Scope of Work For

Project #20-007
Texas urban vegetation BVOC emission source inventory

Prepared for

Air Quality Research Program (AQRP)
The University of Texas at Austin

By

Tejas Shah (Principal Investigator)
Ramboll
Novato, California

Alex Guenther
1 Cervantes Ct
Irvine, California

June 5, 2020
Version #2

QA Requirements: Audits of Data Quality: 10% Required
Report of QA Findings: Required in Final Report

NOTE: The workplan package consists of three independent documents: Scope of Work, Quality Assurance Project Plan (QAPP), and budget and justification. Please deliver each document (as well as all subsequent documents submitted to AQRP) in Microsoft Word format.

Approvals

This Scope of Work was approved electronically on **06/08/2020** 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 **06/08/2020** by Miranda Kosty, Texas Commission on Environmental Quality

Miranda Kosty
Project Liaison, Texas Commission on Environmental Quality

Contents

1.0 Abstract

The overall goal of this project is to improve numerical predictions of regional ozone and aerosol distributions in Texas by using more accurate estimates of biogenic volatile organic compound (BVOC) emissions in Texas urban areas. Isoprene and other BVOC strongly influence atmospheric chemistry in urban Texas urban areas and can dominate the total VOC reactivity of at least some Texas urban locations (Anderson et al. 2019). Although there have been significant advancements in the models used to simulate BVOC emissions, there are still major uncertainties limiting predictability of Texas air quality simulations. Urban areas are the most challenging for BVOC emissions estimation, due to heterogeneity and a lack of vegetation information, and yet they continue to be the least studied. Recent ground surveys of urban tree inventories and increasingly higher resolution remote sensing data products have substantially improved the potential for characterizing the landcover inputs required for biogenic emission models. Therefore, we propose to improve both the Model of Emissions of Gases and Aerosols from Nature (MEGAN, Guenther et al., 2012) and the Biogenic Emission Inventory System (BEIS, Geron et al. 1994) frameworks for estimating BVOC emissions in Texas urban areas. To accomplish this, we will use urban tree inventories and aerial and satellite imagery to develop a high spatial resolution (~1 km) gridded inventory of time-varying Leaf Area Index (LAI), total vegetation cover, and the relative abundance of high BVOC emitting trees (e.g., live oaks, deciduous oaks, sweetgum, palms, pines, juniper) and other vegetation cover types for three Texas urban areas: Austin, Houston, San Antonio.

The primary deliverable will be more accurate landcover inputs for biogenic VOC emission models for estimating BVOC emissions for the urban and suburban areas. Outcomes will include improved biogenic emission estimates and a better understanding of the current uncertainties in urban biogenic emission model simulations. The overall benefit of this project will be more accurate VOC 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 drive the production of ozone and aerosol and other atmospheric constituents relevant for regional air quality. Volatile organic compound (VOC) emissions from trees and other vegetation (biogenic emissions; BVOC) are the dominant source of VOC for Texas urban areas[1]. BVOC emissions are highly variable and their atmospheric concentrations can vary more than an order of magnitude over spatial scales of less than a km 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. The purpose of this project is to improve the spatial

[1]https://www.tceq.texas.gov/assets/public/implementation/air/sip/dfw/dfw_ad_sip_2015/AD/Adoption/DFW_SIP_Appendix_B_060315.pdf

representation of biogenic emissions by using high resolution satellite imagery. This activity will benefit the Texas air quality simulation by improving the accuracy of the biogenic emission inventory for urban areas.

Urban areas are the most challenging for BVOC emissions estimation, due to heterogeneity and a lack of vegetation information, and yet they continue to be the least studied. Recent ground surveys of urban tree inventories and increasingly higher resolution remote sensing data products have substantially improved the potential for characterizing the landcover inputs required for biogenic emission models. This will be accomplished by developing an urban Leaf Area Index (LAI) and high BVOC tree fraction inventory for Texas by synthesizing ground survey data with aerial and satellite imagery. Our approach will capture spatial variation in urban biogenic emissions with ~1 km resolution. These data will then be used to compile suitable input datasets for both MEGAN and BEIS biogenic emissions models.

3.0 Objectives

The project comprises three major tasks:

1. To quantify high resolution (8 day, 10 m) LAI and vegetation cover fraction data for three major Texas urban areas: Houston, San Antonio, Austin.

2. To quantify high resolution (10 m) vegetation distributions of high BVOC emitting trees (e.g., live oaks, deciduous oaks, sweetgum, palms, pines, juniper) in the three major Texas urban areas.

3. To compile and assess vegetation characteristics input data for both MEGAN and BEIS models, update MEGAN Emission Factor Processor to improve processing of urban and other landcover data and investigate sensitivity of Texas urban biogenic emissions to landcover inputs.

4.0 Task Descriptions

Task 4.1. High resolution (8-day, 10-m) LAI and vegetation cover fraction for urban Texas

The LAI and cover fraction data generated for this task will be used to generate a ~1 km resolution database (Task 4.3) of the landcover inputs required by the MEGAN biogenic emission model, to account for spatial and seasonal foliar variations and to simulate changes in leaf age driven emission activity. We will also use the resulting LAI time series data to identify high BVOC emitters based on characteristic timing of leaf on and off events (Task 4.2). Vegetation cover fraction will also be used as a constraint on the total sum of cover fractions for individual tree (e.g., live oak trees, pine trees, etc.) and other vegetation types (e.g. grass, shrubs) created for Task 4.2.

We will use the Simplified Level 2 Product Prototype Processor (SL2P) to estimate LAI and total vegetation cover fraction (TVCF) from Sentinel-2 satellite Multispectral Instrument (S2/MSI) 10 m resolution data. The SL2P uses a neural network approach trained with a globally representative set of simulations from the PROSAILH canopy radiative transfer model (Weiss and Baret, 2016). The S2/MSI data processing includes radiometric and geometric correction using ground control points and a digital elevation model to correct for parallax error. The broad swath width (290 km) of each S2/MSI tile (Figure 1) spans across entire urban regions while the high resolution (10 m) can accurately capture tree cover in an urban setting (Wong et al. 2019).

The Sen2Cor processor will be used for cloud and shadow removal and to convert Sentinel-2 level 1 (MSIL1C) data to atmospherically corrected top-of-canopy reflectance data. We will select relatively cloud free images and will use the Sen2Cor scene classification map to mask any remaining cloudy pixels in the imagery. Each image will be visibly inspected to assess quality and geolocation errors. The S2/MSI satellite data will be accessed from the Copernicus Open Access Hub (https://scihub.copernicus.eu/). A full annual cycle (January to December) of 10-m resolution LAI will be generated for urban zones and surrounding areas as shown in Figure 2. We expect to use 2019 as a representative year (no severe drought) but will make a final selection in consultation with TCEQ staff.

To complete the project with less funding, we reduced the scope from five to three Texas urban areas. We prioritized regions that have available tree inventories which can be used to train the analysis method described in Task 4.2. For both LAI and TVCF data, we will process the Sentinel satellite tiles that cover the selected urban areas. Each Sentinel tile is 10,000 km^2. Within each Sentinel tile, our landuse classification will differentiate vegetated from hard (developed) surfaces. Houston requires 2 tiles (20,000 km^2), whereas Austin and San Antonio each have 1 tile. The original proposal (for 5 cities) would have been 70,000 km^2 and the reduced scope of work (Houston, Austin, San Antonio) is 40,000 km^2.

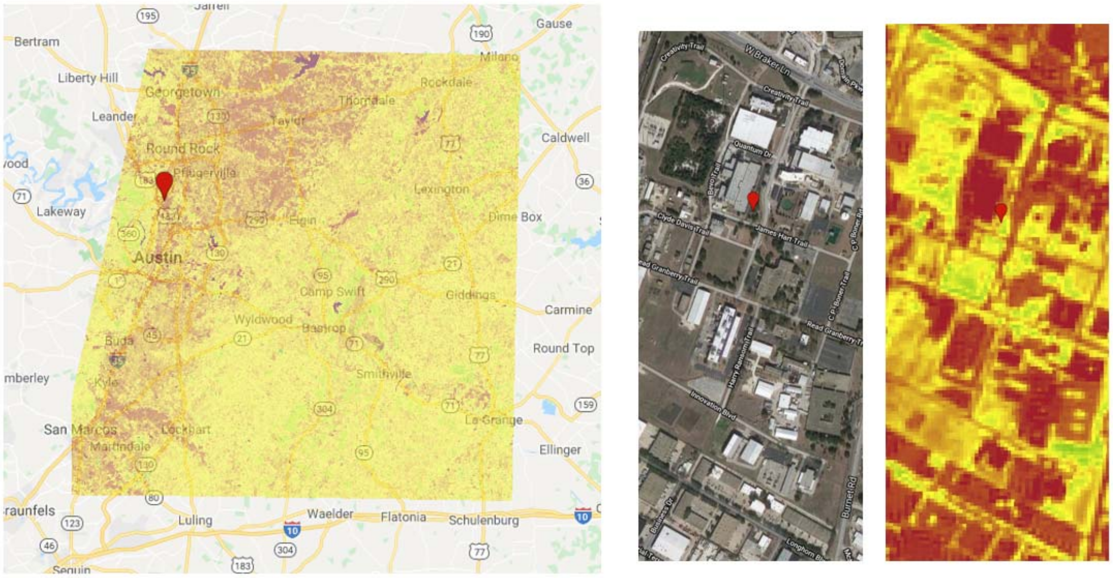

Figure 1. July 2019 Sentinel-2 based LAI estimates at 10 m resolution (red=0, yellow = low, green = high) for Austin TX and surrounding region (left) with zoomed in results for the U. Texas J.J. Pickle campus in Austin (right).

Figure 2. Extent of Texas urban regions (outlined in red) for which LAI, total vegetation cover fraction and vegetation type distributions will be estimated.

Deliverables: Task Technical Memorandum describing development of LAI and total vegetation cover fraction (TVCF).

Schedule: Complete by October 31, 2020.

Task 4.2. BVOC emitting tree distributions for the three major Texas urban areas

Table 1 summarizes the approach for training, extrapolating and assessing BVOC emitting tree cover distributions at 10 m resolution, according to the vegetation type scheme shown in Table 2, for each of the 3 Texas urban areas. The training and assessing activities will utilize a Texas urban tree inventory database, illustrated in Figure 3, that contains over 200,000 geolocated and identified individual trees. This existing urban tree inventory data is a valuable resource but is not a sufficient basis for characterizing Texas urban areas because it does NOT 1) include trees on private property, 2) all Texas urban areas, and 3) provide cover fraction. We will select and characterize more than 240 relatively homogenous zones (i.e., dominated by just one of the vegetation types listed in Table 2) within the 3 Texas urban areas using the approaches described in Subtask 2.1. Most of these areas will target high BVOC emitters and they will be randomly divided into two groups: one for training and the other for an independent assessment. We plan to use Austin as a training area for San Antonio because of the proximity of San Antonio to Austin and the tree inventory data is available for Austin.

Table 1. Approaches for quantifying Texas urban vegetation cover distributions.

Objective	Approach	Description	Imagery	Software
Training and assessment areas	Random point sampling	Identify vegetation in images at points in designated zones	High resolution Google Earth aerial photos	i-TREE
Training and assessment areas	Object based classification	Segment imagery into individual trees and identify by object based analysis	NAIP 60 cm aerial imagery (4 bands)	ARCGIS Pro
Extrapolation	Supervised classification of image pixels	Classify raster pixels at 10 m resolution using machine-learning algorithm	Multi-temporal 10 m Sentinel-2 data (13 bands)	ARCGIS Pro

Table 2. Vegetation type scheme for Texas urban vegetation cover

Urban Texas vegetation scheme	Growth form	MEGAN vegetation type	BEIS (LC ID) and description
Live oaks	Tree	Live oak	(132) Quercus virginiana
Deciduous oaks	Tree	Deciduous oaks	(147) Quercus spp.
Sweetgum	Tree	Sweetgum	(219) Liquidambar styraciflua
Palms	Tree	Palms	(15) Mixed forest
Pines	Tree	Pines	(174) Loblolly pine
Junipers	Tree	Junipers	(85) Juniperus spp.
Other high BVOC trees	Tree	Other high BVOC trees	(15) Mixed forest
Average BVOC trees	Tree	Average BVOC trees	(15) Mixed forest
Low BVOC trees	Tree	Low BVOC trees	(15) Mixed forest
Shrubs	Shrub	Shrubs	(9) shrubland
Herbaceous	Herbaceous	Herbaceous	(8) grassland
Crops	Crops	Crops	(4) cropland
No vegetation	None	Barren	(18) barren

Figure 3. Texas urban tree inventory data in a 10 km area near Texas Southern University in Houston (left) with > 1000 identified and geolocated trees per km2 (right).

Subtask 4.2.1. Training and evaluation areas

We will use the i-Tree Canopy application (see https://canopy.itreetools.org/), a state-of-the-art, peer-reviewed software developed by the USDA Forest Service for urban forestry analysis, to quantify urban vegetation type (Table 2) cover fractions within targeted areas. Training areas defined by ESRI shapefiles will be uploaded into the i-Tree canopy App. Interpreters will classify objects, according to the vegetation type scheme (Table 2), in Google Map aerial photo imagery at random points in each zone. Although i-Tree Canopy is normally used for total tree cover, we will adapt the approach to include high BVOC emitter categories.

We will also employ a complementary object-based classification approach that takes advantage of high resolution imagery (e.g., 30 cm StratMap and 60 cm NAIP 4 band imagery from data.tnris.org) available for urban Texas. Object based approaches group pixels into objects (segmentation) that are identified using a ruleset based on all available data. The developed rule set will then be applied to classify all trees and other vegetation in the training and assessment areas. An illustration of this approach is shown in Figure 4. Geolocated landcover (e.g. National Land Cover Database, NLCD), topography data and the urban tree inventory will be used in the object classification process. The accuracy of our estimates of BVOC emitting trees in these areas will be evaluated using the Texas urban tree inventory shown in Figure 3.

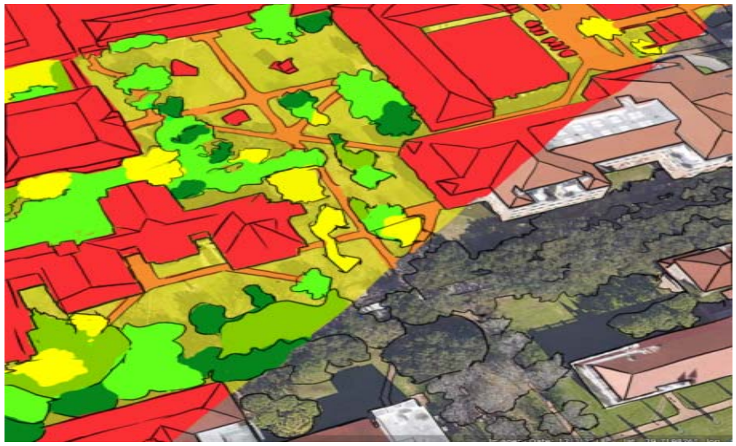

Figure 4. Simulation of object-based analysis of a Google Earth aerial image of Rice University campus. Lower right illustrates segmentation of the image into objects and the upper right illustrates the identification of objects including buildings and monuments (red), sidewalks (orange), grass (yellow-brown), live oak (dark green), deciduous oak (light green), sweetgum (yellow), low BVOC trees (bright green).

Subtask 4.2.2. Supervised classification of raster pixels

We will investigate the performance of at least three machine learning classification approaches (e.g., Random Forest, Support vector machine, Deep learning) and a classical supervised classification technique to determine the best approach for classifying BVOC emission types in each urban area. We will also investigate the use of both the 13 Sentinel-2 bands, with coarse bands regridded to 10 m resolution, and higher spatial resolution imagery (60 cm NAIP data and 30 cm STRATmap data), along with ancillary data (e.g. topography, NLCD landuse, tree surveys) to classify distributions of the thirteen cover types (Table 2) for the 3 Texas urban areas shown in Figure 2. Machine-learning algorithms can improve classification accuracy and run effectively over large areas and synthesize multiple datasets (Abdi, 2020).

The Sentinel-2 imagery resolution (4 bands at 10 m, 9 bands at 20 to 60 m) is not sufficient for identifying individual trees resulting in pixels containing a mixture of the 12 vegetation cover types listed in Table 2. However, the Sentinel-2 combination of frequent (5 day) revisits and multispectral (13 bands) sensor has successfully been used to characterize distributions of multiple tree species in complex landscapes. For example, Sentinel-2 data were used by Hoscilo and Lewandowska (2019) to classify distributions of eight broadleaf and conifer tree species (beech, oak, alder, birch, spruce, pine, fir, and larch) in a mixed forest in Poland and by Nomura and Mitchard (2018) to differentiate tree species (e.g., oil palm, rubber tree, betel nut, mixed forest) in a complex agricultural landscape in southern Myanmar. The utility of the LAI data is not the magnitude of the LAI but the seasonal variation behavior. We have successfully used multi-temporal LANDSAT-TM (30 m) images to quantify oak tree distributions for BVOC emission modelling (Baugh et al. 2001) and expect Sentinel-2 imagery to be a major improvement. For example, the Sentinel-2 data shown in Figure 5 for an urban Texas location illustrates the differences in seasonal LAI patterns for target species (live oak, decid. oak, other deciduous, pines). Live oak LAI is nearly constant across seasons while deciduous oak is high in June and early October and low in January. In contrast, grassy areas have lower LAI in June.

The accuracy of the proposed tree characterization approach will be assessed with ARCGIS confusion matrix assessment of accuracy and overall kappa statistic of agreement using the areas set aside for assessment. The total vegetation cover (Subtask 4.2.1) will be an overall constraint on the sum of individual vegetation cover types.

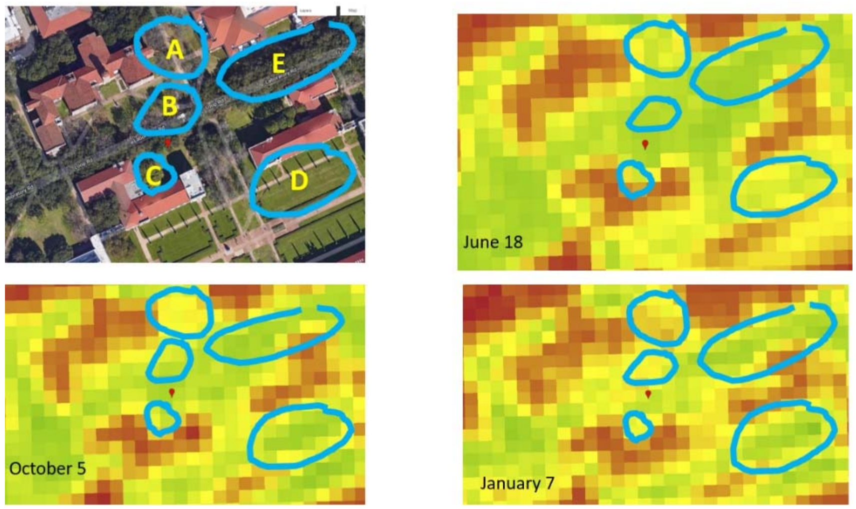

Figure 5. Google Earth image (upper left) of Rice University campus and corresponding Sentinel-2 LAI estimates (red=0, yellow = low, green = high) for June, July and January. On-site inspection and geolocated tree inventory indicates the five circled areas are covered by A: low BVOC trees, B: deciduous oak trees, C: Pine trees, D: grass, E: live oak trees.

Deliverables: Task Technical Memorandum describing development of relative abundance of high BVOC emitting trees and other vegetation cover types.

Schedule: Complete by March 31, 2021.

Task 4.3. MEGAN and BEIS input data, processors and results

The overall goal of Task 4.3 is to provide urban landcover data in an appropriate format for input to the MEGAN3.1 and BEIS3.61 BVOC emission models and to assess the impact of these new landcover data on biogenic emission estimates in urban Texas. To avoid discontinuities associated with inserting a rectangular domain of new data into the existing MEGAN BEIS data, we will apply an urban mask with ~1 km resolution and will replace the existing MEGAN and BEIS landcover only where the built-up area cover is >15%.

Subtask 4.3.1. MEGAN landcover, updated Emission Factor Processor and meteorological input data

ARCGIS will be used to remap the vegetation cover developed for Task 4.2 onto the 30 second (~ 1km) resolution of the MEGAN preprocessor. The results will be in the format required by the MEGAN3.1 emission factor processor (EFP) for integrating plant species-specific emission factors and landcover data to generate landscape averaged emission factors. We will also improve MEGAN capabilities for estimating urban and rural BVOC emissions by revising the EFP python code. This will include simplifying the chemical species and quality indicator (j value) schemes. We will also add the vegetation types introduced in Table 2 into the MEGAN3.1 EFP database and assign appropriate emission factors and vegetation characteristics data.
MEGAN relies on meteorological input data that typically originate from the WRF model and have been re-formatted by the MCIP preprocessor for the CMAQ model. A recent MCIP update deprecated the output of certain data that MEGAN requires but CMAQ no longer requires. The CAMx preprocessor that corresponds to MCIP is named WRFCAMx. We will update WRFCAMx to output meteorological data for MEGAN and thus ensure these data remain easily accessible and simplify application of MEGAN to support CAMx.

Subtask 4.3.2. Integrate Texas urban vegetation data into BELD

We will integrate the Texas urban vegetation cover data developed for Task 4.2 into the BELD database to enable use with BEIS. BELD landuse cover for urban areas is derived from broadly defined (e.g., mixed forest, urban developed, etc.) classes from county level and ~1 km gridded data sources such as agricultural census and Earth Resources Observation Systems (EROS) Advanced Very High Resolution Radiometer (AVHRR) coverages. The BELD, which integrates forest inventory for species level information, provides reasonable estimates of forest coverage by species at multi-state and regional scales. However, the existing urban forest canopy data fail to capture variations that exist within and between most urban areas. A recent comparison of newly available urban forest inventory data versus traditional FIA used in BELD shows that the explicit urban inventories differ in canopy cover and BVOC emission potential by approximately a factor of 3 for Austin. The recent coverages yield BVOC estimates considerably larger than previously modeled. The Texas vegetation coverages developed under Task 4.2 will be integrated into BELD and similar datasets at a minimum scale of 1 km annual peak canopy cover by forest type class. While the current structure of the BELD is technically capable of integrating much higher resolution data for urban areas, we anticipate that high resolution data generated in this work would probably require aggregation to some intermediate spatial resolution for data handling purposes. Higher species, spatial, and temporal resolutions will be available depending on applications. This will include the effects of temporally varying LAI.

Subtask 4.3.3. Assess and compare MEGAN and BEIS sensitivity to Texas urban vegetation data

We will assess the sensitivity MEGAN and BEIS results to Texas urban landcover by comparing landscape average BVOC emission factor distributions generated with 1) current BEIS, 2) current MEGAN, 3) revised BEIS, 4) revised MEGAN. Emissions generated with the four approaches will be investigated for each of the three Texas urban areas. The impact of the new

MEGAN vegetation type distributions and the new MEGAN LAI data will be assessed both individually and in combination.

Deliverables: Task Technical Memorandum describing development of updated urban landcover data in a format required by MEGAN3.1 and BEIS3.61 and results of MEGAN and BEIS sensitivity.

Schedule: Complete by July 31, 2021.

Task 4.4. Project Reporting and Presentation

At the start of the project, we will hold a kickoff call with AQRP and TCEQ representatives to discuss the work plan and specific details of the project, answer questions, and address anticipated issues.

As specified in Section 7 "Deliverables" of this Scope of Work, AQRP requires the regular and timely submission of monthly technical, monthly financial status and quarterly reports as well as an abstract at project initiation and, near the end of the project, submission of the draft final and final reports. Additionally, at least one member of the project team will attend and present at the AQRP data workshop. Ramboll's Principal Investigator 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. The reports will follow templates and accessibility guidelines available on the AQRP website http://aqrp.ceer.utexas.edu/.

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 subaward.

Finally, Ramboll's project team will prepare and submit our final project data and associated metadata to the AQRP archive.

Deliverables: 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.

Schedule: The schedule for Task 4.4 Deliverables are shown in Section 7.

5.0 Project Participants and Responsibilities

This project is being conducted by Ramboll, Wildland Solutions, Alex Guenther, and Chris Geron team under a grant from the Texas Air Quality Research Program (AQRP). The project Principal

Investigator (PI) is Mr. Tejas Shah, who will assume overall responsibility for the research and overall responsibility for quality assurance. Dr. Alex Guenther and Dr. Greg Yarwood will serve as a technical advisor for all tasks. Other staff members instrumental to the technical work include Dr. Ling Huang of Ramboll, Mr. Keith Guenther of Wildland Solutions and Mr. Chris Geron. Dr. Ling Huang will carry out modification to the MEGAN3.1 source code and Emission Factor Processor. Chris Geron led the development of the BEIS biogenic emission model and BELD biogenic emissions landcover database in his past role as a scientist at the US EPA. He is also an expert in tree cover characterization. Mr. Chris Geron will lead the development of BELD biogenic emissions landcover database. The personnel working on this project and their specific responsibilities are listed in Table 3.

The project will be overseen by AQRP Project Manager Dr. Elena McDonald-Buller and TCEQ Project Liaison Miranda Kosty. They will review the project deliverables and documentation.

Table 3. Project participants and their key responsibilities.

Participant	**Key Responsibilities**
Tejas Shah (Ramboll)	Principal investigator, lead Ramboll's effort for compiling MEGAN input data, updating MEGAN3.1 EFP and source code, develop and review reports and presentations, and overall quality assurance.
Greg Yarwood (Ramboll)	Project technical advisor
Dr. Alex Guenther (Independent Consultant)	Lead researcher, technical lead for Task 4.1 and 4.2 to compile high resolution LAI, vegetation cover fraction data and the tree inventory, and reviewer
Chris Geron (Independent Consultant)	Lead the development of BELD biogenic emissions landcover database and contribute to reporting
Keith Guenther (Wildland Solutions)	Lead image processing for landcover characterization, technical consultant, and contribute to reporting
Dr. Ling Huang	Assist with developing input data for MEGAN3.1, carrying out modification to the MEGAN3.1 EFP and source code.
Jean Guo	Assist with various data analysis tasks.

6.0 Timeline

The planned duration of the project is 15 months (June 2020 – August 2021). An overall schedule of project activities by task is shown in Table 4. The schedule assumes a start date during June 2020 and end date of August 31, 2021.

Table 4. Schedule of project activities (tasks are bolded).

ID	Task	2020							2021							
		J	J	A	S	O	N	D	J	F	M	A	M	J	J	A
	Kickoff Meeting	X														
1	High resolution LAI and vegetation cover fraction		X	X	X	X										
2	**BVOC emitting tree distributions**															
2.1	Training and evaluation areas				X	X	X	X								
2.2	Supervised classification of raster pixels								X	X	X					
3	**MEGAN and BEIS input data, processors and results**															
3.1	MEGAN input data, updated EFP and meteorological input data											X	X	X		
3.2	Integrate Texas urban vegetation data into BELD											X	X	X		
3.3	Assess and compare MEGAN and BEIS sensitivity to Texas urban vegetation data													X	X	
5	Monthly Progress Reports	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
5	Quarterly Progress Reports		X			X			X			X			X	
5	Draft Final														X	
5	Final															X
	AQRP Workshop															X

7.0 Deliverables

AQRP requires certain reports to be submitted on a timely basis and at regular intervals. A description of the specific reports to be submitted and their due dates are outlined below. The lead PI will submit the reports, unless that responsibility is otherwise delegated with the approval of the Project Manager. All reports 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. Report templates and accessibility guidelines found on the AQRP website at http://aqrp.ceer.utexas.edu/ will be followed.

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: Friday, July 31, 2020

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 2 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
Quarterly Report #1	May, June, July 2020	Friday, July 31, 2020
Quarterly Report #2	August, September, October 2020	Friday, October 30, 2020
Quarterly Report #3	November, December 2020, January 2021	Friday, January 29, 2021
Quarterly Report #4	February, March, April 2021	Friday, April 30, 2021
Quarterly Report #5	May, June, July 2021	Friday, July 30, 2021

Monthly Technical Reports (MTRs): Technical Reports will be submitted monthly to the Project Manager and TCEQ Liaison in Microsoft Word format using the AQRP FY20-21 MTR Template found on the AQRP website.

MTR Due Dates:

Report	Period Covered	Due Date
Technical Report #1	Project Start - June 30, 2020	Friday, July 10, 2020
Technical Report #2	July 1 - 31, 2020	Monday, August 10, 2020

Technical Report #3	August 1 - 31, 2020	Thursday, September 10, 2020
Technical Report #4	September 1 - 30 2020	Friday, October 9, 2020
Technical Report #5	October 1 - 31, 2020	Tuesday, November 10, 2020
Technical Report #6	November 1 - 30, 2020	Thursday, December 10, 2020
Technical Report #7	December 1 - 31, 2020	Friday, January 8, 2021
Technical Report #8	January 1 - 31, 2021	Wednesday, February 10, 2021
Technical Report #9	February 1 - 28, 2021	Wednesday, March 10, 2021
Technical Report #10	March 1 - 31, 2021	Friday, April 9, 2021
Technical Report #11	April 1 - 30, 2021	Monday, May 10, 2021
Technical Report #12	May 1 - 31, 2021	Thursday, June 10, 2021
Technical Report #13	June 1 - 30, 2021	Friday, July 9, 2021

Financial Status Reports (FSRs): Financial Status Reports will be submitted monthly to the AQRP Grant Manager (RoseAnna Goewey) using the AQRP 20-21 FSR Template found on the AQRP website.

FSR Due Dates:

Report	Period Covered	Due Date
FSR #1	Project Start - June 30	Wednesday, July 15, 2020
FSR #2	July 1 - 31, 2020	Friday, August 14, 2020
FSR #3	August 1 - 31, 2020	Tuesday, September 15, 2020
FSR #4	September 1 - 30 2020	Thursday, October 15, 2020
FSR #5	October 1 - 31, 2020	Friday, November 13, 2020
FSR #6	November 1 - 31, 2020	Tuesday, December 15, 2020

FSR #7	**December 1 - 31, 2020**	**Friday, January 15, 2021**
FSR #8	**January 1 - 31, 2021**	**Monday, February 15, 2021**
FSR #9	**February 1 - 28, 2021**	**Monday, March 15, 2021**
FSR #10	**March 1 - 31, 2021**	**Thursday, April 15, 2021**
FSR #11	**April 1 - 30, 2021**	**Friday, May 14, 2021**
FSR #12	**May 1 - 31, 2021**	**Tuesday, June 15, 2021**
FSR #13	**June 1 - 30, 2021**	**Thursday, July 15, 2021**
FSR #14	**July 1 - 31, 2021**	**Friday, August 13, 2021**
FSR #15	**August 1 - 31, 2021**	**Wednesday, September 14, 2021**
FSR #16	**Final FSR**	**Friday, October 15, 2021**

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: Monday, August 2, 2021

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: Tuesday, August 31, 2021

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 (September 20, 2021). 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 the first half of August 2021.

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 Subaward.

8.0 References

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