure 2). The advanced water prefab looks highly realistic with more complex lighting and wave effects, however, has a shorter viewing distance and disappears as the viewer altitude exceeds a critical distance. The simple water prefab does not have

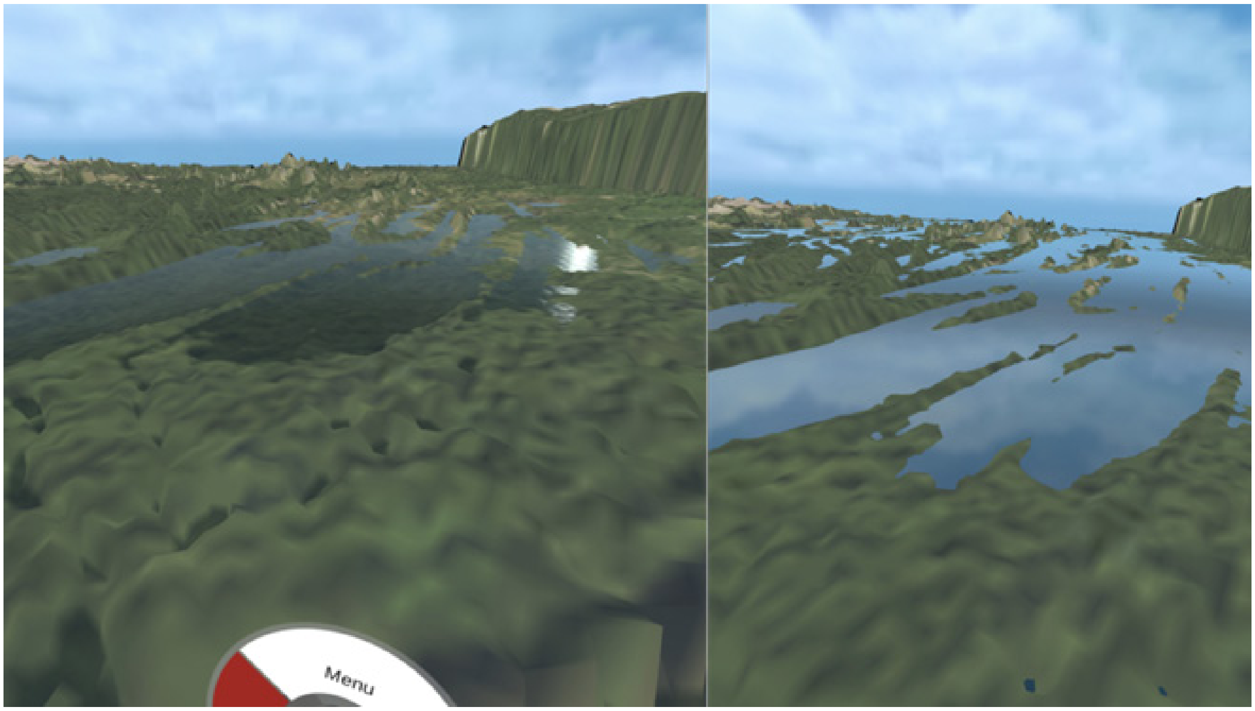

Figure 2. The two water prefabs included with Unity. Advanced water is shown on the left and the simple water is shown on the right.

as much lighting and special effects but is viewable from great heights and longer distances. It was decided to use both prefabs depending on the desired perspective of the user. An animation was made using each prefab and the user has an option of viewing the flood using the simple or more advanced water features.

Using the Oculus Quest, the user can view one of two flooding simulations within a 3D virtual environment. They can have freedom of movement to view the environment from any position at any height. Because of the Quest's head tracking feature, the user can turn their head while moving for additional independent viewpoints.

Current animation control is rather simple. The user can start and pause the animation on demand. There are options to include fast forwarding and rewinding the animation, however, these features are currently not working. The programming for these features within in Unity are more advanced and need more development in the future. Likewise, the pause feature is not working as planned. Pausing completely freezes the entire simulation instead of just pausing the animation while still allowing the user freedom of movement. This is another feature that requires more development in the future.

Performance on the Quest hits the required 72 frames per second (FPS) when not in motion. However, as the user flies around the environment the frame rates begin to drop. Frame rate using the advanced water drops to 31-32 FPS and simple water 33-35 FPS. While a VR simulation can operate with lower frame rates, such low and inconsistent rates can lead to nausea or motion sickness with some users. These low rates also come very close to the 30 FPS limit that the human eye can perceive.

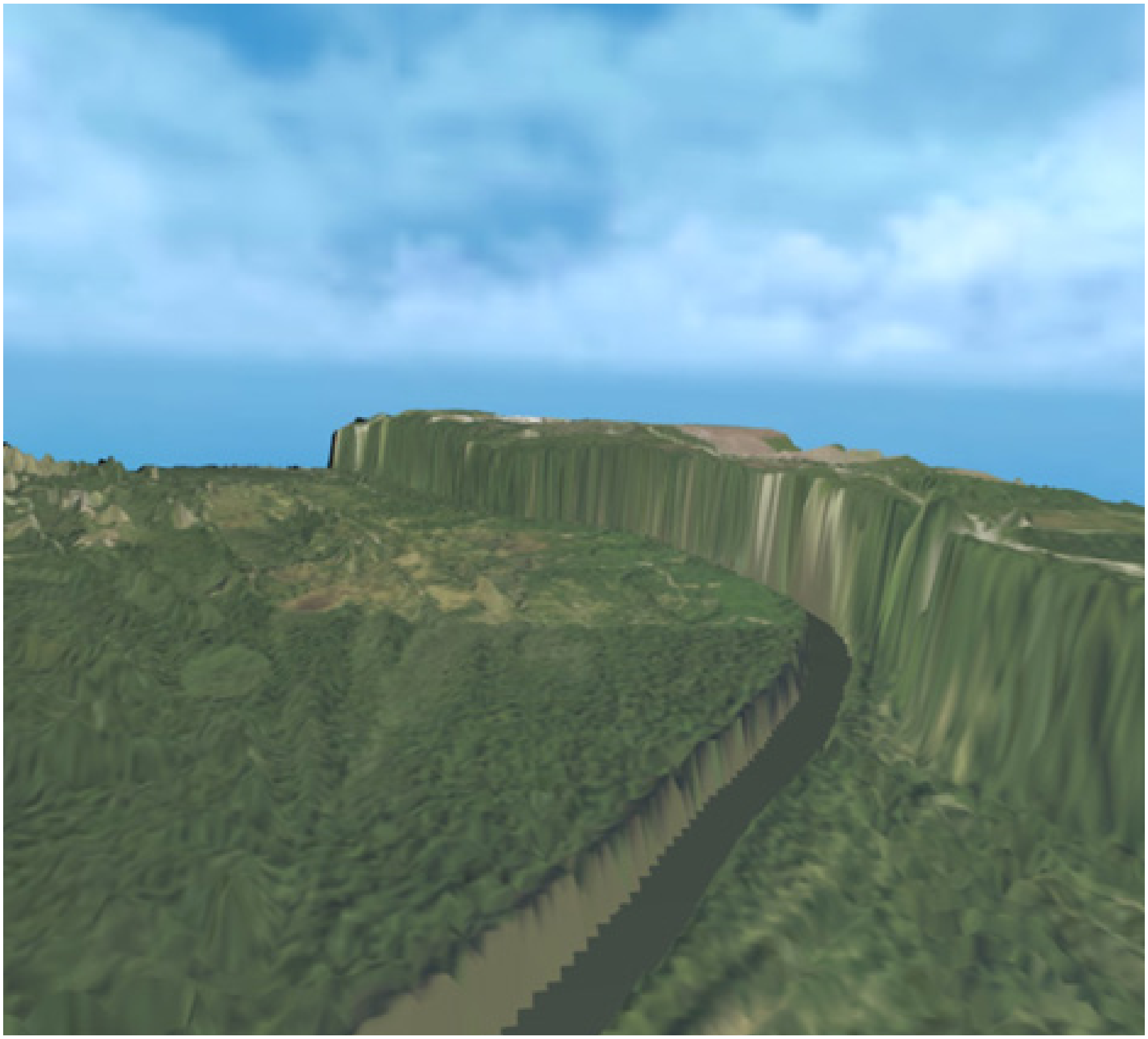

Figure 3. Surface defects caused by DEM exaggeration.

Anything lower will lead to poor VR experience with stuttering and choppy movement and animation. More optimization to achieve higher frame rates is needed in the future.

Discussion

Landscape level visualization can be facilitated on the Oculus Quest, however, there are several limitations. The number of 3D objects within a scene is one of the biggest limitations. While the Quest has a modern chipset capable of 3D graphics, it does not have the same power as a dedicated computer system. Too many 3D objects result in lower system performance because the Quest simply cannot keep up with drawing them all at once. Having a larger number of 3D objects is suitable of smaller scale projects, but for larger scales a mixture of 3D and 2D is more suitable.

Another limitation is that the draw/viewing distance for some prefabs is limited. Some were designed to be viewed on a much smaller scale. This limit had to be increased for a large landscape level view. When increased, the larger draw distance led to some performance issues because of higher demands on the Quest.

Creating a 3D surface leads to some visual distortion and unintended effects with the Unity prefabs. DEM exaggeration can lead to a surface model with unrealistic high and low spots (Figure 3). While there are sections of the Great Pee Dee River that have banks occurring ten to fifteen feet (3.05 to 4.57 m) above the surface, they appear as exaggerated as in Figure 3. Such exaggerations create unrealistic views of the landscape and lower the effectiveness of the visualization.

As discussed before, frame rates are another large limitation. Low frame rates can result in choppy and stuttering movement within the environment. This can cause the user to have nausea or motion sickness. Causing user discomfort would completely invalidate the intended purpose of the project.

Optimization of the virtual environment is highly critical to successful viewing. This includes having optimal performance and smooth frame rates. Several things can be done to improve performance on the Quest. Limiting the amount of real time lightening effects, shadows, and reflection plays a large role in improving performance. Less use of these features allows the Quest to use system resources for rendering other features and faster frame rates. Limited or no object physics should be included in the environment. Likewise using "baked" lighting, prerendered real time lighting effects and shadows, also frees up system resources because the Quest does not need to calculate these effects in real time. Use of graphics with heavy textures (larger than 4 megabytes) should be limited as well. This frees up the Quest memory for additional effects and performance.

Future areas of exploration for visualization using the Quest should use of the 2019 and above versions of Unity. These versions include the Lightweight Rendering Platform that was made for standalone system such as the Quest. This rendering platform improves performance on standalone systems by using memory more efficiently along with having more advanced features for texture optimization and use. This feature was not present in Unity when this project was being conducted. Further investigation should be performed using the Quest's Link system that allows it to be connected to the computer via a USB cord. This makes the Quest a dummy terminal allowing a higher performance PC to do all the computational work. This breaks away from the stand alone feature of the headset, but a new Air Link feature allows the same to be accommodated over a wireless connection. Using such a hybrid system may allow for more detailed large-scale visualizations to be conducted with greater performance.

Conclusions

Standalone headsets such as the Oculus Quest can be used for landscape level visualization but have several limitations. Optimization can help to overcome some of these limitations. Also, identifying the main features to be visualized as realistically as possible can lead to improvements. More research using the more advanced features of the Quest may lead to making visualizations more advanced and detailed in the future. Use of VR might not be optimal for portraying flooding information currently. However, increased adoption of VR in the general market may allow it to be a valuable tool for future visualization of the environment.

Acknowledgements

- The South Carolina Water Resource Center for providing funding to complete this project.
- Volunteer work done by Jim Hendrix for delineating the HEC-RAS cross sections.
- Clemson PhD student Jeremy Forsythe for assistance in finding the NAIP database.

References

Brunner, G.W. 2016. HEC-RAS, River Analysis System Hydraulic Reference Manual. CPD-69. Davis, CA: US Army Corp of Engineers, Hydrologic Engineering Center.

Griffin M, M. Malsick, H. Mizel, and L. Moore. 2019. Historic rainfall and record-breaking flooding form Hurricane Florence in the Pee Dee Watershed. Journal of South Carolina Water Resources. 6(1): 28–35.

South Carolina Department of Natural Resources. 2018. SCDNR – LiDAR Data Status by County. Available at: http://www.dnr.sc.gov/GIS/lidarstatus.html. Accessed 28 December 2021.

Unity. 2021. Unity Real-Time Development Platform|3D, 2D VR & AR Engine. Available at: https://unity.com/. Accessed 27 December 2021.

U.S. Department of Agriculture. 2021. NAIP Imagery. Available at: https://www.fsa.usda.gov/programs-and-services/aerial-photography/index. Accessed 18 May 2021.

U.S. Geological Survey. 2021. US Geologic Survey, Current Water Data for South Carolina. Available at: https://waterdata.usgs.gov/sc/nwis/rt.6(1):28–35. Accessed 28 December 2021.

Williams, T. M. 2008. Incorporating GIS in river hydraulic modeling: Assessing the ability to predict ecological consequences of river modification on floodplain forests. In Proceedings of the 6th Southern Forestry and Natural Resources GIS Conference (2008), P. Bettinger, K. Merry, S. Fei, J. Drake, N. Nibbelink, and J. Hepinstall, eds. Athens, GA: University of Georgia. pp. 3-13.

Williams, T.M., D. Hitchcock, B. Song, and T. O'Halloran. 2019. Hurricane Florence flooding in Georgetown County: A qualitative explanation of the interactions of estuary and tidal river. Journal of South Carolina Water Resources. 6(1): 36-45.

Williams T.M., B. Song, D. Hitchcock, and T.L. O'Halloran. 2020a. Streamflow and tidal dynamics in the Lower Pee Dee Basin: Hurricane impacts. Journal of South Carolina Water Resources. 7(1): 67-80.

Williams T.M., B. Song, D. Hitchcock, and T.L. O'Halloran. 2020b. Floodplain geomorphology and response to hurricanes: Lower Pee Dee Basin, South Carolina. Journal of South Carolina Water Resources. 7(1): 81-90.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar, and J. Uzu, eds. 2022. pp. 41-53.

Proceedings Paper

Sources of error from dense understory vegetation in Coastal Plain forest hydrologic analyses using LiDAR DEMs

Thomas M. Williams
Baruch Institute of Forest Science and Coastal Ecology, Clemson University
Georgetown, SC, 29442, tmwllms@clemson.edu

Brian J. Williams
Baruch Institute of Forest Science and Coastal Ecology, Clemson University
Georgetown, SC, 29442, bwilli8@clemson.edu

Bo S. Song
Baruch Institute of Forest Science and Coastal Ecology, Clemson University
Georgetown, SC, 29442, bosong@clemson.edu

Jeremy D. Forsythe
Baruch Institute of Forest Science and Coastal Ecology, Clemson University
Georgetown, SC, 29442, jdforsy@clemson.edu

Thomas L. O'Halloran
Baruch Institute of Forest Science and Coastal Ecology, Clemson University
Georgetown, SC, 29442, tohallo@clemson.edu

Abstract

Forests of the lower Atlantic and Gulf Coastal Plains have unique hydrology that is dominated by low relief and shallow water tables which can cause soil saturation and flooding over a large part of a watershed. GIS is now commonly used to delineate contributing areas and compute other parameters used in hydrologic study and modeling. A hydrology toolbox has been a standard tool within ArcGIS since the late 20th century. During the 21st century, availability of high-resolution LiDAR and the hydrology toolbox make many tasks of hydrologic studies routine. Small experimental watersheds are the most widely used method to study forest hydrology, and the delineation of small watersheds is easily conducted with LiDAR DEMs and the hydrology toolkit. LiDAR produces reliable ground surface DEMs since many photons reflected from the ground surface are last to return to the sensor. These last returns are easily separated from those produced by higher vegetation. However, dense vegetation, such as *Spartina alterniflora*, along the Atlantic coast of North America can preclude ground returns

and LiDAR DEMs of salt marshes may be unreliable. In this paper we will show how pocosin vegetation can similarly limit the ability of LiDAR to accurately measure surface elevations on forested watersheds of the Lower Coastal Plain. This problem is particularly severe since the difference in elevation of coastal forested watersheds are in the same order of magnitude as the error caused by dense pocosin vegetation. In this paper, we will examine a small forested coastal watershed with recent high quality LiDAR DEM data, that includes areas of dense pocosin vegetation (*Lyonia* spp. *Ilex* sp.) that produce DEM anomalies. We will examine errors caused in watershed delineation caused by these DEM anomalies and methods to identify them based on, high-resolution true color imagery, and measured understory density associated with accurate and anomalous DEM data.

Keywords: Watershed delineation, ArcGIS hydrology toolkit, elevation errors, pocosin, *Lyonia* spp.

Introduction

Geography has been associated with hydrology since the mid-17th century when Pierre Perrault compared the flow of the Siene River to rainfall on the watershed above Paris (Rosbjerg and Rodda, 2019). Since then, the geographic aspect of hydrology progressed as land survey methods improved. Over three hundred years later, Maidment outlined how GIS could be used to perform many tasks used in hydrological sciences (Hellweger and Maidment, 1999). The hydrology toolbox was added to Arc-View 3.2 (Olivera et al., 1998) and has been a part of the subsequent versions of ArcGIS since that time.

The definition of watershed boundaries is one of the most basic hydrologic tasks first incorporated into GIS (Jensen, 1991) and is a basic task of the hydrology toolbox. A topographic map is converted to a digital elevation model (DEM), a raster with the value of each grid cell being the mean elevation of that cell. The first step is to “fill” all small depressions in the DEM so that all cells slope smoothly towards cells on the perimeter of the DEM. The “flow direction” command calculates the steepest path from the target cell to the eight cells surrounding it. If the analyst has known point(s), such as culvert or sampling locations, a point file of these locations can be combined with the flow direction surface to define the watershed flowing to each point. If a stream network is not known the “flow accumulation” command creates a surface where each grid cell has a value of the number of cells flowing towards that point. By specifying a minimum number of contributing cells, the watershed command will create watershed boundaries of all cells meeting that criterion on the DEM.

Early adoption of the toolbox was limited by the available 3 arc-second national DEM, which equated to approximately a 30 m x 30 m grid cell for most of the US (Olivera et al.,1998). Forest hydrology research has focused on small, paired watersheds (Bren, 2016) and 30 m x 30 m grid cells were too large to be useful for forest hydrology research. DEMs developed from U.S. Geological Survey (USGS) quadrangle sheets and aerial photography still were not very accurate in headwaters watersheds (Heine et al., 2004). In the southern Piedmont and mountains of the United States, LiDAR-derived DEMs now facilitate accurate mapping of small, forested watersheds (James et al., 2007).

The Lower Coastal Plain presents much greater challenges in watershed definition. The entire lower coastal plain is made up of former marine terraces that are less than 30 m in elevation (Colquhoun, 1974). Forest hydrology research on the Lower Coastal Plain is plagued by very mild slopes and indistinct watershed boundaries. Amatya et al. (2013) documented difficulties determining the watershed of Turkey Creek, a moderately sized third-order watershed that had been gauged since 1964 on the Francis Marion National Forest in Berkley County, South Carolina (SC). Turkey Creek was gauged in 1964 at a point where US 41 crosses the creek, the present location of USGS 02172035 Turkey Creek above Huger, SC. In 1964, the Turkey Creek watershed was defined from field reconnaissance and panchromatic aerial photos and contained an estimated 3240 ha (Young, 1965), which was later revised to 4575 ha. When the present USGS gauge was installed in 2004 the watershed area was estimated using ArcView hydrology toolkit, with 30 x 30 m grid cells with 1 m vertical resolution, and it was estimated to contain 4,920 ha. Between then and 2010, a variety of methods were used to refine that data and resulted in watershed area values from 5,880 ha to 7,260 ha (Amatya et al. (2013). Finally, with a 1.5 m x 1.5 m grid with 18 cm vertical accuracy LiDAR-based DEM, the watershed was estimated to contain 5,240 ha. Amatya et al. (2013) noted that the final estimate required editing the DEM to account for forest road culverts near the watershed boundary.

In 2019 the South Carolina Water Resources Center provided funds to expand an eddy- covariance tower study of CO_2 and H_2O exchange between a longleaf pine (*Pinus palustris*) stand and the atmosphere (Forsythe et al., 2020). The expansion included measurements of water as unsaturated soil moisture, saturated groundwater, and surface runoff (Williams et al., 2020). The tower senses a region of longleaf pine stand, approximately 200 m in radius, located on Hobcaw Forest in eastern Georgetown County, SC. To measure surface flows, a 0.61 m (2 ft) Parshall Flume was placed in a small stream downgradient from the tower. A key aspect of the research will be to use the flume volume estimates in comparison to the measured evapotranspiration of the stand, as measured by the tower.

In this paper we evaluated the watershed definition application of the ArcGIS Hydrology toolbox to determine the watershed flowing to the flume described above. Since we had data from three separate LiDAR missions that were conducted over the area between 2003 and 2017, we examined the LiDAR-derived watershed areas in the same way Amatya et al. (2013) examined the definition of the Turkey Creek watershed.

Methods

The tower and flume are located in eastern Georgetown County, SC, on property of the

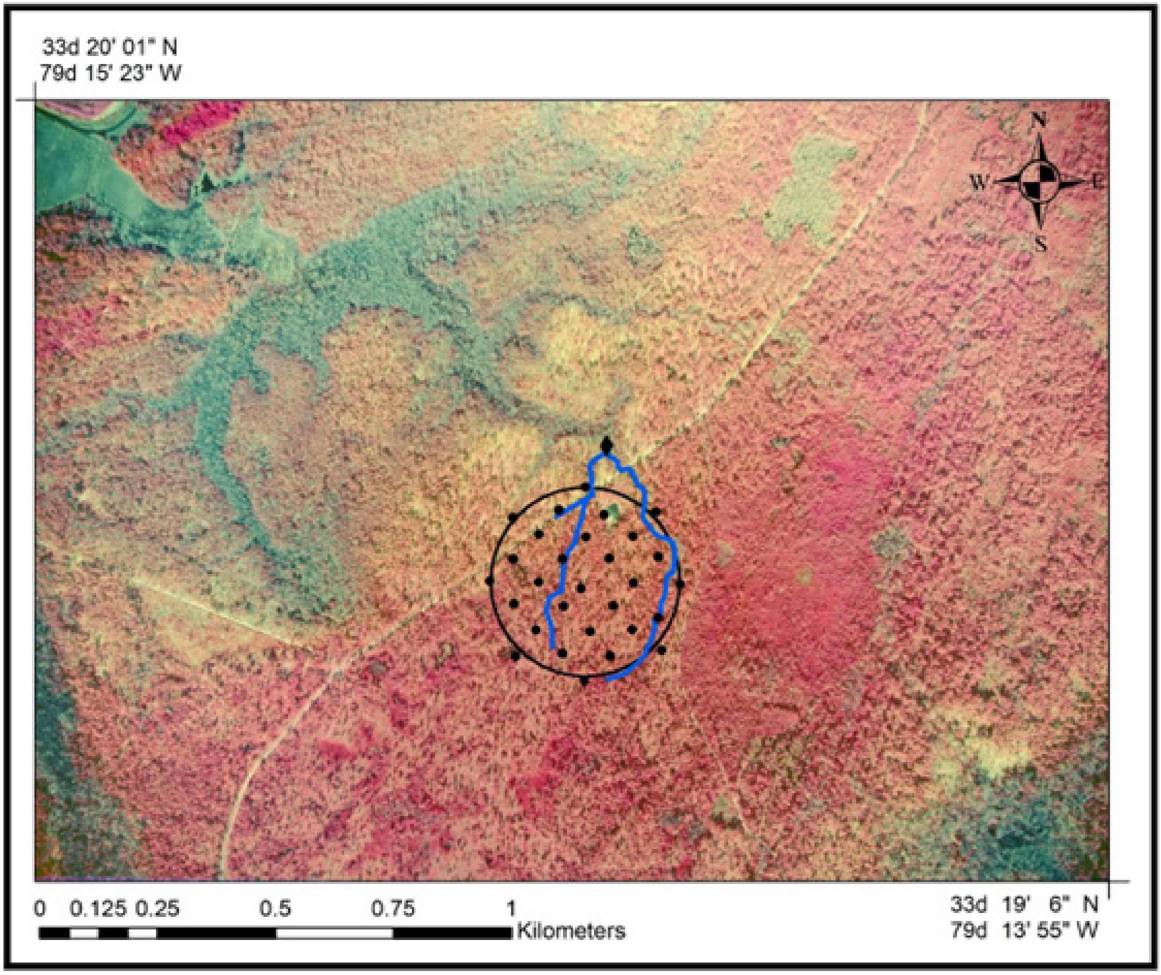

Figure 1. Location of study site with position of the tower footprint (black circle) installed flume (black diamond), shallow wells, and empirical stream channels (blue lines). Background is a color infrared aerial photo overlain (30% transparent) on the 2009 DEM.

Belle W. Baruch Foundation, locally named Hobcaw Forest. In January 2019, an eddy-covariance tower was erected in a stand of mature longleaf pine within the Hobcaw Forest (33°19’27” N, 79°14’58” W). That stand was subject to a selective harvest in 1952 where 10 in (25 cm) diameter limit cut was imposed and has been subject to periodic prescribed fire since the mid-1970s (Williams and Lipscomb, 1984). The tower is 37 m tall and senses a region surrounding the tower (hereafter called tower footprint) approximately 400 m in diameter (Forsythe et al., 2020). In July 2019, 29 shallow groundwater wells were located within a 400 m diameter circle, associated with the tower footprint, at an average spacing of 72 m (Figure 1). These wells were equipped with water level sensors that have operated since that time. Sensors were monitored monthly and following severe storms.

Six Forest Inventory and Analysis (FIA) style forest inventory plots were installed within the tower sensed area in June 2019 and resurveyed in May-June 2021. Each main plot consisted of 4 sub-plots, one at plot center and three 20 m from the center separated by 120° angles, one north, and one each to the southeast and the southwest. Each sub plot consisted of a 15 m radius overstory plot where all trees were measured for DBH, species and height, and a 5 m radius understory plot where plants were inventoried by species into three height classes, 0-0.5 m, 0.5- 1.0 m, and 1.0-2.0 m. Sub-plot centers were also surveyed for X (easting), Y (northing), and Z (elevation) coordinates using a Trimble R8 survey grade GPS from a benchmark location determined by repeated triangulation using the National Oceanic Atmospheric Administration (NOAA) Online Position User Service, OPUS (National Oceanic and Atmospheric Administration, 2019).

LiDAR data has been available for Hobcaw Forest since 2009 through informal arrangements among the Baruch Institute staff and other GIS professionals. Anand Jayakaran obtained a set of raw LiDAR data flown in 2003 by a NOAA program of coastal monitoring. Last return data was used with ArcGIS LAS tools to produce a surface DEM for the Baruch Property. That DEM was produced in NAD 83 UTM coordinates with elevation reference to NAVD 88 datum and a grid size of 2 m x 2 m. In 2011, Don Lipscomb and Jeff Vernon obtained a countywide DEM and high resolution (1:4,800) ortho aerial photos from the Georgetown County GIS Department. These items were in the NAD83 South Carolina State Plane Coordinate System, and the DEM had a grid cell size of 5 ft x 5 ft with elevation expressed as feet, NAVD 88. These data had been collected in the winter of 2009 as part of a joint Georgetown County South Carolina Department of Natural Resources (SCDNR) program. However, the data was not part of the state LiDAR coverage, as the elevation of the large portions of the county covered by tidal marshes was flown at varying tide levels and did not reflect true ground surfaces. The 2009 DEM data came from Georgetown County GIS as several hundred text files, one for each 2000 ft x 2000 ft South Carolina State Plane grid in the county. These files were converted to ArcGIS grid files and mosaicked into a complete coverage of Hobcaw Forest. These data were inspected to see they were similar to the DEM obtained from NOAA LiDAR and used in presentations that featured English units.

In 2017, a LiDAR mission was flown over Georgetown County during periods of low tide and the LiDAR data was then available from the SCDNR GIS Data Clearinghouse (South Carolina Department of Natural Resources, 2019). In August, of 2019 the LiDAR DEM data for the county was obtained from that site. Like 2009, this data was in NAD 83 South Carolina State Plane Coordinates with 5 ft x 5 ft grid cells and elevation in NAVD88. This DEM was the most up-to-date data and will be used as an elevation base for all data collected in the project. The horizontal coordinates were converted to NAD88 UTM Zone 17N with the ARC-GIS transform command and grid cells 2 m x 2 m and nearest neighbor resampling. Elevation data was converted to meters by dividing each cell value by 3.2808 ft per meter.

In January 2020, a 0.61 m (2 ft) Parshall Flume was installed in the small creek that originates in the tower footprint. The flume location was chosen to include runoff from as much of the tower footprint as possible and as little as possible from outside the tower footprint. The flume position was established based on surface water observations following heavy rains. Two years of field observation, including two hurricanes and a tropical storm, revealed intermittent flows in locations across the footprint areas. The observed intermittent flows have been mapped as an empirical stream network (Figure 1).

The position of this flume was used as a pour point in ArcGIS 10.6 Hydrology toolbox to create a watershed boundary polygon in each of the three LiDAR DEMs described above. Each DEM was clipped by an Area of Interest (AOI) much larger than the expected watershed boundary and analyzed to produce a flow direction surface. The flume location was then used as a pourpoint to determine the watershed from this flow direction surface. In addition to the flow direction surface and watershed polygon, a flow accumulation surface was determined for each DEM to estimate stream positions.

Finally, the elevation of each FIA style subplot center was determined from the Real-Time Kinemetric (RTK) survey and the 2017 DEM elevation of that point. The DEM was magnified to the point individual grid cells were clearly visible and the INQUIRE tool was used to obtain the DEM value for the subplot center. In this way, the analyst was assured that the center location was not on a grid cell margin. These DEM elevations were compared to the RTK derived elevation. The RTK elevation was corrected for a consistent 24.2 cm positive bias. The RTK benchmark and a second check point were compared to all three DEM elevations of those points and a random error of roughly 9.5 cm was found between the DEM values and the positive 24.2 cm RTK bias seen in all three.

Results

The most important data produced by the comparison is shown in Figure 2 and Table 1. The calculated watershed boundary differed by 68% between the three DEMs. The largest watershed was determined using the 2003 DEM (Figure 2a). A characteristic of this DEM was many apparent mounds that were near 6 m in elevation, appearing bright red on the DEM. The watershed boundary surrounds many of these red areas in the northeast and southwest where the calculated boundary and the empirical boundary differ most widely. In contrast to the 2003 DEM, the 2009 DEM (Figure 2b) has fewer of these apparent mounds, and the color stretch results in a red shift of the entire AOI such that the shift from orange to red on this DEM represent roughly 4.5 m instead of 5 m as in Figure 2a and 2c. The calculated watershed area with the 2009 DEM is the minimum of the three calculated boundaries. The watershed boundary calculated from the 2017 DEM (Figure 2c) is like 2003 in that it has an excursion to the southwest of the empirical boundary. Although the southwest extension occurs in both the 2003 and the 2017 calculated boundaries, they do not agree. The extension on the 2017 DEM watershed is well to the west of the one in the 2003 DEM watershed.

All three calculated watersheds are similar in the northern section of the AOI where there is more relief and soils are better drained. All three have an extension to the northwest along the forest road that is prominent in Figure 1. It appears this is indeed a portion of the watershed that was not correctly included in the empirical watershed.

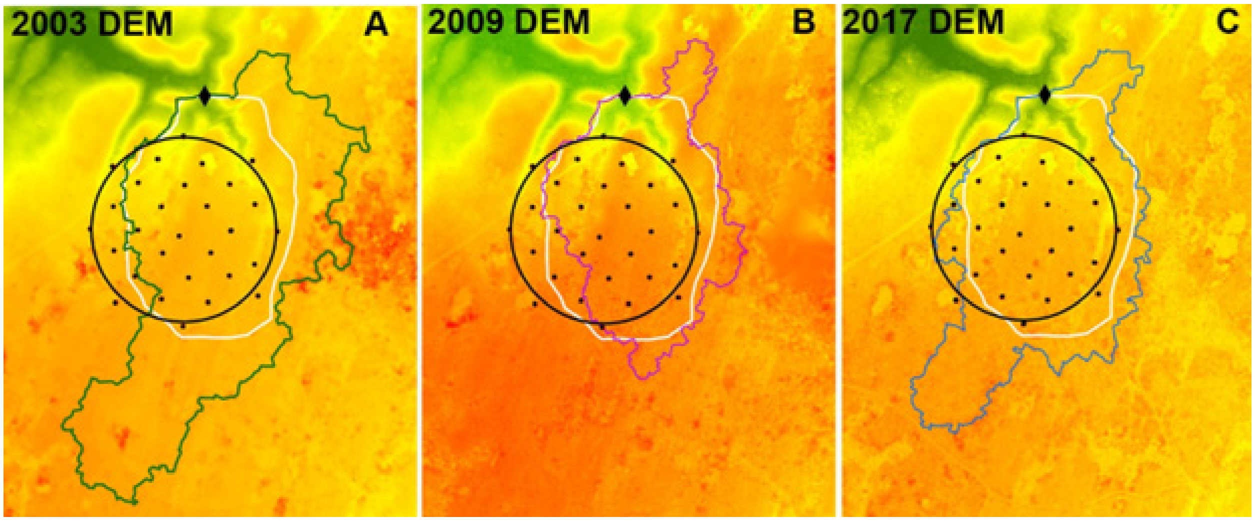

Figure 2. Watershed boundaries determined with the ArcGIS Hydrology toolkit using DEMs for 2003 - a, 2009 - b, and 2017 – c. Flume location, tower footprint and wells are as in Figure 1. The empirical watershed is outlined in white. DEM stretched colors approximately green 1-2 m, yellow 2-3 m, orange 3-4 m, red 5-6 m. The 2009 DEM AOI had slightly smaller range, so colors are shifted slightly redder.

Source	Area (ha)	Depth of water equivalent to 10,000 m^3 of flow at flume (mm)
NOAA 2003 LiDAR	30.2	33
County 2009 LiDAR	17.6	57
County 2017 LiDAR	23.9	42
Field manual estimate	15.9	63

Table 1. Comparison of the three automated watershed boundaries from various LiDAR DEM sources and manual field observations.

South of that extension the empirical, the 2009 DEM, and the 2017 DEM watershed boundaries agree. That section of the boundary is a smaller forest road (with no ditches) that we have not seen water cross. All three DEM-derived boundaries show an area east of the small road. There are several apparent mounds on the east side of the road that determine the DEM-derived boundaries.

It is obvious that the DEM-derived watershed boundaries differ quite widely and consequently have very different implications for estimation of runoff from the tower footprint. Since the tower footprint and the watershed are not coincident, any comparison of ET and runoff will depend on an accurate per unit area estimate. Per unit area volume is most often referred to as a depth (e.g., mm) which is comparable to areal rainfall estimates. Table 1 illustrates the problem that differences in watershed boundaries cause. Flow through the flume is measured in cubic meters and converted

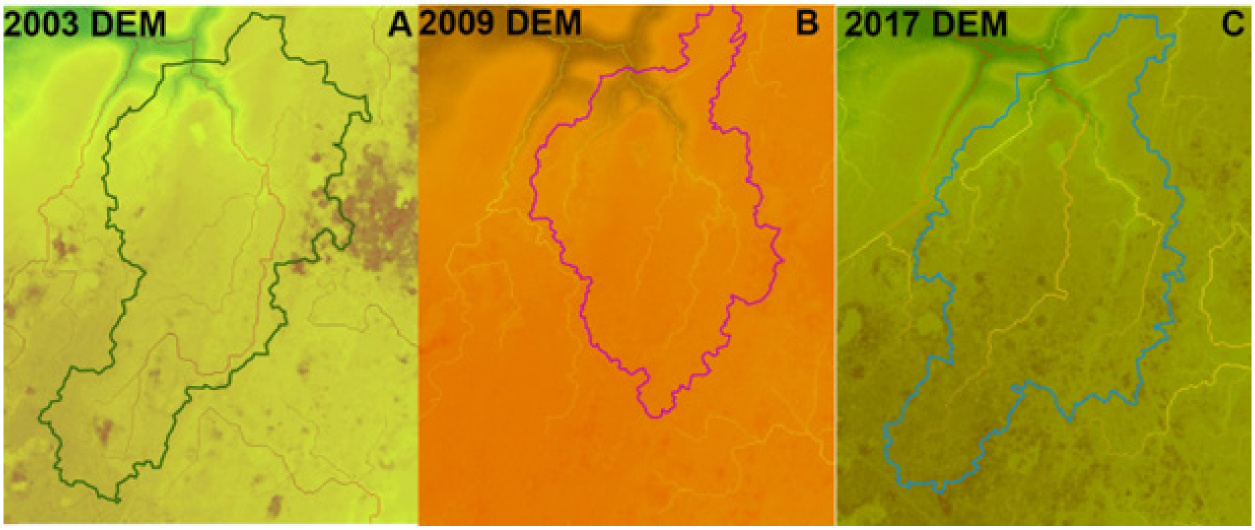

Figure 3. Overlay of flow accumulation surfaces on each DEM. Areas of accumulation (streams) are marked by thin red lines in Figure 3a and yellow in Figure 3b and 3c.

to mm over the watershed area. In Table 1 we see the variation in the estimated mm of runoff for each derived watershed. It is obvious estimates of runoff are not sufficiently precise to be useful for the large ET experiment.

The connection of the apparent mounds and the differing watershed boundaries can be further understood by examining the flow accumulation surfaces associated with each DEM. In Figure 3, the flow accumulation surfaces are transparently overlain on the appropriate DEM and potential streams are shown in a contrasting color. Comparison of these predicted streams to those observed in Figure 1 reinforce the conclusion the DEM-derived watersheds are not likely to be correct. On both Figure 3a and 3c, the most dominant predicted stream across the watershed has never been observed. These predicted streams originate among the apparent mounds in the southwest and wind their way to the main channel that is well predicted in the northern section of all three figures. Variations in the number and position of these apparent mounds become very important in the upper portion of the watershed where landscape gradients are least. Where the landscape is nearly flat, a one-meter change in microtopography may induce slopes over a large distance during the depression filling process. If the mound is not real topography but an artifact of the LiDAR collection or DEM construction, then the resultant watershed can be erroneous.

Vegetation density has been shown to be a problem for LiDAR DEMs in salt marshes as marshes have small topographic relief and low (< 2 m) dense vegetation that is difficult to distinguish from true last returns (Wang et al., 2009). Understory vegetation may also produce the same problems on low gradient forested watersheds. We examined the role of understory vegetation utilizing the FIA style vegetation plots that were installed as part of the tower study (Figure 4). At the center of each subplot a 5 m radius understory plot measured species, height, and percent cover of all understory plants. These were

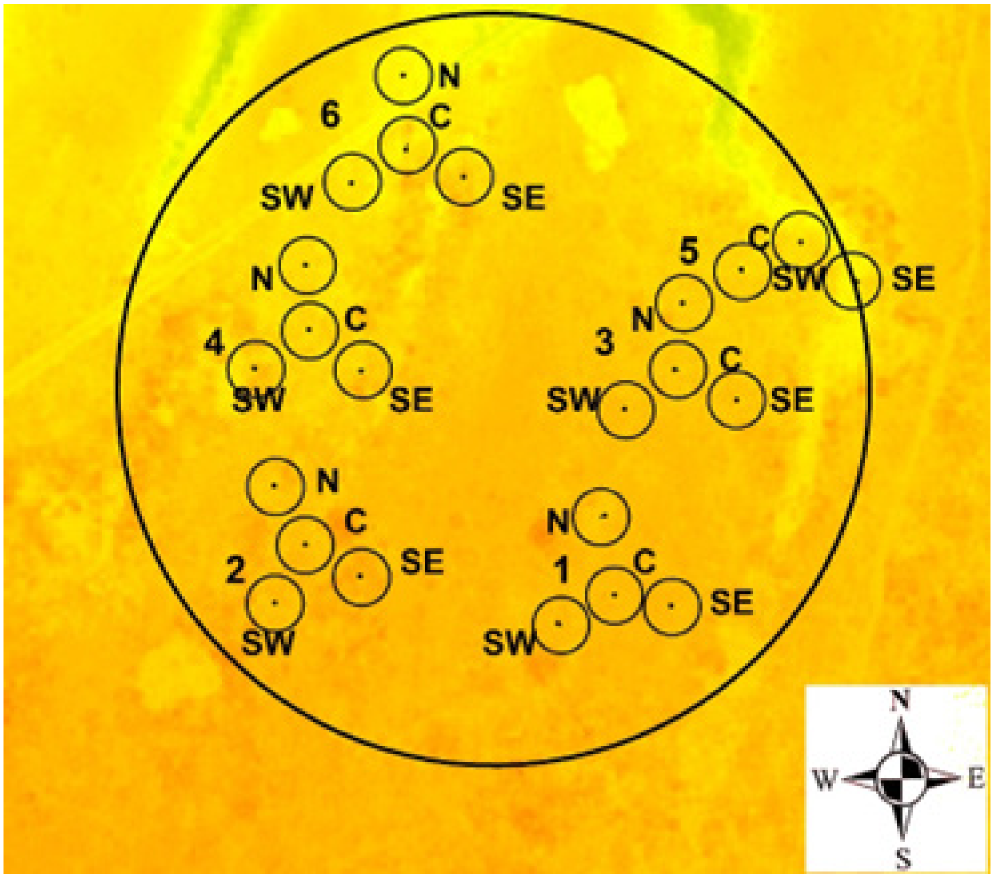

Figure 4. Location of FIA style plots in tower footprint (400 m diameter circle) and relation of plots to 2017 DEM elevations (elevation ranges same as Figure 2).

stratified into 0-0.5 m, 0.5 -1.0 m and 1.0-2.0 m subsamples. Dual-channel RTK surveys located X,Y coordinates on 23 points with Z at 22 points. As discussed in methods, these surveys were less accurate than normally associated with professional RTK surveys, but produced an elevation estimate comparable to the 2017 LiDAR DEM ± approximately 20 cm.

Each subplot is listed in Table 2 with “DEM elevation - RTK elevation” noted as DEM errors. Of the 22 subplots, where error could be calculated, 6 subplots had an error greater than 20 cm. The prevalence of vegetation induced DEM errors was quite high on this stand, which had not been prescribed burned for ten years. The data were very clear that the most important species causing errors in the DEM was *Lyonia lucida* (fetterbush). In five of the six subplots *Lyonia lucida* had at least 60% crown cover in the 1-2 m height class. Only in one plot was *Ilex glabra* (inkberry-gallberry), another evergreen shrub, the dominant species.

Discussion

The data from the understory analysis shows a clear relationship between the density

Table 2. Correspondence of DEM height error and plant species abundance in FIA style subplots. Note understory percent cover was estimated at three levels (0-0.5, 0.5-1, 1-2 m) so the total cover exceeded 100%. At each height species were ranked by percent cover.

Plot	Error (cm)	Understory cover (%)	Top genus-species cover	1-2 m (%)	Top genus-species cover	0.5-1 m (%)
1n	-19.5	131.5	*Ilex glabra*	20	*Ilex glabra*	20
1c	-1.5	109	*Ilex glabra*	30	*Ilex glabra*	25
1sw	14.5	161	*Ilex cassine*	25	*Ilex cassine*	27
1se	-2.5	165	*Ilex glabra*	40	*Vaccinium corymbosum*	30
2n	27.5	160	*Lyonia lucida*	18	*Lyonia lucida*	19
2c	7.5	171	*Liquidambar styraciflua*	25	*Vaccinium corymbosum*	31
2sw	31.5	269	*Ilex glabra*	45	*Vaccinium corymbosum*	40
2se	70.5	167	*Lyonia lucida*	63	*Lyonia lucida*	21
3n		188	*Liquidambar styraciflua*	10	*Vaccinium corymbosum*	75
3c	-7.5	133	*Vaccinium corymbosum*	30	*Vaccinium corymbosum*	20
3sw	-3.5	180	*Ilex glabra*	20	*Vaccinium corymbosum*	50
3se	8.5	202	*Liquidambar styraciflua*	30	*Vaccinium corymbosum*	40
4n	11.5	162	*Ilex glabra*	30	*Vaccinium corymbosum*	31
4c	4.5	203	*Liquidambar styraciflua*	35	*Vaccinium corymbosum*	45
4sw	57.5	138	*Lyonia lucida*	90	*Lyonia lucida*	30
4se	18.5	154	*Vaccinium corymbosum*	23	*Vaccinium corymbosum*	14
5n		108	*Vaccinium corymbosum*	10	*Vaccinium corymbosum*	21
5c	0.5	109	*Lyonia lucida*	11.5	*Vaccinium corymbosum*	21
5sw	-3.5	120	*Ilex glabra*	10	*Ilex glabra*	17
5se	6.5	60	*Lyonia lucida*	7	*Lyonia lucida*	7
6n	-6.5	107	*Liquidambar styraciflua*	12	*Liquidambar styraciflua*	12
6c	32.5	79	*Lyonia lucida*	40	*Lyonia lucida*	10
6sw	-0.5	210	*Persea borbonia*	26	*Ilex glabra*	23
6se	111.5	141	*Lyonia lucida*	65	*Lyonia lucida*	15

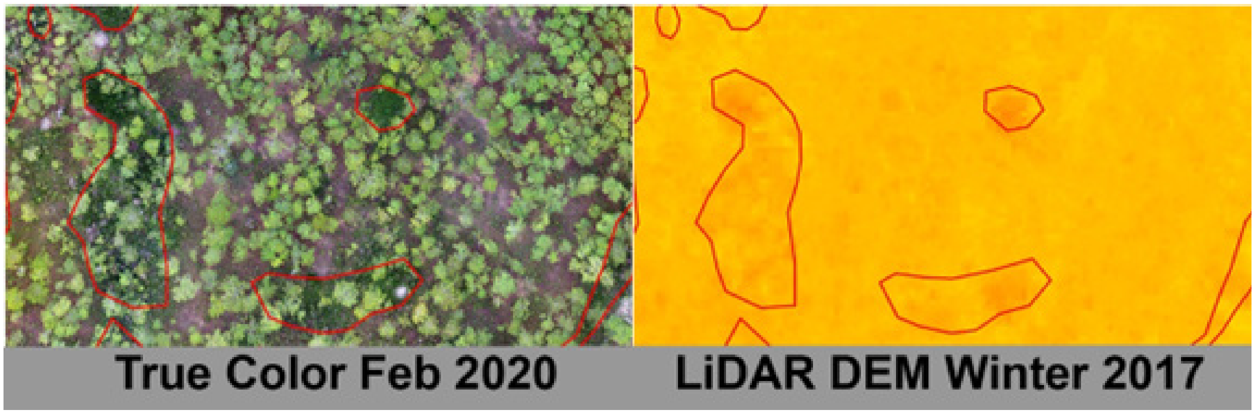

Figure 5. Example digitized areas of thick evergreen shrubs on a winter high resolution color orthomosaic and transfer of those polygons to LiDAR DEM to recognized apparent mounds that impair correct interpretation of watershed boundaries.

of tall (0.5-2 m) evergreen shrubs and DEM errors. Cover densities of 60-90% by evergreen shrub vegetation appear to be the cause of apparent mounds in the DEMs that resulted in variation in the position of the watershed boundary. We have been examining the tower footprint with high resolution UAV based aerial photography since May of 2019 (Williams et al., 2019). A mission on February 27, 2020, was used to create an orthomosaic covering the footprint area on that date. The presence of thick evergreen shrubs was easily seen on this orthomosaic and areas of the vegetation could be easily digitized as unique polygons (Figure 5). The digitized polygons can then be easily transferred to the DEM and be used as boundaries to edit the errors from the DEM.

Since the presence of thick evergreen shrubs was closely related to DEM errors, a possible cause of the vast differences in LiDAR data may have been related to prescribed burning history. This stand was burned on a 5-year schedule until 1989 when Hurricane Hugo greatly reduced timber inventory and revenue to fund management activities. Prescribed burning was limited in the late 1990's, resumed in the mid-2000's, was curtailed following the financial crisis of 2008 and resumed with the aid of the Nature Conservancy in the last few years. Hence, the stand had not been burned for nearly 10 years in 2003, had been burned prior to 2009, but was not burned again until 2021. The relation of burning and DEM errors could be a subject for further research.

Findings of this paper have created a significant problem for the tower research project. We have no objective estimate of the watershed area measured by the flume and no firm estimate of runoff based on an association with the evapotranspiration levels estimated by the tower. High resolution photography may allow identification of DEM errors but not an estimate of the true ground elevation. We need an objective way to estimate the elevation of the identified polygons. At present, the best options are simple interpolation from the edges of each polygon. Field profile leveling might also be needed if the dense vegetation hides depressional areas. *Lyonia lucida* often occurs in and around depressions so that a simple interpolation may not reveal the true elevation.

The project will require more research efforts to identify a correct DEM and watershed boundary.

Conclusion

The ArcGIS Hydrology toolkit has become an accepted method for the standardized definition of research watersheds. When combined with LiDAR supported DEMs this method can accurately define surface watersheds. However, on low relief, low gradient watersheds, as found on the lower Atlantic Coastal Plain, LiDAR-based DEMs are subject to artifacts caused by dense evergreen shrubs. We used three DEMs that were based on LiDAR missions in 2003, 2009, and 2017 to calculate the watershed associated with a flume on a small forest stream. Variation of anomalies caused by vegetation changes resulted in spatial differences in the watershed boundary of several hundred meters and variation in modelled watershed size from 17.9 to 30.2 ha. On Lower Coastal Plain forested watersheds, the DEM may need to be modified to eliminate the anomalies caused by thick evergreen shrubs before an accurate watershed boundary can be determined.

References

Amatya D., C. Trettin, S. Panda, and H. Ssegane. 2013. Application of LiDAR data for hydrologic assessments of low gradient watershed drainage characteristics. Journal of Geographic Information System. 5: 175-191.

Bren, L. 2016. An introduction to Forest hydrology. In Forest Hydrology: Processes, Management, and Assessments. 1-6, D.M. Amatya, T.M. Williams, L. Bren, and C. de Jong, eds. Oxfordshire, UK: CABI.

Colquhoun, D.J. 1974. Cyclic surficial stratigraphic units of the Middle and Lower Coastal Plain, central South Carolina. In: Post-Miocene Stratigraphy, Central and Southern Atlantic Coastal Plain, 179-190. J.R. Dubar, R.Q. Oaks, eds. Logan, UT: Utah State University Press.

Forsythe, J.D., T.L. O'Halloran, and M.A. Kline. 2020. An eddy covariance mesonet for measuring greenhouse gas fluxes in coastal South Carolina. Data. 5: 97.

Heine, R.A., C.L. Lant, and R.R. Sengupta. 2004. Development and comparison of approaches for automated mapping of stream channel networks. Annals of the Association of American Geographers. 94: 477–490.

Hellweger, F.L., and D.R. Maidment. 1999. Definition and connection of hydrologic elements using geographic data. Journal of Hydrologic Engineering. 4: 10-18.

James, L.A., D.G. Watson, and W.F. Hansen. 2007. Using LiDAR data to map gullies and headwater streams under forest canopy: South Carolina, USA. Catena. 71: 132-

144.

Jensen, S.K. 1991. Applications of hydrologic information automatically extracted from digital elevation models. Hydrologic Processes. 5: 31-44.

National Oceanic and Atmospheric Administration 2019. National Oceanic and Atmospheric Administration, National Geodetic Survey, Online Positioning User System. Available at: https://geodesy.noaa.gov/OPUS/ Accessed 20 July 2019.

Olivera, F., S. Reed, and D. Maidment. 1998. HEC-PrePro v.2.0: An ArcView pre-processor for HEC-Hydrologic Modeling System. Proceedings of the 18th ESRI User Conference. San Diego, CA: Esri.

Rosbjerg, D., and J. Rodda. 2019. IAHS: A brief history of hydrology. History of Geo- and Space Sciences. 10: 109–118.

South Carolina Department of Natural Resources. 2019. LiDAR status by County. Available at: http://www.dnr.sc.gov/GIS/lidarstatus.html. Accessed 29 November 2019.

Wang, C., M. Menenti, M.-P. Stoll, A. Feola, E. Belluco, and M. Marani. 2009. Separation of ground and low vegetation signatures in LiDAR measurements of salt-marsh environments. IEEE Transactions on Geoscience and Remote Sensing. 47: 2014-2023.

Williams, T.M., and D.J. Lispcomb. 1984. A logging history of Hobcaw Forest. Note 38. Clemson Forestry.

Williams, T.M., T.L. O'Halloran, B. Song, J.D. Forsythe, and B.J. Williams. 2020. Evaluating high water table hydrology and eddy covariance measurements of evapotranspiration at a newly instrumented watershed in coastal South Carolina. In Proceedings 7th Interagency Conference on Research in the Watersheds. Tifton, GA: USDA-Agricultural Research Service. pp. 47.

Williams, T.M., B.J. Williams, B. Song, J. Forsythe, and T.L. O'Halloran. 2019. Mapping natural forest stands with low-cost drones. In Proceedings of the 12th Southern Forestry and Natural Resource Management GIS Conference, Merry, K., P. Bettinger, M. Crosby, I-K. Hung, T. Lee, R. Lowe, Q. Meng, J. Siry, and B. Song, eds. Athens, GA: Warnell School of Forestry and Natural Resources. pp. 135-146.

Young, C.E. 1965. Precipitation-runoff relations on small forested watersheds in the Coastal Plain, Study Plan Addendum No. 2, Technical Report FS-SE-1602. U.S. Department of Agriculture, Forest Service.

Keynote Address Abstracts

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar, and J. Uzu, eds. 2022. pp. 55.

Keynote Address Abstract

Navigating the maze of GIS tools and solutions: Discovering, evaluating, and selecting GIS solutions that meet management needs, real or anticipated

Elizabeth Martinez
The Forestland Group, LLC.
Chapel Hill, NC, 27514, elizabeth@forestlandgroup.com

Abstract

The Forestland Group (TFG) is the largest private owner of hardwood timberlands in the United States. The company manages over 2 million acres of timberlands in the United States and Latin America. The complex requirements of managing naturally regenerating hardwoods puts unique pressures on selecting the best tools to get the job done.

Over the 24+ years that I have worked at TFG there have been huge changes in technology, GIS software, and data availability. There are new analysis capabilities and new workflows. More data and tools are great, but it also means more complexity. How to decide on next steps?

This will be a general overview of GIS for TIMO purposes

- Opportunities - High resolution satellite imagery, ArcGIS organization accounts, field apps, drones, LiDAR, availability of improved sources of data, etc.
- Challenges – cost, changes in workflows, resistance to change, overcoming doubts, sorting out analyses and interpreting data, etc.

Important as the development of GIS technology and forestry is for our work, it is also critical that the forestry community share ideas and solutions to advance the science of forest management.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 56.

Keynote Address Abstract

Land asset management: Where are we now?

Clarence Neese
Orbis, Inc.
Charlotte, NC, 28273, cneese@orbisinc.com

Abstract

From the early days when GIS was still a concept, to modern day where the technology is now unmistakably a part of our day-to-day operations, GIS has been an integral part of molding the land asset management industry. From community statistics to environmental data, we are now able to communicate and share visual representations of what you can only see on a map, as well as the important details that you can't. As the land management industry shifts and adapts to the needs of the 21st century, we will continue to build solutions that assist in navigating this ever-changing landscape.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 57.

Keynote Address Abstract

Carbon: Connecting the dots between measurements, management, and markets

Max Nova
NCX
San Francisco, CA, 94115, max@ncx.com

Abstract

Corporate net-zero pledges have stimulated demand for forest carbon credits, but there are many complicated steps between growing a tree and selling certified carbon credits to a big company. In this talk, NCX founder Max Nova will outline the forest carbon value chain and identify the points at which forest managers and GIS technology play key roles. Max will discuss the carbon accounting mechanics behind some of the recent forest carbon controversies and the role that remote sensing can play in improving the quality and scalability of forest carbon markets.

Presentation Abstracts

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 59.

Presentation Abstract

Applicability of smartphone sensor-based applications for forest measurements

Angel Adhikari
Warnell School of Forestry and Natural Resources, University of Georgia
Athens, GA, 30602, Angel.Adhikari@uga.edu

Alicia Peduzzi
Warnell School of Forestry and Natural Resources, University of Georgia
Athens, GA, 30602

Cristian Montes
Warnell School of Forestry and Natural Resources, University of Georgia
Athens, GA, 30602

Sagar Godar
Warnell School of Forestry and Natural Resources, University of Georgia
Athens, GA, 30602

Katrina Henn
Warnell School of Forestry and Natural Resources, University of Georgia
Athens, GA, 30602

Abstract

Forest measurement is key to characterize forest attributes providing the quantitative information about trees and forest stands necessary for forest management, planning and research. Tree diameter and height are the fundamental metrics of forest measurement. The conventional way of measuring them is resource intensive and prone to errors depending on skilled personnel. Current advancement in smartphone-based sensors and its accessibility has opened a new avenue for its applicability in forestry sector for both data recording and geographic positioning. For instance, recent smartphones are equipped with distance and angle measuring sensors similar to the sensors used in the Vertex clinometer, one of the most advanced distance and tree height measuring instruments.

Besides geographic positioning and angle measuring sensors, Apple Inc. introduced a LiDAR sensor in its latest smartphone iPhone 12 Pro and iPad Pro. LiDAR is an

acronym for Light Detection and Ranging, which is an active remote sensing technology popular for creating a three-dimensional map of the surrounding environment. The LiDAR in the iPhone range is approximately 5 m and has the capability of emitting up to 10,000 laser pulses per second, which makes it a promising tool to use for tree diameter measurement and surface modelling. Furthermore, newer smartphone applications such as Arboreal Forest allow direct measurement of tree heigh, diameter, distance, and raw data recording, which can be downloaded in files of open format. Therefore, applicability of smartphone sensors and applications for forest measurement seems promising but is yet to be uncovered. This study specifically aims to explore how smartphone sensors-based methods and applications can be incorporated for forest measurement.

For this study, 150 trees of both coniferous and broadleaf from three different age groups – young, middle aged and mature – will be selected applying systematic sampling from the forest stands at University of Georgia Whitehall Forest in Athens. Trees with a DBH >10 cm will be considered for diameter and height measurement using both, Arboreal Forest application and traditional forest inventory tools, such as diameter tape and the Vertex clinometer. The measured height and diameter with both methods will be compared using statistical methods such as a Tukey test to evaluate differences per tree for each of the age groups. Furthermore, this research will explore the capability and precision of smartphone sensors for supporting forest inventories at the local level, specifically contributing to existing forest measurement methods by providing easier and low-cost spatial and biometric data collection methods.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 61.

Presentation Abstract

Why did the elephant cross the Zambezi?

Molly Azami
Center for Geospatial Research, University of Georgia
Athens, GA, 30602, meazami@uga.edu

Marguerite Madden
Center for Geospatial Research, University of Georgia
Athens, GA, 30602

Andrea Presotto
Geography and Geosciences, University of Salisbury
Salisbury, MD, 21801

Malvern Karidozo
Connected Conservation
Victoria Falls, Zimbabwe

Ferrell Osborn
Connected Conservation
Victoria Falls, Zimbabwe

William Langbauer
Biologica Sciences, Bridgewater State University
Bridgewater, MA, 02325

Abstract

The northern border of Zimbabwe is the centerline of the Zambezi River. On the other side of the border is Zambia. A group of researchers studying human-elephant conflict in and around the town of Victoria Falls, is interested in understanding why, when and where elephants cross the Zambezi River. Researchers from the University of Georgia, Salisbury University, and Bridgewater State University in the U.S. are collaborating with scientists from Connected Conservation and the Victoria Falls Wildlife Trust located in Zimbabwe to tag 15 bull African elephants with GPS collars. All the tagged elephants were identified as problem animals engaging in breaking fences, crop raiding, and threatening local residents. Although the bulls primarily live, roam and forage in

Zimbabwe, many of them do cross the river and the border into Zambia. There is a designated cooperative conservation area that includes the length of this border that is upstream of the world-famous Victory Falls. This conservation area is called the Kavango Zambezi Transfrontier Conservation Area or KAZA for short. While the conservation efforts are cooperative, there are still complications and policy issues that arise when a Zimbabwean elephant is involved in a human-wildlife conflict incident in Zambia. This is one reason for which it is important to understand the drivers of elephant cross-border activity and the spatial-temporal patterns of bull movement in and around the Zambezi River. Having this information would also be critical for planned development of lodges, restaurant, and tourist attractions along the Zambezi so that human-elephant conflict can be minimized.

This research analyzes the environmental variables of terrain (elevation & slope variations), land cover, precipitation, and wet/dry seasons, along with human activity, to determine what factors attract these bull elephants to the river, the riverbanks, and the islands in the river. Using the GPS data collected every hour from the collars and turning the point locations into tracks using a combination of Python and ArcGIS Pro tools, geospatial overlay analyses indicate a strong influence of predicted river crossing location is the slope of the land and ruggedness of the terrain. The tracks of the bulls show that they typically cross from Zimbabwe to Zambia via corridors between hills, to then wander in and out of the river on the Zambian side which has a gentler slope into the river. There are also several islands that are frequently visited, but only from the Zambian side. A 2016 land cover data set created by the World Wildlife Fund using European Space Agency's Sentinel-2 A/B Multispectral Instrument (MSI) 10 m satellite imagery designates these island areas as woodland and low shrub cover interspersed with graminoid wetlands. Confirmation of specific vegetation that may be attracting these elephants in different seasons will be conducted by field researchers on the ground. Human impact is also expected to be a driver for the bull movement patterns across and along the river, including tourist activities related to Victoria Falls, hotels and restaurants along the river and fences that attempt to prevent them from wandering into agricultural fields and destroying crops and irrigation equipment. It is hoped that our models of bull movements in and around the Zambezi River will assist decision makers, minimize conflict while giving the bulls viable optional paths and answer the question, "Why did the elephant cross the Zambezi?"

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 63.

Presentation Abstract

ArcGIS Field Maps

Grace Beatty
Orbis, Inc.
Charlotte, NC, 28273, gbeatty@orbisinc.com

Abstract

Based in Charlotte, NC, Orbis, Inc. provides technology-focused solutions for the timberland, forestry and land management industries. Orbis' diverse service offerings include:

- GIS solutions and mapping
- Recreational lease management
- Data management & cloud-based applications
- Property tax management
- Technology consultation
- Custom application development
- E-commerce solutions

Staffed with subject matter experts, our team assists and partners with the nation's leading landowners and asset managers to unlock everything you can see on a map, in addition to everything you can't. We help clients navigate digital transformation, implement best practices and solve problems that are specific to the industry.

Orbis is well-known for developing and continuously improving benchmark, game-changing solutions that have been in place for over 20 years. In the process of migrating clients to ArcGIS Online, we not only provide data management solutions, but we also guide and equip clients with digital tools that they can apply in the field.

Using ArcGIS Field Maps, we enable clients to create simple field applications that help improve data workflow and maintenance. Because the solutions are cloud-based, this allows for more interaction, communication, and productivity in the fields and across organizations.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 64.

Presentation Abstract

A strategy for forest inventory automation in a forestry consulting company

Mike Berzinis
Southern Forestry Consultants
Charlotte, NC, 28226, mberzinis@soforest.com

Thurston (Trip) L. Chavis, III
Milliken Forestry Company, Inc.
Columbia, SC, 29210

Abstract

Forestry information demands are increasing, and markets are changing, making automation and real time answers a business imperative. Mobile ready and web-based cloud computing platforms offer an innovation path for forestry companies with minimal infrastructure to invest in. However, until recent years, there have been few forestry specific technologies which are architected to bring the power of the commercial cloud home to foresters.

Today we discuss how Milliken Forestry Company is adopting the Prism forest inventory solution to automate and simplify its operations. The adoption of Prism as a cloud-based Software as a Service (SaaS) aligns with Milliken's strategy to grow and thrive on a foundation of modern cloud computing tech like Intuit's Quickbase and Esri's Web GIS.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 65.

Presentation Abstract

Assessing urban forests and suitability of bioswales at Redstone Arsenal

Cameron Boland
School of Forestry & Wildlife Sciences, Auburn University
Auburn, AL, 36849, cjb0089@auburn.edu

Lana Narine
School of Forestry & Wildlife Sciences, Auburn University
Auburn, AL, 36849

Adam Maggard
School of Forestry & Wildlife Sciences, Auburn University
Auburn, AL, 36849

Rebecca Barlow
School of Forestry & Wildlife Sciences, Auburn University
Auburn, AL, 36849

John Kush
School of Forestry & Wildlife Sciences, Auburn University
Auburn, AL, 36849

Abstract

Redstone Arsenal (RSA), located in Huntsville, Alabama, is a military installation that practices land management while promoting sustainability. For this project, an urban forest inventory is being conducted to analyze potential tree risk and overall urban tree conditions. To improve urban tree zones, geospatial data, such as soil hydrologic groups and runoff rates will be analyzed alongside the inventory. Additionally, the implementation of bioswales can improve urban tree areas at RSA by assisting in soil infiltration and decreasing runoff. The overall objectives of this project are to analyze cost-benefit components of an urban forest inventory at RSA through i-Tree Eco and determine placement of bioswales across the installation using ArcGIS Pro and i-Tree Hydro. Using i-Tree Canopy, randomized tenth acre urban plots will be created within urban priority areas across RSA. Random samples of street segments will be generated in ArcGIS Pro for i-Tree Streets. Ground inventory data will be collected by taking tree measurements such as diameter at breast height (DBH), height, crown width, and crown height, and conducting ISA tree assessments. Urban trees within the plots will have

locations marked using a GPS unit. The ground inventory data will be analyzed in conjunction with publicly available geospatial data, such as, soil and runoff data obtained from the Soil Survey Geographic database (SSURGO). Hydrological impacts will be analyzed using i-Tree Hydro to examine urban tree cover and impervious surfaces to determine suitable placement of bioswales. The output will be a map of RSA containing the urban forest inventory data, soil hydrologic, and runoff rate data to determine urban zones that can benefit from the addition of bioswales.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 67.

Presentation Abstract

Forest health monitoring in the 21st century: Technology and applications

Anthony Elledge
U.S. Department of Agriculture, Forest Service
Asheville, NC, 28804, anthony.elledge@usda.gov

Chris Asaro
U.S. Department of Agriculture, Forest Service
Asheville, NC, 28804

Abstract

The U.S. Forest Service division of Forest Health Protection works with state and federal partners to collect spatially-explicit data on forest disturbances by insects and diseases in association with abiotic factors such as storms, drought, and climate change. Data collection has historically been a combination of ground-survey and aerial survey using small, fixed-wing aircraft. Over the last ten years, remote sensing technology, GIS, and new software apps have revolutionized the way this data can be collected, processed, and analyzed. The constantly shifting technology landscape has presented challenges in terms of national consistency of data collection and reporting, but has also presented opportunities to collect more data on a greater variety of disturbance agents than ever before.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 68.

Presentation Abstract

ArcGIS Online for forest management consultants

Joel Feltman
Orbis, Inc.
Charlotte, NC, 28273, jfeltman@orbisinc.com

Abstract

Based in Charlotte, NC, Orbis, Inc. provides technology-focused solutions for the timberland, forestry and land management industries. Orbis' diverse service offerings include:

- GIS solutions and mapping
- Recreational lease management
- Data management & cloud-based applications
- Property tax management
- Technology consultation
- Custom application development
- E-commerce solutions

Staffed with subject matter experts, our team assists and partners with the nation's leading landowners and asset managers to unlock everything you can see on a map, in addition to everything you can't. We help clients navigate digital transformation, implement best practices and solve problems that are specific to the industry.

Orbis is well-known for developing and continuously improving benchmark, game-changing solutions that have been in place for over 20 years. One example of this is assisting clients with ArcGIS Online migration using GIS-powered forest management solutions.

Orbis works with forest management consultants to assess and identity project and data needs. Based on our findings, we then work to migrate and implement data into digital, secure and sharable spaces. With our team of industry experts combined with Esri's online platforms, forest management clients are getting custom-built solutions thatprovide an architectural strategy and road map for their businesses.

One of these proprietary solutions is LITAS, a GIS-powered land transaction due diligence service. By analyzing historical data, applying GIS mapping technology and

flagging discrepancies, LITAS helps prevent costly errors and maximizes ROI. The service gives landowners, managers, and attorneys total visibility into their transactions and properties.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar, and J. Uzu, eds. 2022. pp. 70.

Presentation Abstract

Using Esri technology for forest inventory: Providing scalable, affordable, Android and cloud-based solutions

Kerry Halligan
Mason, Bruce & Girard, Inc.
Portland, OR, 97205

Darian Yawn
LandMark Spatial Solutions, LLC.
Starkville, MS, 39759

Mark Books
LandMark Spatial Solutions, LLC.
Starkville, MS, 39759, mbooks@lmssmail.com

Abstract

In this presentation MB&G and LandMark Spatial Solutions will present their combined approach to a modern, efficient, scalable solution for timber inventory data collection, processing, and management. They will discuss and demonstrate how their integrated (Esri, cloud, Android, TCruise-based) solutions are helping foresters across the United States be more accurate and efficient in the field and office.

Advantages of this solution include: 1) easily collaborate with colleagues and contractors including near real time cruise status updates, 2) tight integration with Esri's solutions including ArcGIS Dashboards, 3) secure scalable solutions that eliminates data silos, 4) modern workflow, no cables or emails required, 5) highly configurable solutions supports custom cruise specs and integrations e.g., TCruise, FVS, Trimble, 6) supports wide range of ruggedized Android devices for extended battery life, featuring high quality GPS data collection and robust data backup via SD card, 7) seasoned solution refined over a decade by feedback from over 1,000 foresters, 8) cost effective solution that leverage existing software license and skills, 9) industry leading in-person and online support system.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 71.

Presentation Abstract

Improving wildlife management decisions together - GADNR and F4 Tech

Craig Hedman
F4 Tech
Tallahassee, FL, 32301, CHedman@thinkf4.com

Matt Payne
Georgia Department of Natural Resources
Social Circle, GA, 30025

Abstract

The Georgia Department of Natural Resources - Division of Wildlife (GADNR) owns and manages 73 fee simple Wildlife Management Areas (WMAs) throughout Georgia totaling approximately 467,103 acres. Sustainable management is fundamental to GADNR practices particularly as it relates to wildlife habitat, wildlife populations, and timber-based revenue.GADNR has recognized that additional data and information on current habitat conditions will help inform resource allocations, the siting of habitat restoration projects, and management precision.

Since 2017, F4 Tech has worked with GADNR on natural resource management projects focused on forest/vegetation data collection, analysis, and modeling that directly support strategic planning, tactical planning, and operational decision making. An underlying reason for this multi-part project is that GADNR is responsible for sustainably managing wildlife habitat and wildlife populations across the State while meeting a revenue goal each year.

This joint presentation will focus on the improvements made in supporting decision making, enhancing continuous improvement and reinforcing the Department's overall mission using a mix of the latest technology tools along with well-established protocols for resource planning.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar, and J. Uzu, eds. 2022. pp. 72.

Presentation Abstract

Robotic forest inventory

Elizabeth Hunter
Treeswift
Philadelphia, PA, 19146, elizabeth@treeswift.com

Abstract

Treeswift builds robots and algorithms to collect, produce, and manage complex forest data. Using uniquely customized unmanned aerial vehicles (UAVs) built especially for forestry, and analytics relying on artificial intelligence, we translate structurally complex measurements into key metrics used by our clients to make land management decisions. In this talk, we will discuss Treeswift's robotic forest inventory and mapping system and present results from using this system in the US Southeast. Treeswift developed the first of its kind under-canopy intelligent, autonomous UAV equipped with a suite of high-resolution sensors. By flying under the canopy, we capture data that was previously impossible to collect and push it through our analytics pipeline to detect and extract individual per-tree metrics. Treeswift strives to offer an unparalleled technological solution which is accurate, efficient, and scalable for forest landowners and to provide actionable data on every tree.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 73.

Presentation Abstract

The effects of nearby trees on GPS accuracy in forest environment

Taeyoon Lee
Warnell School of Forestry and Natural Resources, University of Georgia
Athens, GA, 30602, taeyoon.lee@uga.edu

Pete Bettinger
Warnell School of Forestry and Natural Resources, University of Georgia
Athens, GA, 30602

Abstract

Thanks to recent developments of GPS technologies, different types of GPS receivers have started to be applied in various fields for research purposes. These include cell phones, GPS watches, and other small format receivers. As a result, the evaluation of the positional accuracy of these GPS receivers has garnered attention, as the positional accuracy can have important consequences for research analyses that rely on positional information. Indeed, there have been many attempts to evaluate GPS receiver positional accuracy in forest conditions. Although few studies have focused on the correlation with accuracy and environmental conditions, including temperature, humidity, and atmospheric pressure, there have been a limited number of studies investigating the effects of forest structure around survey points. Therefore, this study was conducted to investigate the effects of nearby trees on positional accuracy of GPS receivers, and to determine whether the errors observed are systematic. This study was conducted at the Whitehall Forest GPS Test Course in Athens, Georgia. A total 26 of control points were precisely determined based on four previously surveyed control points. Three different types of GPS receivers (mapping grade receiver, recreation grade receiver, and smartphone) were utilized to evaluate positional accuracy. The study site was visited twenty times during the leaf-off season to collect positional data. The forest structure measurements included distance and azimuth from each control point to each nearby tree, as well as tree diameter (DBH), the density and basal area of trees around each control point. These measurements are used to analyze the correlation between positional accuracy and forest structure. We anticipate rejecting our null hypothesis that the nearby forest structure does not have a significant effect on positional accuracy.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 74.

Presentation Abstract

Forestry inventory modernization – Successes and lessons learned in North Carolina's transition to an Esri-based solution

John Lovette
North Carolina Wildlife Resources Commission
Raleigh, NC, 27699, john.lovette@ncwildlife.org

Chris Jordan
North Carolina Wildlife Resources Commission
Raleigh, NC, 27699

Casey Phillips
North Carolina Wildlife Resources Commission
Raleigh, NC, 27699

Kerry Halligan
Mason, Bruce, & Girard, Inc.
Portland, OR, 97205

Abstract

North Carolina Wildlife Resources Commission manages over 2 million acres of game lands for the conservation of wildlife species and to provide public access for hunting, fishing, trapping, and other outdoor recreational opportunities. Until recently, the commission had been using a range of desktop GIS and tabular data collection and analysis tools to inventory and manage the forestry resources on these lands. The commission sought an upgraded solution to address several issues, including aging field data collection devices, inefficient and non-standardized data management workflows, and system integration challenges. With Mason, Bruce & Girard, the commission has implemented a system based on the ArcGIS platform to address these issues. Built from the ground up on Esri technology, the MB&G Inventory Management Solution provides an end-to-end inventory system that includes web and mobile applications, as well as seamless integration with ArcGIS Desktop, Dashboards, and key forest information systems such as Forest Vegetation Simulator (FVS) and TCruise. This presentation will cover the process of transitioning to a modern ArcGIS-based inventory management solution, including the benefits, challenges faced, and lessons learned.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 75.

Presentation Abstract

Evaluation of digital surface model derived from digital aerial photogrammetry for operational forest inventory applications in the southeastern USA

Shingo Obata
National Institute for Mathematical and Biological Synthesis, University of Tennessee
Knoxville, TN, 37996, sobata@utk.edu

Todd Schroeder
U.S. Department of Agriculture, Forest Service, Southern Research Station
Knoxville, TN, 37919

Monica Papeş
Department of Ecology and Evolutionary Biology, University of Tennessee
Knoxville, TN, 37996

Abstract

National forest inventories (NFI) report estimates of attributes related to forest area and growing stock volume for the area of interest, such as countries, states, and provinces. NFI is primarily based on field plots data and enhanced by the auxiliary information. The Forest Inventory and Analysis (FIA) program collects tree and stand level data to produce statistical estimates of forest attributes to analyze the current status and condition of the forests in the USA. Although FIA have collected reliable field plots data for years, it cannot estimate the stand level forest attributes since a single plot represents about 2400 ha of land area. To create wall-to-wall estimates of principal forest attributes such as canopy height, Light Detection and Ranging (LiDAR) has been used as auxiliary data. Although LiDAR provides exceptional spatial detail about forest structure, it is expensive to collect for the entire area of interest of NFI. Another type of data available is digital surface models (DSM) derived from point clouds created from digital aerial photogrammetry (DAP). In comparison to LiDAR, DSM costs less but the points acquired are limited to the surface of the landscape.

The objective of this presentation is to validate the accuracy of the canopy height estimated by DSM through the comparison with FIA plots and LiDAR point cloud data. Our study area encompasses the entire Virginia and Tennessee, located in the southeastern USA. The National Agriculture Imagery Program (NAIP) dataset is

selected as the source of DAP, and it is processed to point cloud. LiDAR point clouds are acquired from the 3D Elevation Program managed by the U.S. Geological Survey. DSM is calculated by subtracting the digital elevation model from the elevation of NAIP point cloud. It is expected that the outcome of this research assures the quality of the state-wide canopy height model that can be created at substantially lower cost than the one made from LiDAR.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 77.

Presentation Abstract

Using crowdsourced data for image classification in remote sensing

John Perkins
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849, jdp0023@auburn.edu

Lana Narine
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849

Abstract

iNaturalist is a free mobile application that allows users to contribute to the natural sciences by taking pictures of organisms and uploading them to the application's database. Upon uploading images to the database, geographic and temporal data for the image are recorded using the mobile device's built-in geotagging feature for images. Users can then identify species using iNaturalist's artificial intelligence program and confirm other user's identifications through the application's social networking function. Once an identification receives a consensus from the online community on iNaturalist, it receives a "research-grade" label. These research-grade images can then be used by ecologists as a record for measuring populations of species or as ground-truth data for vegetation classification. Ground-truth data are used in remote sensing for training and validation of classified images. The collection of these data requires the intensive collection of field data that results in higher research costs. The use of voluntarily collected field data using citizen science tools, such as iNaturalist, may reduce the need for some fieldwork. The purpose of this project is to review relevant literature on the use of iNaturalist and other "citizen science" project data in remote sensing and highlight their advantages and disadvantages in remote sensing, followed by a case study in using iNaturalist data in remote sensing for classifying forest species in Auburn, Alabama.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 78.

Presentation Abstract

Remote sensing of forest attributes with a GIS database of Redstone Arsenal

John Perkins
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849, jdp0023@auburn.edu

Lana Narine
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849

Adam Maggard
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849

John S. Kush
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849

Rebecca J. Barlow
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849

Abstract

RSA is a military installation located in Huntsville, AL along the Tennessee River. It consists of planted pine stands as well as natural hardwood-dominated areas that act as barriers between civilian and military operations. According to the Sikes Act, RSA must conduct a forest inventory every 10 years to protect its natural resources and ensure that the installation is acting in accordance with state and federal law. Remote sensing of forest resources is a growing field within the forestry discipline and is often touted as a more cost-effective solution compared to traditional forest inventory methods. Still, ground-truth data are needed as training and validation data for any estimates and classifications in remote sensing. The goal of this project is to create a geographic information system (GIS) database for Redstone Arsenal (RSA) forest attribute values and use these data as training and validation data for remotely sensing forest canopy cover, basal area, and volume across the study area. The GIS database for RSA (DBH), merchantable height, and total height were recorded. Data were collected from plots located along grid lines in stands greater than 5 acres in size. Plot size was determined

according to forest type. Pine-dominated stands were measured using 1/20th acre plots while hardwood and mixed pine-hardwood stands were measured using 1/10th acre plots. Plots were located using global position system (GPS) field units and individual tree data at each plot were measured using traditional forest mensuration tools and techniques. Ground truth data from the GIS database will be used for training and validation of estimates derived from imagery acquired by aerial, satellite, and light detection and ranging (LiDAR) platforms. Several techniques will be used to analyze the image including random forest algorithms, neural networks, support vector machines, and compared with traditional remote sensing approaches like maximum likelihood and ISODATA classifications. Deliverables from these classifications will show the distribution of tree species, basal area/acre, and volume of timer across RSA.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 80.

Presentation Abstract

Predicting forest stand statistics in the southeastern U.S. with Sentinel 2 powered by artificial intelligence

Héctor I. Restrepo
American Forest Management, Inc.
Charlotte, NC, 28217, Hector.Restrepo@afmforest.com

Nathan Herring
American Forest Management, Inc.
Charlotte, NC, 28217

Laura Parker
American Forest Management, Inc.
Charlotte, NC, 28217

Will Woodroof
American Forest Management, Inc.
Charlotte, NC, 28217

Abstract

The timberland investment is a sophisticated financial instrument that requires and utilizes the best existing theory, technology, and models to inform decisions. Modern timberland management comprehensively combines a wide array of knowledge disciplines such as forest biometrics and inventory, remote sensing, computer sciences, spatial statistics, silviculture and genetics, forest economics and finance, forest planning (operations research), and forest policy. Although all topics are relevant and deserve equal attention, we will focus our discussion on the first four scientific topics: forest biometrics, remote sensing, computer sciences, and spatial statistics. Sound forest biometric practices assure the rigor of forest inventories and the quality of growth and yield estimations. However, inventorying large areas by traditional forest inventory techniques is expensive and time-consuming, so remote sensing is becoming more prevalent in obtaining accurate and cost-efficient forest statistics estimates. The Copernicus Sentinel program has significantly contributed to the science and practice of remote sensing for forestry applications by making accessible high-frequency, high-resolution, wide-swath, multi-spectral satellite imagery for the globe. Pairing geolocated forest measurements and satellite imagery allow for the construction of artificial intelligence models that substantially expand local estimations to a much broader

regional scale. This forest system has shown to be very useful in timberland acquisition, appraisal, and real estate projects across the Southeastern U.S. However, as occurs with all systems, a permanent refinement is needed to update and improve estimations.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 82.

Presentation Abstract

Wood, wood everywhere but where is the demand?

Ruth Cardinal Seawell
Larson & McGowin, LLC.
Mobile, AL, 36607, rseawell@larsonmcgowin.com

Grant Larsen
Larson & McGowin LLC.
Mobile, AL, 36607

Abstract

Timber supply has been increasing across the Southeast for several decades. At the same time mill demand has been changing due both to company consolidation and constantly evolving specifications and utilization rates. In this presentation, we will provide a spatial analysis of mill demand across Southeast utilizing geographic information systems (GIS) to examine market restrictions due to transportation, physiographic and other spatial limitations. In addition, we will utilize 'Big Data' from a variety of private and public resources to create 'Deep Data' of timber supply and timber prices across the Southeast. Deep Data, in contrast to Big Data, is organized data analyzed and filtered such that it is relevant and informative. The combination of this spatial and Big Data analysis allows timber managers to better understand of the spatial and temporal patterns in wood consumption as well as track mill production by type and major species.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 83.

Presentation Abstract

Enhancing harvest management through technology

Rachael Shanks
Silvics Solutions, LLC.
Mobile, AL, 36607, rachaelshanks@silvics.com

Kurt Krueger
Larson & McGowin, LLC.
Mobile, AL, 36607

Greg Triplett
Larson & McGowin, LLC.
Watkinsville, GA, 30677

Abstract

Data availability and technological advancements have greatly enhanced forest land managers' ability to increase profit margins, reduce costs, and reduce loss. Better tools allow for better planning and a deeper understanding of what is happening in our forests before, during, and after the occurrence of silvicultural activities.

In this discussion, we will walk you through a case study of how we utilized GIS data, electronic load tracking data from our LoadBOSS electronic ticketing system, and monthly mosaiced imagery data to actively monitor a timber sale's progress and potential load security issues.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 84.

Presentation Abstract

Impact assessment of invasive plants on wetlands, coastal prairies, and forests to evaluate the effectiveness of monitoring and control measures

Nisham Thapa
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849, nzt0037@auburn.edu

Lana Narine
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849

Zhaofei (Joseph) Fan
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849

Shoayang Yang
Forest Resources and Environmental Conservation, Virginia Tech
Blacksburg, VA, 24061

Kasip Tiwari
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849

Abstract

Invasive plant species have been recognized to cause major ecological and environmental problems, such as threatening the sustainable development of native forest ecosystems, impair soil nutrient cycling and alter the community structure. They have irreversible impacts on native species and can ultimately replace the native vegetation. Invasive species are the main cause to the decline of 42% of United States endangered and threatened species. Among the invasive species that have become well established in the southern coastal region of United States, *Triadica sebifera* (Chinese tallow) and *Ligustrum sinense* (Chinese privet) are enlisted as the worst invasive plants.

The general objectives of the study are to assess the impact of Chinese tallow and Chinese privet on coastal region forests. For this purpose, preliminary study will be carried out to select the study area having different degree of Chinese tallow and

Chinese privet invasion. The study area having naturally regenerated forest patch with no or little human disturbance will be selected for the better representation of the impact of different degree of invasion. After the study site has been selected, field data collection will be carried out. The study area will be divided into several homogeneous patches having evenly distributed forest structure. Depending upon the homogeneity of the patches, simple random sampling and 16 m^2 quadrat sampling will be used at every 5 m distance. On each quadrat moisture, field coordinates, DBH, height and cover of overstory, midstory and understory will be measured. For the overstory, age of the tree, increment of tree at 10 years and 5 years will be recorded to model the impact of invasion on tree growth at different invasion degrees. The data analysis will be carried out at patch level, quadrat level, and tree level to access the impact of Chinese tallow and Chinese privet based on the different degree of invasion. Also, the canopy cover percentage of the species will be used to visualize the accurate distribution map of Chinese tallow and Chinese privet in the study area.

Distribution maps play a vital role in detection of invasion, can help to conduct the assessment of the severity of invasion and support the best management method applicable for the eradication of invasive plants. The impact assessment based on different degree of invasion aids to understand the reason for the probability of invasion and the factors that supported the invasion. It acts as a tool to select the most effective method to control the factor that support invasion.

Poster Abstracts

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 87.

Poster Abstract

Using airborne and spaceborne LiDAR to estimate forest inventory parameters: A case study over forests in the southeastern US

Schyler Brown
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849, sbb0056@auburn.edu

Lana Narine
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849

John Gilbert
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849

Abstract

In the Southeastern U.S., forests are being managed for merchantable products, restoration, and carbon stock analysis. Estimates of forest inventory parameters such as basal area (BA), volume, and aboveground biomass (AGB) are necessary to help foresters better manage stands. Estimates of forest parameters from field methods over large areas can be labor intensive and expensive. By integrating publicly available remote sensing data (RS), it is possible to mitigate these costs and attain spatially complete estimates. One potential platform for estimating BA, volume, and AGB is the Global Ecosystems Dynamics Investigation (GEDI), a spaceborne lidar that launched in December of 2018. Focusing on the Solon Dixon Forestry Education Center (SDFEC) site in southern Alabama, our objectives include 1) generating wall to wall estimates of BA, volume, and AGB using publicly available airborne LiDAR from the 3D Elevation Program (3DEP) and high-resolution imagery, and field inventory data, and 2) comparing GEDI derived height metrics and AGB with airborne LiDAR reference datasets. Wall-towall reference estimates of BA, volume, and AGB are produced using airborne lidar and field inventory data consisting of BA, volume and AGB from 512, 0.04-hectare plots, where airborne LiDAR metrics are used as independent variables in variable selection and model building. The resulting wall-to-wall forest inventory estimates over the study site will be used for comparisons with data from GEDI. Validation of these estimates are important to better understand their utility for application, carbon stock and sequestration analysis, drought damage analysis, and even locating crop and lumber yield areas.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 88.

Poster Abstract

Mapping floodplain wetlands using flood image classification and topographic buffering

Thomas Ciarlante
Natural Resource Ecology and Management, Oklahoma State University
Stillwater, OK, 74078, thomas.ciarlante@okstate.edu

Bryan Murray
Natural Resource Ecology and Management, Oklahoma State University
Stillwater, OK, 74078

Daniel Dvorett
Oklahoma Conservation Commission
Oklahoma City, OK, 73105

Craig Davis
Natural Resource Ecology and Management, Oklahoma State University
Stillwater, OK, 74078

Sara Gilmer
Oklahoma Conservation Commission
Oklahoma City, OK, 73105

Abstract

The majority of Oklahoma wetlands were mapped through the National Wetlands Inventory (NWI) in the 1980's, primarily using single-date color-infrared imagery. NWI map accuracy appears to be particularly poor along highly dynamic river systems and associated floodplain wetlands, including the North Canadian and Salt Fork of the Arkansas Rivers, which can present problems in identifying wetlands that are only flooded during portions of the year. Additionally, depressional wetlands may be dry for several consecutive years due to variable rainfall patterns in the semi-arid Central Great Plains, which makes wetlands susceptible to omission from traditional single-date mapping. This project aims to provide an updated NWI map of wetlands along these two river systems and to design an automated method of identifying and mapping these unique wetlands. Using Sentinel-2 satellite imagery from dates following 5-year recurrence flood events determined from U.S. Geological Survey stream gauges, floodplain areas with open water or high levels of water saturation were identified.

Using Python and ArcGIS, a series of selections and buffers were constructed to find the likely extent of inundation using high-resolution topography data. This method allows for a simple identification of areas likely to be inundated often enough to contain wetland hydrologic indicators using remotely sensed data despite interference from canopy or other types of overhead cover. These results will be compared to the results of traditional mapping conducted by supervised classification. We also will conduct field visits to determine the accuracy of both methodologies. NWI data sets will be updated based on the method of highest accuracy.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 90.

Poster Abstract

Woody residue biomass availability and transport costs to supply a biofuel production facility

Michael K. Crosby
School of Agricultural Sciences and Forestry, Louisiana Tech University
Ruston, LA, 71272, mcrosby@latech.edu

Eric McConnell
Department of Forestry, Mississippi State University
Mississippi State, MS, 39762

Jason J. Holderieath
School of Agricultural Sciences and Forestry, Louisiana Tech University
Ruston, LA, 71272

Abstract

As biofuel production continues to gain traction, producers will search out ways to source material for fuel conversion. Pine forests in the southeastern United States provide an excellent source for harvest residues that can be converted into, for example, biodiesel. Using a proposed site for a biofuel production facility in Louisiana as an example, Forest Inventory Analysis (FIA) data were queried for harvest residue estimates (i.e., tops and limbs) within the State. Subsequent to this, the proposed facility location was buffered at distances of 5-, 15-, 30-, 50-, and 100-mile radii to provide a parish-level estimate of residue availability and scenarios for transportation to the facility. There are between 3,900 lbs/ac - 137,000 lbs/ac, between 5- and 100-miles of the facility. Varying transportation costs from $0.10/ton/mile to $0.20/ton/mile, moisture content of residues between 45%-55%, and load limits from 20-28 tons, we calculated estimates for green ton costs of residue brought to the facility. The maximum payable fiber price ranges from $5.25/ton to $32.06/ton delivered. This provides a method of estimation for other potential sites/markets for wood residues. Further, the methodology could be expanded to include workforce needs, etc., related to facility establishment in other areas.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 91.

Poster Abstract

Simulated and actual growth comparison of the Bienville National Forest

Jason J. Holderieath
School of Agricultural Sciences and Forestry, Louisiana Tech University
Ruston, LA, 71272, jjhold@latech.edu

Michael K. Crosby
School of Agricultural Sciences and Forestry, Louisiana Tech University
Ruston, LA, 71272

Eric McConnell
Department of Forestry, Mississippi State University
Mississippi State, MS, 39762

James R. Meeker
U.S. Department of Agriculture Forest Service, Forest Health Protection
Pineville, LA, 71360

Chris A. Steiner
U.S. Department of Agriculture Forest Service, Forest Health Protection
Pineville, LA, 71360

Brian Strom
U.S. Department of Agriculture Forest Service, Forest Health Protection
Pineville, LA, 71360

Crawford (Wood) Johnson
U.S. Department of Agriculture Forest Service, Forest Health Protection
Pineville, LA, 71360

Abstract

Through 2019, the southern pine beetle (SPB) has affected approximately 16,000 of the 178,000 Bienville National Forest (BNF) (Crosby et al. *Forthcoming*). The United States Forest Service shifted its management focus from multiple use sustained yield to ecosystem management without changing the composition of existing forests. This change in management is suspected of having exacerbated the intensity and extent of the SPB infestation. As part of our ongoing project to evaluate the impact of SPB activity

in Mississippi, we will be assessing the carbon that was not, but would have been, sequestered under a management regime that more resembles acceptable southern pine silviculture. A spatially explicit growth and yield model of the BNF will fit inventory data, including recorded volumes and planting dates, to simulate forest growth under ideal and actual management. This poster will report volume comparisons between the simulated and actual data.

Citation: Michael K. Crosby, T. Eric McConnell, Jason J. Holderieath, Mary A. Funderburk, James R. Meeker, Chris A. Steiner, Brian Strom, and Crawford (Wood) Johnson. Forthcoming. Tracking the Extent and Severity of a Southern Pine Beetle Outbreak. In: Proceedings of the 21st Biennial Southern Silvicultural Research Conference.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 93.

Poster Abstract

Spatial dependencies identify primary forest industry timber zones in Mississippi

Eric McConnell
Department of Forestry, Mississippi State University
Mississippi State, MS, 39762, eric.mcconnell@msstate.edu

Michael K. Crosby
School of Agricultural Sciences and Forestry, Louisiana Tech University
Ruston, LA, 71272

Abstract

Understanding the relationship between a county's number of wood-using mills and the spatial dependence of harvesting timber products among counties should provide meaningful information regarding forestry's competitive advantage across Mississippi. Primary processing mill locations were obtained from an online directory while timber harvest data were obtained from the Mississippi State University Extension Service's 2019 Harvest of Forest Products report. A Spatial Lag of X (SLX) Poisson Regression model was utilized with mill counts per county as the dependent variable. Timber product harvest levels (thousand green tons) for pine sawtimber, hardwood sawtimber, pine poles, pine pulpwood, and hardwood pulpwood per county were predictors along with a spatial weight matrix of Mississippi's 82 counties. The matrix was calculated using county centroids and filtered to include only county relationships where $w_{ij} < 1 / 100\ miles^2$. The matrix was normalized so that the row sums equaled 1.00.

Strong linkages were found within two "timber zones" of South Mississippi. Greater hardwood pulpwood harvesting indicated a significant own-county mill presence ($p = 0.0565$). Moreover, neighboring counties that produced more pine sawtimber and pulpwood products possessed greater numbers of mills ($p = 0.0067$ for sawtimber and $p = 0.0185$ for pulpwood). Zone #1 consisted of 12 counties in southwest Mississippi. Zone #2 comprised 4 counties in southeast Mississippi. The results suggest a localization of forest-based enterprises could provide lower hauling costs, better stumpage prices, bring a more complete harvest of the site, and consequently improve timberland's position as an attractive financial asset. These counties could also make attractive subjects for industry targeting initiatives that strengthen supply chains and further improve local advantages.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 94.

Poster Abstract

Evaluating classification methods for assessing southern pine beetle damage using high resolution satellite data

Austin O'Neal
School of Agricultural Sciences and Forestry, Louisiana Tech University
Ruston, LA, 71272, aro028@latech.edu

Michael K. Crosby
School of Agricultural Sciences and Forestry, Louisiana Tech University
Ruston, LA, 71272

Eric McConnell
Department of Forestry, Mississippi State University
Mississippi State, MS, 39762

Jason J. Holderieath
School of Agricultural Sciences and Forestry, Louisiana Tech University
Ruston, LA, 71272

Connor Gay
City of Ruston
Ruston, LA, 71272

James R. Meeker
U.S. Department of Agriculture Forest Service, Forest Health Protection
Pineville, LA, 71360

Chris A. Steiner
U.S. Department of Agriculture Forest Service, Forest Health Protection
Pineville, LA, 71360

Brian Strom
U.S. Department of Agriculture Forest Service, Forest Health Protection
Pineville, LA, 71360

Crawford (Wood) Johnson
U.S. Department of Agriculture Forest Service, Forest Health Protection
Pineville, LA, 71360

Abstract

Understanding the relationship between a county's number of wood-using mills and The ability to detect forest disturbances remotely provides valuable information for assessing the extent of the disturbance and the deployment of treatment and monitoring protocols. In an effort to assess the extent of a southern pine beetle (SPB) outbreak in the Bienville National Forest (BNF) in Mississippi, WorldView-2 imagery was acquired and assessed for its capability to classify acres impacted by SPB. Supervised classification was performed on the image with seven training classes. For this classification, overall accuracy was 70% while producer and user accuracy for three impact classes (i.e., active infestation, standing dead trees, and removals) ranged from 29.4% to 100%. The estimated area impacted ranged from approximately 3,500 acres actively infested to 11,000 acres removed. Defining and differentiating training pixels for classification was difficult resulting in much confusion for actively infested and standing dead classes, which will require some refining. Manual interpretation requires more time and would impede the deployment of field-based crews to assess impacts. Further refining training sites and combining vegetation/field categories would likely improve user's error in classifications. Still, this data is useful for managers in guiding assessment and treatment (e.g., select cuts, salvage, etc.) within the impacted areas.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 96.

Poster Abstract

Using unmanned aerial systems (UAS) to measure crop damage from wild pigs to corn, cotton, and peanut fields in southwestern Georgia

Justine L. Smith
Warnell School of Forestry and Natural Resources, University of Georgia
Athens, GA, 30602, Justine.Smith@uga.edu

L. Mike Conner
The Jones Center at Ichauway
Newton, GA, 39870

Michael T. Mengak
Warnell School of Forestry and Natural Resources, University of Georgia
Athens, GA, 30602

Roger C. Lowe
Warnell School of Forestry and Natural Resources, University of Georgia
Athens, GA, 30602

Abstract

Wild pigs (*Sus scrofa*) have been translocated legally and illegally for hunting purposes. Illegal relocations of wild pigs aided in their northern and westward range expansion. Originally introduced in the 1500s by Spanish settlers, populations of wild pigs are now found in at least 35 states with an estimated population surpassing 6 million animals. Costs associated with wild pigs for removal and crop and timber damage exceed USD $3.8 billion annually. The objectives of this study are to 1) observe changes in wild pig damage to crops as pig reduction methods are implemented by USDA APHIS Wildlife Services under the guidance of the National Feral Swine Damage Management Program and 2) compare unmanned aerial system (UAS) sampling methods across four field types experiencing wild pig damage. We began UAS sampling in May 2021. We selected 14 fields for sampling, including 4 corn (*Zea mays*), 3 peanut (*Arachis hypogaea*), 5 cotton (*Gossypium* spp.) and 2 mixed corn/peanut fields. Sampling methods included flights to 15 random waypoints, flying random transects, and conducting 2 circular flights per field. The exterior circular flight was flown at the radius plus 12 m to capture the edge; the interior circular flight at half the radius plus 6 m. All flights were flown at an elevation of 70 m followed by on-the-ground measurements. Data will be used to assess impact of pig removal efforts on crop damages, estimate

economic loss attributed to wild pigs, and determine an efficient sampling method for quantifying wildlife damage in fields.

Proceedings of the 13th Southern Forestry and Natural Resource Management GIS Conference
Warnell School of Forestry and Natural Resources, University of Georgia, Athens, GA USA
K. Merry, P. Bettinger, C. Cieszewski, M. Crosby, A.R.G. Garzon, J. Siry, B. Song, Z. Ucar,
and J. Uzu, eds. 2022. pp. 98.

Poster Abstract

Mapping forest canopy height using ICESat-2 and Landsat-8 data over the southeastern US

Kasip Tiwari
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849, kzt0041@auburn.edu

Lana Narine
School of Forestry and Wildlife Sciences, Auburn University
Auburn, AL, 36849

Abstract

The Ice, Cloud, and land Elevation Satellite-2 (ICESat-2), launched September 2018, is a follow-on mission to ICESat, which operated from 2003 to 2009. ICESat-2's land and vegetation height product or ATL08, provides terrain and canopy height estimates at a 100 m step size in the along-track direction. ICESat-2 data does not cover the entire area but integrating these observations with Landsat imagery will provide full coverage. The upscaling of canopy height estimates to develop a full coverage map can be useful to scientists in understanding and modeling a wide range of ecological, hydrological, and atmospheric processes in forest ecosystem and for forest/land managers to assess habitat suitability for a variety of species, assess fire threats, predict potential fire behavior, and estimate timber volume. The aim of this study is to develop methods for mapping canopy height at the regional scale, using ICESat-2 data. Mapped products are being developed for the Southeastern Plains Ecoregion and Middle Atlantic Coastal Plain ecoregion at a 30 m spatial resolution, consistent with the spatial resolution of Landsat imagery. Focusing on only strong beams from nighttime acquisitions, tracks over the ecoregions were downloaded. The h_canopy i.e., 98th percentile height for a segment, h_max_canopy (maximum canopy height), h_min_canopy (minimum canopy height), h_mean_canopy (mean canopy height) parameters has been extracted from ATL08 data. The National Land Cover Database (NLCD) 2019 land cover map will be used to mask forested areas and Vegetation indices (normalized difference vegetation index (NDVI), the enhanced vegetation index (EVI), and modified soil-adjusted vegetation index (MSAVI)), and texture variables (texture contrast: NDVI_con; texture entropy: NDVI_ent, and texture variance: NDVI_var) from Landsat-8 will be used to extrapolate ICESat-2 canopy height to the regional level. Two different methods will be applied for determining canopy height 1) machine learning modeling using Random Forest and 2) geostatistical modeling, with regression kriging. Statistical values will be

calculated to quantify the accuracy of ICESat-2 canopy heights generated from each modeling approach, using reference airborne LiDAR data. The statistical values to determine accuracy are: 1) mean bias, 2) mean absolute error (MAE), 3) coefficient of determination (R^2), 4) root mean square error (RMSE), 5) percent root mean square error (%RMSE). This study will highlight potentially more accurate approach to upscale canopy height as well as provides information about the possibility of combining satellite data for future monitoring of canopy height dynamics over larger spatial extent.

F4 TECH
New Services Wider Breadth
Technology Driven
Mobile Solutions for Android and IOS
Highly Streamlined Cloud-Based Solutions
thinkF4.com
850-385-3667
Foresters Leading Innovation
F4 TECH
COLLECT DATA
ANALYZE INTERPRET AND REPORT DATA
DEVELOP PLANS
CONDUCT FIELD PROJECTS
ASSESS RESULTS
LANDOWNER MISSION GOALS OBJECTIVES
DIFFERENCE

Turn Acres Into Assets
Orbis helps asset managers and investors simplify the process of acquiring and managing large land holdings with technology-enabled solutions and services.
Orbis
www.orbisinc.com
Orbis, Inc.
@OrbisIncUSA
Orbis, Inc.
info@orbisinc.com