Scope of Work for

Project #18-005
Next steps for improving Texas biogenic VOC and NO emission estimates

Prepared for

The Texas Air Quality Research Program (AQRP)

The University of Texas at Austin

By

Alex Guenther (Principal Investigator)

Department of Earth System Science

School of Physical Sciences

University of California, Irvine

Greg Yarwood (Co-Principal Investigator)

Tejas Shah

Ling Huang

Ramboll

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Approvals

This Scope of Work was approved electronically on October 15, 2018 by Elena McDonald-Buller, The University of Texas at Austin

Elena McDonald-Buller
Project Manager, Texas Air Quality Research Program

This Scope of Work was approved electronically on October 19, 2018 by Doug Boyer, Texas Commission on Environmental Quality

Doug Boyer
Project Liaison, Texas Commission on Environmental Quality

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1.0 Abstract

The overall goal of this project is to improve numerical model predictions of regional ozone and aerosol distributions in Texas by reducing uncertainties associated with quantitative estimates of biogenic VOC and NO emissions from Texas and the surrounding region. Although there have been significant advancements in the procedures used to simulate these biogenic emissions, there are still major uncertainties that limit predictability of Texas air quality simulations. This includes significant gaps in our understanding of biogenic emissions and their implementation in numerical models including isoprene, monoterpene and sesquiterpene emission factors and soil NO emissions. Therefore, we propose to improve the capability of the Model of Emissions of Gases and Aerosols from Nature (MEGAN, Guenther et al., 2012) framework to estimate emissions of these compounds. To accomplish this, we will conduct high quality measurements of isoprene, monoterpene and sesquiterpene emission factors at eastern Texas field sites near San Antonio, Dallas, and Houston and integrate these results, and those from other studies, into MEGAN.

The primary output of the proposed research will be a more accurate approach for estimating biogenic VOC and NO emissions. Outcomes will include improved biogenic emission estimates and a better understanding of the current inconsistencies in various biogenic emission observational datasets and model simulations. The overall benefit of this project will be more accurate VOC and NO emission estimates for the Texas air quality simulations that are critical for scientific understanding and the development of regulatory control strategies that will enhance efforts to improve and maintain clean air.

2.0 Background

Emissions of reactive gases from the earth's surface drives the production of ozone and aerosol and other atmospheric constituents relevant for regional air quality. Emissions of some compounds, including BVOCs and NO, are highly variable and can vary more than an order of magnitude over spatial scales of a few kilometers and time scales of less than a day. This makes estimation of these emissions especially challenging and yet accurate quantification and simulation of these fluxes is a necessary step towards developing air pollution control strategies and for attributing observed atmospheric composition changes to their causes. Biogenic VOC emission models assume that emission rates are the product of an emission factor (EF) and an emission activity factor, similar to the approach used for most anthropogenic emission estimates. While research activities tend to focus on emission activity factors, it is clear that uncertainties in EF make an important contribution and may even dominate the total uncertainty in BVOC emission rate estimates (Arneth et al. 2011, Guenther 2013).

Most biogenic emission models, including the latest version of BEIS3.6 and MEGAN2.1, classify all Texas trees as either an emitter or non-emitter for isoprene and have 4 or less categories for monoterpenes and sesquiterpenes. All versions of BEIS3 uses EFs that were developed over 20 years ago with an isoprene EF of 24.3 nmol m^{-2} s^{-1} for all Texas isoprene emitting trees. Geron et al. (2001) assessed the measurements used to develop the BEIS3 EF and concluded that most of the isoprene EF data suffered from a lack of recorded light/temperature growth conditions, self-shading of leaves in branch enclosures, few upper canopy measurements, perturbed measurement environments including low CO2 and high stress, no measurements of vegetation stress or physiological status, variable time of day and season, and other factors. Of particular concern was the lack of information on leaf growth environment, especially light and temperature, and the expected bias towards sampling shaded foliage in the lower part of the canopy. When examining species previously classified as low emitters, Geron et al. found that sun-lit leaves of these species had similar emissions as other high isoprene emitters. They concluded that any interspecies differences that may exist were obscured by the variability due to these other factors.

Only a few BVOC EF studies have characterized Texas vegetation in recent decades. One of those studies examined two Texas isoprene emitting tree species (Lahr et al. 2015) and reports isoprene EF for sweetgum and post oak trees of about 30 nmol m^{-2} s^{-1} for sun leaves of both tree species at a rural site. The sweetgum emission factors were higher (44 nmol m^{-2} s^{-1}) at an urban site and lower at a suburban site (25 nmol m^{-2} s^{-1}). The opposite was the case for Post Oak with lower emissions (29 nmol m^{-2} s^{-1}) at the urban site and higher emissions (40 nmol m^{-2} s^{-1}) at the suburban site. While Lahr et al. concluded that this was evidence that isoprene emissions are lower at rural compared with urban/suburban sites, we hypothesize that the observed differences are simply due to differences in the light environment of the measured leaves. Although Lahr et al. classified all of their samples as representing "sun leaves", Niinemets et al. (2010) has shown that leaves classified as "sun leaves" can have very different light environments that can lead to isoprene EFs that vary by more than a factor of 2 and that this variability is highly correlated (r2=~0.9) with the light environment as measured by the daily average integrated quantum flux density. The lack of a quantitative measure of leaf light environment may explain much of the difference between reported isoprene EF data and the values used in models such as BEIS3.6 and MEGAN2.1. The MEGAN3 approach enables estimation of EF for individual plant species and accounts for within canopy variation in isoprene EF driven by daily average integrated quantum flux density. Measurements of isoprene EF data for important Texas tree species, that account for leaf light environment, can be integrated into MEGAN3 to provide more accurate isoprene emission estimates for Texas.

Soil microbes are thought to contribute about 15% of global NO emissions and 40 to 80% of total NO emissions in some agricultural regions with high fertilizer application rates (Hudman et al. 2012). BEIS3.6 and MEGAN3.0 use the approach of Yienger and Levy (1995) to estimate biogenic soil NO emissions, which captures some major features of soil NO emissions including biome specific emission factors and the major meteorological drivers of precipitation and temperature. Hudman et al. updated these procedures by 1) relating emissions to soil moisture, rather than precipitation, 2) decoupling water availability and temperature dependence and modifying the time scale, 3) improved gridded inventories for chemical fertilizers and manure, and 4) using MODIS-based growing season start and end dates for fertilizer application, and 5) including wet and dry nitrogen deposition, and 6) incorporating a representation of available N pool that includes natural, fertilizer and deposition sources. They integrated these procedures on-line within the GEOS-Chem model and used satellite observations to show that the approach could reproduce the observed interannual variability (Hudman et al. 2012). Rasool et al. 2016 integrated the Hudman et al. model into CMAQ and improved the driving variables by using 1) 12 km soil biome map for the US, 2) daily year-specific fertilizer data. This approach has also been incorporated into the version of MEGAN that is embedded in WRF-chem (Chen, W., X.

Wang, A. Guenther et al., manuscript in preparation). All three of the modelling activities described above have integrating this soil NO emission model within a CTM as a coupled approach. While this has the advantage of directly utilizing the environmental conditions, including nitrogen deposition, from these models and enabling potential feedbacks between emissions and climate, there remains an unmet need for using this improved approach to estimate soil NO emissions for off line simulations using air quality models such as CAMx (Ramboll 2018). Updating the Yienger and Levy (1995) soil NO emissions approach currently used in MEGAN3.0 with an approach similar to the recent implementation in WRF-chem (Chen et al.), which is based on Hudman et al. with the Rasool et al. advancements, would improve capabilities for estimating NO emissions for off-line simulations.

3.0 Objectives

The project has the following objectives:

1. Conduct field measurements of isoprene, monoterpene and sesquiterpene emission factors of important eastern Texas plant species and investigate the variability within and among species and vegetation types.

2. Update the MEGAN3 model by incorporating an improved soil NO emission approach and integrating the emission factor data from objective 1 into MEGAN emission factor processor.

3. Investigate sensitivity of updated biogenic emissions estimated for Texas and surrounding regions.

4.0 Task Descriptions

4.1 Measure Texas BVOC emission factors and their variability

Synthesizing BVOC emission factors is complicated by the large differences in quality of BVOC emissions data (Geron et al. 2001). MEGAN3 introduces an approach where emissions data are assigned a quality rating, called a "j" value" of 0 to 4 and allows users to choose a cut off level for data quality. We will develop and describe in detail a clear approach for characterizing emissions data associated with each category. The measurement approaches available for making measurements of a given data quality level will be identified and the advantages and disadvantages of various approaches will be assessed. We will introduce a new quality rating, j = 5, that will include 1) chlorophyll and maximum quantum efficiency of photosystem II quantified using a Photosynq multispeQ flourometer and long-term characterization of the long-term light and temperature environment using the approach of Niinements et al. (2010). The Niinemets (2010) approach consists of measuring the leaf angle and taking a digital photograph of the canopy above the leaf and using canopy gap fraction software to estimate the light environment (fraction of direct and diffuse light) that the leaf is exposed to throughout the day. This is based on leaf angle, sun angle throughout the day and the canopy structure above the leaf. The j=5 quality data will also include all of the requirements for j=4 data which is based on the measurement protocols of Niinements et al. 2011. These protocols include 1) dynamic open path leaf enclosure with well mixed chamber that minimizes contact with leaf and is constructed of inert materials and flow rate sufficiently high to assure residence time of < 3 minutes) and scrubbed of oxidants, 2) controlled short-term light and temperature environment, 3) quantified physiological status by measurements of photosynthesis and transpiration, 4) establish steady state conditions.

We will conduct high quality (j= 5) isoprene, monoterpene and sesquiterpene emission factor measurements during late May to mid June in eastern Texas at urban and rural sites within and around San Antonio and Houston. We will deploy a four-person field team to operate three BVOC emission factor measurement systems. A fifth person will be based in our UC Irvine laboratory to receive and immediately analyze samples shipped from the field. Two measurement systems, consisting of LICOR 6400 environmental control and gas exchange systems integrated with in-situ portable photoionization detector gas chromatographs (Photovac Voyager) will be used for rapid measurement of a large number of isoprene EFs. A third system, a custom built BVOC measurement system designed to minimize leaf disturbance and constructed of inert materials coupled with a pump to collect solid absorbent saples that will be shipped to our Irvine CA lab for analysis by Gas Chromatography with Time-Of-Flight Mass Spectrometry and Flame Ionization Detector (GC-TOFMS/FID), will be used for measuring emissions of other BVOC, including monoterpenes and sesquiterpenes. We will use all of the QA/QC procedures that have previously been used to successfully measure leaf-level BVOC emission measurements with these instruments (Geron et al. 2016). These procedures include 1) blanks measured from empty cuvette prior to each leaf measurement, 2) leaf temperature and light changed gradually from ambient to target conditions, 3) solid absorbent cartridge collected for each species for positive identification of isoprene, and 4) in-situ calibration after every fifth measurement using a standard cylinder referenced to a certified standard.

The LICOR6400+GC-PID systems will characterize at least seven of the dominant isoprene emitters in eastern Texas including 1) the two dominant evergreen oaks Quercus virginiana (southern live oak) and Q. fusiformis (plateau live oak), 2) Q. stellata (post oak) and at least one other Texas dominant broadleaf oaks such as Q. nigra (water oak) or Q. falcata (southern red oak) and 3) Liquidambar styraciflua (sweetgum) and members of at least two other genera such as Nyssa sylvatica (blackgum), Salix (willow) or Platanus (sycamore). At least 3 replicate measurements will be made on 8 leaves of 6 trees of the 7 species for a total of more than 1000 measurements. The custom built cuvette with cartridge sampling and offline GC-TOFMS/FID analysis will measure isoprene, speciated monoterpenes and sesquiterpenes, and other BVOC from the same 7 species listed above and at least 23 additional species for a total of at least 30 dominant Texas species. The additional 23 species will include at least 4 urban tree species, at least 11 other native tree species, and at least 8 crop species. The urban species will include Triadica sebifera (Chinese Tallow tree) and at least three other common urban species such as Fraxinus velutina (Arizona ash), Magnolia grandiflora (Magnolia), Lagerstroemia indica (crape myrtle), Catalpa bignonioides, Celtis occidentalis (hackberry), and Cinnamonum camphora (Camphor). The other native species will include Pinus taeda (loblolly pine), Prosopis glandulosa (honey mesquite), Juniperus ashei (ashe juniper), Ulmus crassifolia (cedar elm), Carya illinoinensis (Pecan), Juniperus virginiana (eastern redcedar) and at least five other species such as P. elliottii (slash pine), P. palustris (longleaf pine), Q. laurifolia (laurel oak), Q. marilandica (blackjack oak), Q. phellos (willow oak), Q. velutina (black oak), Fraxinus pennsylvanica (green ash) or Taxodium distichum (bald cypress). At least 2 replicate measurements will be made on 3 leaves of 2 trees of the 30 species for a total of at least 360 measurements. The Texas crop species will include cotton, corn, sorghum, wheat, alfalfa, coastal bermuda grass, peanuts, and soybeans. At least 3 replicate measurements will be made on 3 leaves of 3 plants of these 8 species for over 140 measurements.

Locating rural field sites will be facilitated by the Texas Eco-lab program (www.texasecolab.org) which is a partnership between landowners with ecologically valuable land and university researchers. The eco-lab has a detailed description of each property, including a species list of all tree species, which indicates that all of our target species will be accessible at locations within three major ecoregions:

Oak/juniper and mesquite savanna. Over 50 eco-lab properties in Kendall, Kerr, Bandera, Bexar, and Travis counties together have the following species: Pecan, hackberry, Ashe juniper, honey mesquite, plateau live oak, Texas oak, Southern red oak, Shin oak, Lacey oak, Chinese Tallow tree, cedar elm, persimmon, mountain-laurel.

Pine/oak forest. Over 10 eco-lab properties in Montgomery, San Jacinto, Henderson, Harris, and Upshur counties together have loblolly pine, pin oak, water oak, sweet gum, green ash, eastern redcedar

Post oak savanna. Over 10 eco-lab properties in Austin, Bastrop, Grimes, Lee, and Waller counties together have post oak, mesquite, eastern red cedar, cedar elm, hackberry, bumelia.

The urban tree species will be measured on the campus of U. Houston and on nearby streets. We will use the Houston tree inventory to locate and identify target trees. The tree inventory is available for download (https://koordinates.com/layer/25245-houston-texas-street-tree-inventory/) and contains the exact GPS location, plant species, and other information for more than 193000 trees located on Houston streets. Additional field measurements on selected species will be made in Irvine, CA for comparison. The dominant Texas crops will be grown and measured under field conditions at the UCI arboretum.

4.2 MEGAN model improvements

4.2.1. Improved soil NO emission approach

Hudman et al. (2012) developed an improved approach for estimating soil NO emissions by 1) relating emissions to soil moisture, rather than precipitation, 2) decoupling water availability and temperature dependence and modifying the time scale, 3) improving gridded inventories for chemical fertilizers and manure, and 4) using MODIS-based growing season start and end dates for fertilizer application, and 5) including wet and dry nitrogen deposition, and 6) incorporating a representation of available N pool that includes natural, fertilizer and deposition sources. They integrated these procedures on-line within the GEOS-Chem model and used satellite observations to show that the approach could reproduce the observed interannual variability (Hudman et al. 2012). Rasool et al. 2016 integrated the Hudman et al. model into CMAQ and improved the driving variables by using 1) 12 km soil biome map for the US, 2) daily year-specific fertilizer data.

We will replace the soil NO emission approach that is currently used in MEGAN3 (and also in BEIS3.6), which is based on Yienger and Levy (1995), with an approach based on Hudman et al. with the Rasool et al. advancements. Soil moisture and landcover type, two of the key model inputs for estimating soil NO emissions, are already available as inputs to MEGAN3 for estimating BVOC emissions. For daily fertilizer application rates, another required input, users will have the option of using a long-term average climatology that will be available as a standard input for the MEGAN3.1 model or substituting year-specific fertilizer application data. Year-specific fertilizer rates can be calculated using the FEST-C modeling system (https://www.cmascenter.org/fest-c/) that uses the USDA EPIC model to simulate plant demand-driven fertilizer applications to commercial croplands throughout the continental US including Texas (Cooter et al. 2012). Instructions for using FEST-C to generate MEGAN3.1 inputs for a specific year will be included in the updated MEGAN3.1 users guide. We will handle atmospheric nitrogen deposition in a manner similar to fertilizer use by giving the user an option between using a daily climatology that will be provided on the MEGAN website or substituting year-specific input values. The climatology will be based on CAM-Chem global nitrogen deposition estimates (Lamarque et al. 2012). Instructions for generating year specific inputs will be included in the updated MEGAN3.1 users guide.

4.2.2. Integrate new Texas BVOC EF observations into MEGAN

The MEGAN3 framework includes an emission factor processor (EFP) that integrates plant species-specific emission factors and landcover characteristics data to generate landscape averaged emission factors. The EFP provides a transparent approach that enables users to determine the information that goes into the landscape average emission factor at any location in a model domain. The EF data generated by task 1 (see section 4.1) will be compiled and entered into the EFP and used to generate landscape average emission factors for input to MEGAN.

4.3 MEGAN3.1 sensitivity analysis of Texas biogenic emissions

We will investigate MEGAN3.1 model sensitivity and evaluate the response of changes in BVOC emissions factors and soil NO modelling procedures. This emissions sensitivity modeling will be conducted to characterize the impact of the Task 1 emission factor database development (see section 4.1) and the Task 2 MEGAN3 model improvements (see section 4.2). The model comparisons will be limited to MEGAN2.1, MEGAN3, MEGAN3.1, and BEIS3 simulations. There will be no CAMx simulations conducted for this project. We will select a small number of best estimates (for MEGAN2.1, MEGAN3, MEGAN3.1, BEIS3) and a sensitivity test of MEGAN3.1 BVOC emission inventories for comparison against aircraft flux data from the 2013 Southeast Atmosphere Study (SAS). The purpose of the evaluation is to constrain the MEGAN3.1 emissions using the SAS aircraft flux data. The AQRP Project 14-016 2013 modeling platform will be used (Yu et al., 2017). The modeling domain and time period encompass nearly all of the overland flight tracks of the NCAR C-130 and NOAA P-3 aircraft. A detailed description of the aircraft data and their application for emission model performance is described by Yu et al. 2017. For the selected MEGAN3.1 emission inventories, we will compare modeled and measured BVOC fluxes along the aircraft flight tracks. In addition, we will compare the selected MEGAN3.1 emission inventories with MEGAN3, MEGAN2.1 and BEIS3 emission estimates using the SMOKE-BEIS3 setup provided by TCEQ and assess differences in the model predictions.

5.0 Project Reporting and Presentations

As required, monthly technical, monthly financial status, and quarterly reports as well as an abstract at project initiation and, near the end of the project, the draft final and final reports will be submitted according to the schedule shown in Section 8.0. Dr. Guenther or his designee will electronically submit each report to both the AQRP and TCEQ liaisons and will follow the State of Texas accessibility requirements as set forth by the Texas State Department of Information Resources (http://aqrp.ceer.utexas.edu/). Dr. Guenther and Dr. Yarwood anticipate attending and presenting at the AQRP data workshop. Draft copies of any planned presentations (such as at technical conferences) or manuscripts to be submitted for publication resulting from this project will be provided to both the AQRP and TCEQ liaisons per the Publication/Publicity Guidelines included in Attachment G of the Sub-award. Final project data and associated metadata will be prepared and submitted to the AQRP archive.

Dr. Guenther will lead the project reporting activities with Dr. Yarwood and Mr. Shah and with assistance from team members at UCI and Ramboll. Deliverables include the abstract, monthly technical reports, monthly financial status reports, quarterly reports, draft final report, final report, attendance and presentation at AQRP data workshop, submissions of presentations and manuscripts, project data and associated metadata. The schedule for deliverables is shown in Section 8.0.

6.0 Project Participants and Responsibilities

Project roles and responsibilities for UC Irvine and Ramboll are described in this section.

University of California at Irvine

- ***Dr. Alex Guenther*** will provide overall supervision and integration of the BVOC emission factor measurements and modeling and will be responsible for the preparation and submission of the monthly progress, quarterly progress, and final reports.

Ramboll

- ***Dr. Greg Yarwood*** will provide high-level coordination with Dr. Guenther and staff members at Ramboll. Dr. Yarwood will consult with staff members at Ramboll on the MEGAN model development and assessment and advise on results reporting in collaboration with Dr. Guenther.

- ***Mr. Tejas Shah*** will lead Ramboll’s contribution to the Task 4 MEGAN3 model sensitivity testing and evaluation task with assistance from Dr. Ling Huang and Dr. Ross Beardsley.

- ***Dr. Ling Huang*** will work with Dr. Guenther on the MEGAN3 model improvements in Task 3, with Dr. Huang carrying out modification to the MEGAN3 code.

7.0 Timeline

A timeline of project activities is shown in Table 1.

Table 1. Schedule of project activities (tasks are bolded).

ID	Task	Aug 2018	Sept 2018	Oct 2018	Nov 2018	Dec 2018	Jan 2019	Feb 2019	Mar 2019	Apr 2019	May 2019	Jun 2019	July 2019	Aug 2019
1	***Measure BVOC EF***					X	X	X	X	X	X	X		
2	***MEGAN improvements***													
2a	*Soil NO model*			X	X	X	X							
2b	*BVOC EF*									X	X	X		
3	***Assessment of MEGAN Performance***										X	X	X	
R	*Monthly Technical & Financial Progress*	X	X	X	X	X	X	X	X	X	X	X	X	X
R	*Quarterly*		X			X			X			X		
R	*Draft Final*											X	X	
R	*Final*													X
R	*AQRP Workshop*													X

8.0 Deliverables

Project reporting and presentation requirements are described in Section 5.0. Deadlines for required deliverables are presented below.

Abstract: At the beginning of the project, an Abstract will be submitted to the Project Manager for use on the AQRP website. The Abstract will provide a brief description of the planned project activities, and will be written for a non-technical audience.

Abstract Due Date: TBD, 2018

Quarterly Reports: Each Quarterly Report will provide a summary of the project status for each reporting period. It will be submitted to the Project Manager as a Microsoft Word file. It will not exceed two pages and will be text only. No cover page is required. This document will be inserted into an AQRP compiled report to the TCEQ.

Quarterly Report Due Dates:

Report	Period Covered	Due Date
September 2018 Quarterly Report	July, August, September 2018	September 28, 2018
December 2018 Quarterly Report	October, November, December 2018	December 31, 2018
March 2019 Quarterly Report	January, February, March 2019	March 29, 2019
June 2019 Quarterly Report	April, May, June 2019	June 28, 2019

Monthly Technical Reports (MTRs): Technical Reports will be submitted monthly to the Project Manager and TCEQ Liaison in Microsoft Word format using the FY18-19 MTR Template found on the AQRP website.

MTR Due Dates:

Report	Period Covered	Due Date
Aug2018 MTR	Project Start - August 31, 2018	September 8, 2018
Sep2018 MTR	September 1 - 30, 2018	October 8, 2018
Oct2018 MTR	October 1 - 31, 2018	November 8, 2018
Nov2018 MTR	November 1 - 30 2018	December 8, 2018
Dec2018 MTR	December 1 - 31, 2018	January 8, 2019
Jan2019 MTR	January 1 - 31, 2019	February 8, 2019
Feb2019 MTR	February 1 - 28, 2019	March 8, 2019
Mar2019 MTR	March 1 - 31, 2019	April 8, 2019
Apr2019 MTR	April 1 - 28, 2019	May 8, 2019
May2019 MTR	May 1 - 31, 2019	June 8, 2019
Jun2019 MTR	June 1 - 30, 2019	July 8, 2019
Jul2019 MTR	July 1 - 31, 2019	August 8, 2019
Aug2019 MTR	August 1- Project end	Project end date

Financial Status Reports (FSRs): Financial Status Reports will be submitted monthly to the AQRP Grant Manager (Maria Stanzione) by each institution on the project using the FY18-19 FSR Template found on the AQRP website.

FSR Due Dates:

Report	Period Covered	Due Date
Aug2016 FSR	Project Start - August 31, 2018	September 15, 2018
Sep2016 FSR	September 1 - 30, 2018	October 15, 2018
Oct2016 FSR	October 1 - 31, 2018	November 15, 2018
Nov2016 FSR	November 1 - 30 2018	December 15, 2018

Dec2016 FSR	December 1 - 31, 2018	January 15, 2019
Jan2017 FSR	January 1 - 31, 2019	February 15, 2019
Feb2017 FSR	February 1 - 28, 2019	March 15, 2019
Mar2017 FSR	March 1 - 31, 2019	April 15, 2019
Apr2017 FSR	April 1 - 28, 2019	May 15, 2019
May2017 FSR	May 1 - 31, 2019	June 15, 2019
Jun2017 FSR	June 1 - 30, 2019	July 15, 2019
Jul2017 FSR	July 1 - 31, 2019	August 15, 2019
Aug2017 FSR	August 1 - 31, 2019	September 15, 2019
FINAL FSR	Final FSR	October 15, 2019

Draft Final Report: A Draft Final Report will be submitted to the Project Manager and the TCEQ Liaison. It will include an Executive Summary. It will be written in third person and will follow the State of Texas accessibility requirements as set forth by the Texas State Department of Information Resources. It will also include a report of the QA findings.

Draft Final Report Due Date: August 1, 2019

Final Report: A Final Report incorporating comments from the AQRP and TCEQ review of the Draft Final Report will be submitted to the Project Manager and the TCEQ Liaison. It will be written in third person and will follow the State of Texas accessibility requirements as set forth by the Texas State Department of Information Resources.

Final Report Due Date: August 30, 2019

Project Data: All project data including but not limited to QA/QC measurement data, metadata, databases, modeling inputs and outputs, etc., will be submitted to the AQRP Project Manager within 30 days of project completion (). The data will be submitted in a format that will allow AQRP or TCEQ or other outside parties to utilize the information. It will also include a report of the QA findings.

AQRP Workshop: A representative from the project will present at the AQRP Workshop in August 2019.

Presentations and Publications/Posters: All data and other information developed under this project which is included in published papers, symposia, presentations, press releases, websites and/or other publications shall be submitted to the AQRP Project Manager and the TCEQ Liaison per the Publication/Publicity Guidelines included in Attachment G of the Sub-award.

9.0 References

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Work Plan Appendix 1

Figure A1. Texas Parks and Wildlife ecoregion map

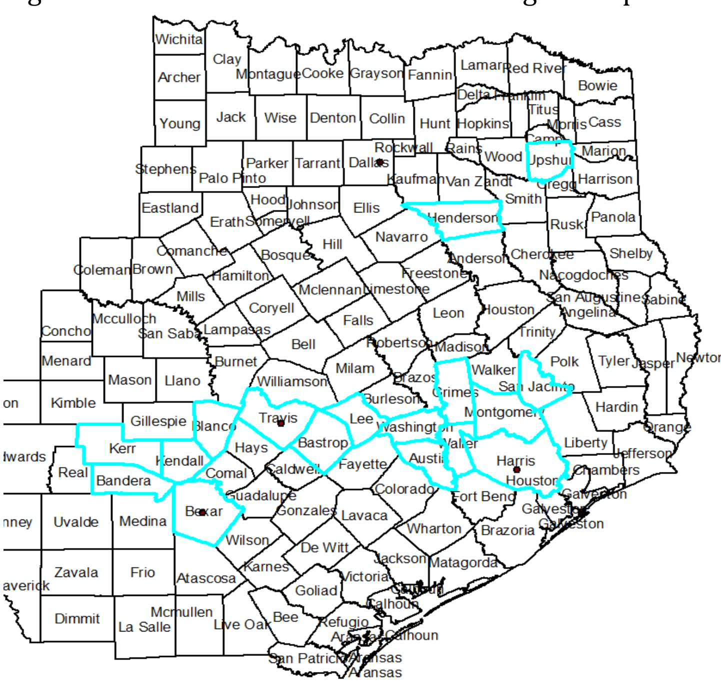
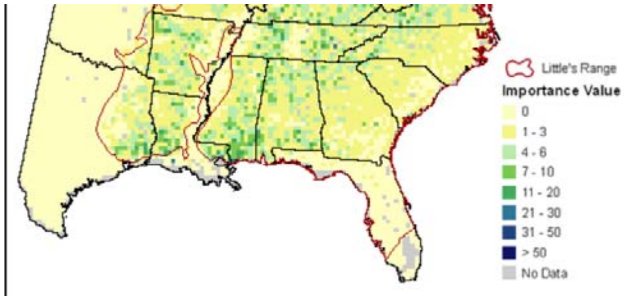
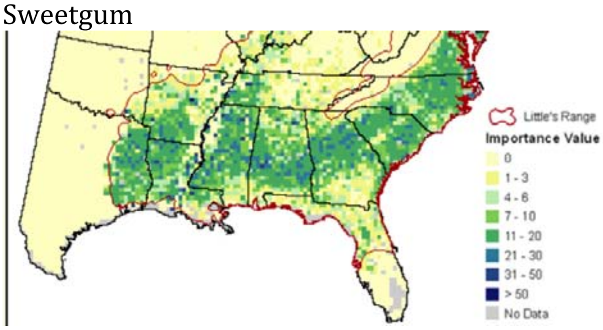


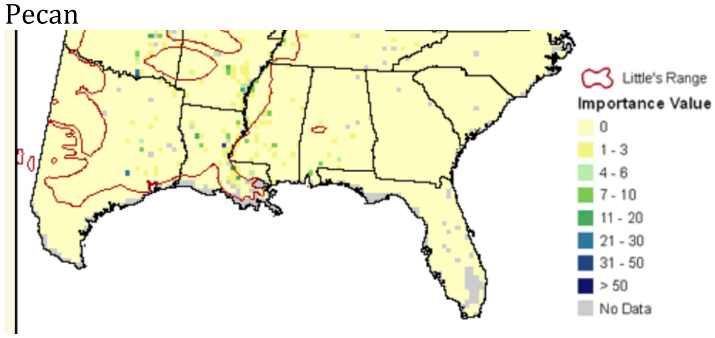
Figure A2. Location of counties with potential Eco-lab field sites is indicated by blue line. Blackgum



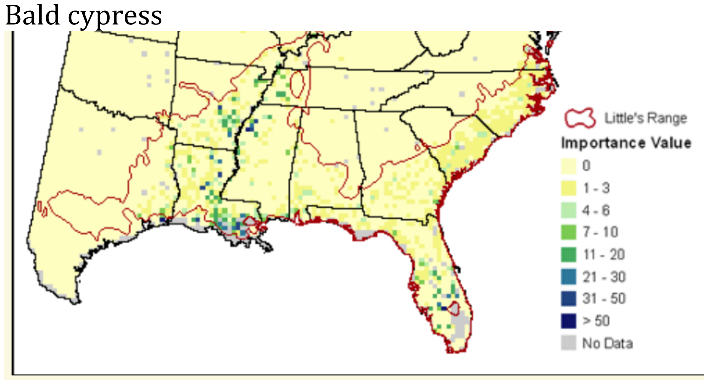
Sweetgum



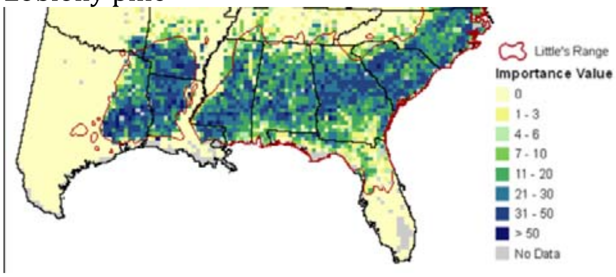
Pecan



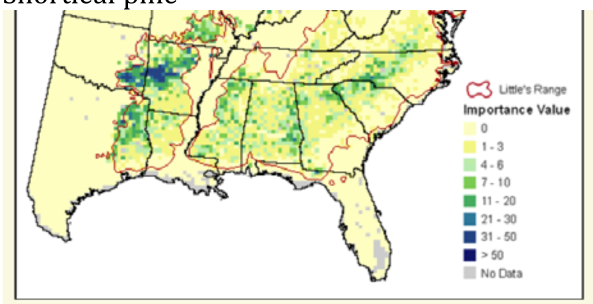
Bald cypress



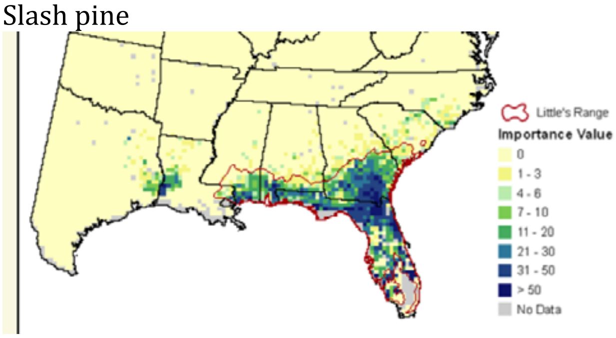
Loblolly pine



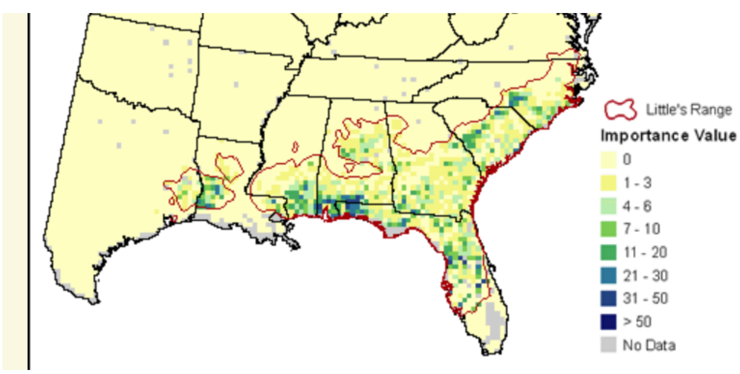
Shortleaf pine



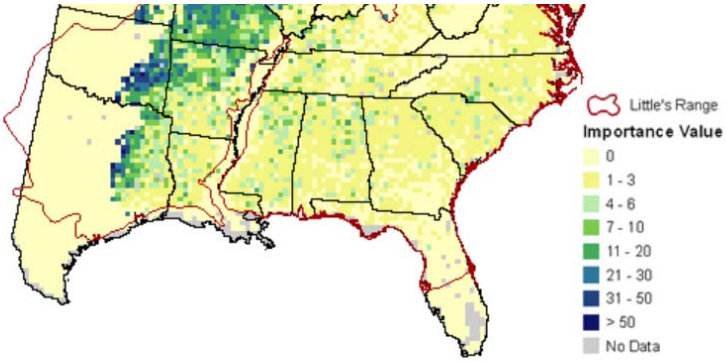
Slash pine



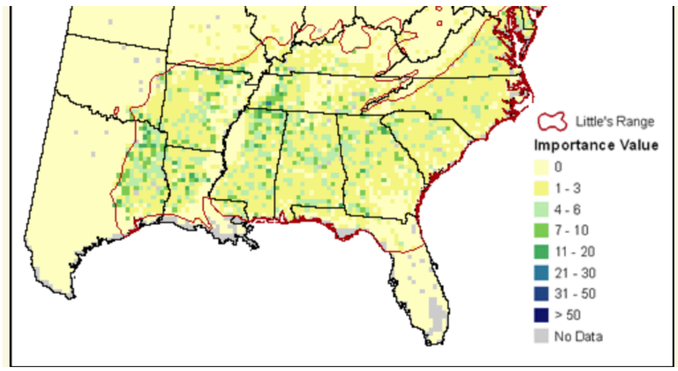
Longleaf pine



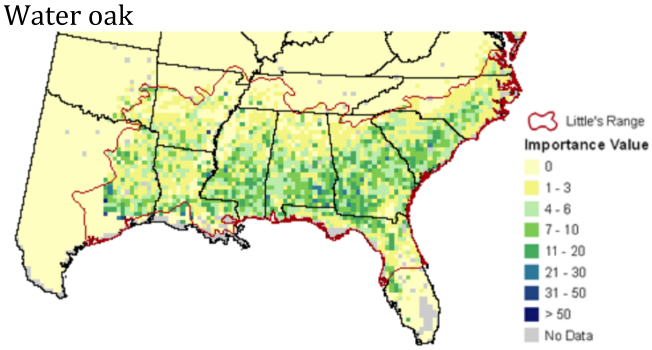
Post oak



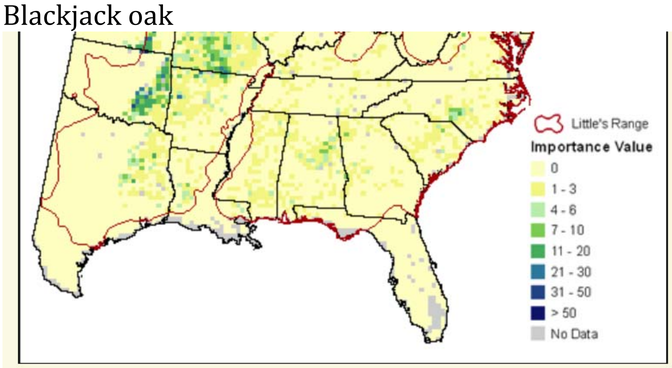
Southern red oak



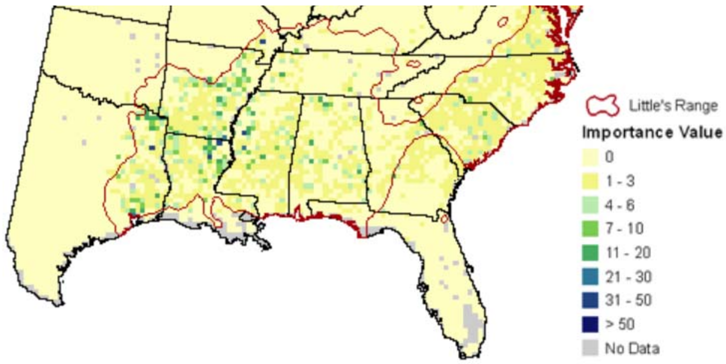
Water oak



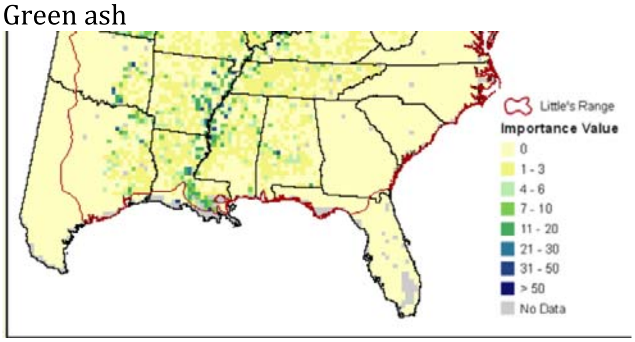
Blackjack oak



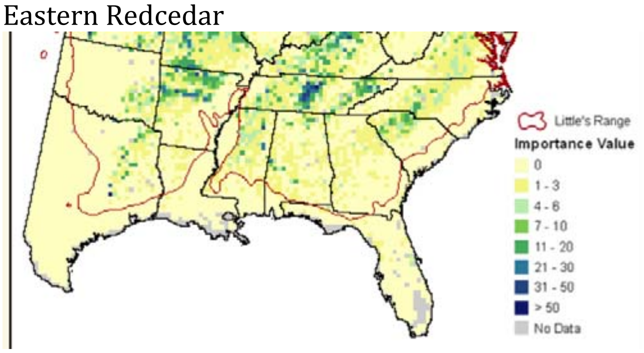
Willow oak



Green ash



Eastern Redcedar



Cedar elm

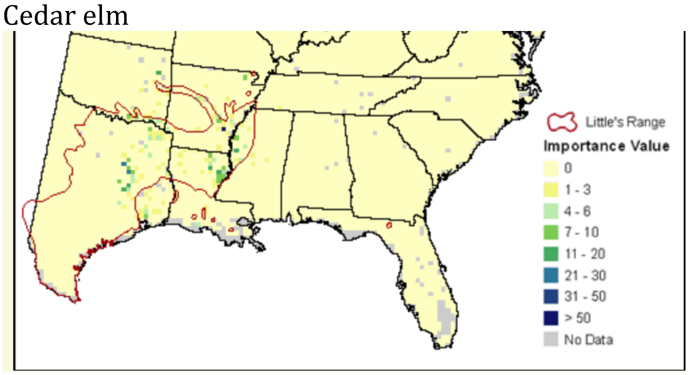


Figure A3. Current range of target trees based on FIA data (https://www.fs.fed.us/nrs/atlas/tree)