SUSTAINABLE BIOECONOMY FOR ARID REGIONS (SBAR)

Summary Report – Quarter 1, 2019

Information submitted by project partners; synthesized by:
Alix Rogstad, Project Director

USDA Cover Page

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ACCOMPLISHMENTS
January 2019 – March 2019

INTRODUCTION AND PROJECT MANAGEMENT

General Overview: Project Organization

The Sustainable Bio-economy for Arid Regions (SBAR) Center of Excellence continues to receive project direction and oversight from Dr. Kimberly Ogden, who leads the overall research effort and ensures adequate progress toward meeting project goals. The SBAR Project Director (Alix Rogstad) continues to manage all of the day-to-day project administration and business affairs, as well as coordination, communication, and data sharing among partnering organizations and institutions.

A comprehensive project evaluation plan, approved in July 2018, continues to be effective at capturing detailed progress on the project's defined objectives. As a living document, the evaluation plan will change over the project life to reflect revised research questions, project goals and big-picture, overall objectives.

Advisory Board

Two individuals joined the Advisory Board this quarter, replacing those that have rolled off. The two new members are John Holladay (Pacific Northwest National Laboratory) and Paul "Paco" Ollerton (Tierra Verde Farms) (Table 1). Receiving the signed non-disclosure agreements (NDA) to ensure confidentiality of research data, information, and conclusions for the duration of the project is on going. To date 5 NDAs have been completed and returned, 4 other Advisory Board members are subject to existing project NDA and confidentiality agreements, and the remaining 7 NDAs are pending.

Table 1. *SBAR Advisory Board members.*

Advisory Board Member	Company/ Representation	Year Joined Board
Chris Cassidy	USDA, Rural Development	2018
Matt Chavez	Independent Grower, NM	2017
Steve Csonka	Commercial Aviation Alternative Fuels Initiative (CAAFI)	2017
Mark DeDecker	Bridgestone Americas, Inc.	2017
Gary Deen	Double D Farms, AZ	2017
William Goldner	USDA, National Institute of Food and Agriculture	2017
John Holladay	Pacific Northwest National Laboratory	2019
Chris Kuzdas	Environmental Defense Fund	2018
Homer Marks	Southwest Indian Agriculture Association, Tohono O'odham Nation	2017
Newt McCarty	NMSU, Extension Educator	2018
Jaroy Moore	Texas A&M Agrilife Research & Extension Center	2017
Alex Muravijov	Guar Resources	2017
Paul "Paco" Ollerton	Tierra Verde Farms, AZ	2019
Matt Payne	West Water Research, Inc.	2018
Bob White	Bridgestone Americas, Inc.	2017

Budget and Financial Management

On-going budget management activities are working effectively, and all project expenditures are on track. Rogstad continued to develop sub-award agreements, non-disclosure agreements, and work with partners to ensure grant funds are spent according to the project plan and approved scopes of work.

Sub-awards are fully activated with all project partner institutions: Bridgestone Americas, Inc., New Mexico State University (NMSU), Colorado School of Mines (CSM), Colorado State University (CSU), and the USDA-Agricultural Research Service (USDA-ARS). All sub-awards are progressing appropriately.

Component Working Group Meetings

All five SBAR component working groups continued to participate in scheduled online meetings to ensure forward momentum on all project tasks. Smaller focus group meetings were scheduled and facilitated as necessary. During this reporting period, the virtual meeting space (via Zoom) was utilized 42 times for over 71.3 hours. An additional 12 meetings were hosted during the same timeframe that did not require the virtual meeting space.

LEADS Team Meetings

The component leaders and co-leaders (LEADS) continued to meet with Ogden and Rogstad during established twice-monthly meetings held via SBAR's dedicated Zoom online meeting space.

2019 SBAR Annual Retreat

The 2019 SBAR Annual Retreat is under development. The meeting will be hosted at the University of Arizona in Tucson (12-13 September), in collaboration with the Association for the Advancement of Industrial Crops (AAIC).

Communication and Reporting

Reporting schedules for researchers are established and working well. Quarterly reports submitted are synthesized and made available to the research team and Advisory Board members. A Task Tracker Report is provided to the LEADS, which gives a status update for each team member per component. The Task Tracker Report is a proactive management tool that allows the identification of issues before they become risks for overall project completion.

Website and Social Media

The SBAR-specific website (www.sbar.arizona.edu) continues to be regularly updated and maintained, serving as the "face" of the SBAR Center. There were 576 unique sessions from January – March 2019, which was an increase of 100 unique visits as compared to the previous quarter. Page views occurred in 20 different countries this quarter (top two: USA and India), though since activation the website has had visitors from 30 different countries (Table 1).

This quarter experienced an increase of 300 webpage visits from the USA as compared to last quarter, which demonstrates an increase in awareness about the SBAR Center. There have been 2,058 unique website sessions since July 2018. The highest visited website pages during

this period included those that provide the project overview/general description, define the mission/objectives, and highlight our research teams and project partners. The website will be updated regularly as the project unfolds.

Table 2. *Web traffic to the SBAR Center webpage since inception.*

Country	Time Period		
	Jul – Sep 2018	Oct – Dec 2018	Jan – Mar 2019
Australia		X	X
Austria	X		
Brazil			X
Canada	X	X	X
China		X	X
Egypt		X	
Estonia			X
Ethiopia		X	
France			X
Germany	X	X	
Hong Kong	X	X	
India	X	X	X
Iran	X		X
Israel			X
Italy	X	X	X
Japan	X	X	X
Kuwait		X	X
Malaysia			X
Mexico		X	X
Nepal		X	
New Zealand	X		
Pakistan		X	
Philippines	X		
Poland			X
South Africa			X
Thailand	X		
Turkey		X	X
United Kingdom	X	X	X
United States	X	X	X
Zambia			X

FEEDSTOCK DEVELOPMENT & PRODUCTION

Project Coordination: The two Feedstock Development (FD) working groups continue to meet monthly and on an as-needed basis in between monthly meetings. The UA continues to lead both monthly meetings, which are leveraged to ensure all team members are on schedule and research work can seamlessly integrate between components. The FD team members also meet during weekly research team meetings (all-hands) hosted at both the UA and New Mexico State University. These weekly briefings provide an opportunity for open communication regarding on-going experiments and results.

Issues/Risks:
The USDA-ARS's main **issue** is personnel. Transformations and plant culture maintenance requires a lot of hands-on time and skill. Student interns were used in the summer of 2018 to perform transformations with fair results. We were able to hire a more experienced technician in October 2018, and progress accelerated. Unfortunately, the technician resigned effective April 2019. We are in the process of looking for additional technician help.

Due to a thrips infestation in the greenhouse, plant leaves were damaged and need to recover before treatments can proceed. This is causing a slight delay in the cuticular wax experiments.

The rainfall received in late September and early October 2018 and accompanying cool temperatures delayed start of the Eloy and Maricopa studies. A Marana preemergence study was established in September 2018 and the Maricopa preemergence and preplant-incorporated herbicide experiments started in October; good data was obtained in the studies. Ultimately, we were unable to proceed with the Aim and clethodim postemergence studies. This will delay getting a new 24c SLN for Aim use on guayule seedlings by 6 to 12 months. However, we will eventually get the data FMC needs to support this registration. The problems at Eloy will probably not delay obtaining additional grass herbicide registrations.

We have a 6 month delay for analysis of the soils sampled in Year 1. This delay is related to the training of new personnel and developing quality control procedures to deal with high variability in the analysis of chemical properties and DNA biomass extracted from the soils.

Objective 1. Improve biomass quantity and quality through genetics and traditional breeding.

Task #	Description of Task	Deliverable	Target Completion Date
1 Dierig	Evaluate USDA germplasm lines	Ploidy analysis completed	31 Aug 19
2 McMah	Prepare expression vectors for downregulation of SEPATALLA3 and FLOWERING LOCUS T genes in guayule	Complete construct for transformation work on SEPATALLA3	30 Nov 18 31 Mar 19

		Complete construct for transformation work on FLOWERING LOCUS T	
3 McMah	Perform plant transformations using all 3 constructs (AP1, SEP3, FT)	Confirmed transformation for invitro plants – 6 lines AP1 Confirmed transformation for invitro plants – 6 lines SEP3 Confirmed transformation for invitro plants – 6 lines FT	30 Jun 19 30 Jun 19 30 Jun 19
4 Ray	Evaluate Yr1 growth and rubber/resin content in guayule germplasm lines	Growth characteristics determined in 21 guayule germplasm lines Rubber/resin content determined in 21 guayule germplasm lines	15 Oct 18 15 Oct 18
5 Ray	Compare root growth/architecture and water use in direct-seeded and transplant-established guayule	Plantings established Compare root growth and top growth for direct-seeded and transplant-established plants	5 Nov 18 15 Jun 19
6 Ray	Develop protocols for collection/evaluation of guayule leaf cuticular wax	Preliminary information to finalize protocol both for leaf collection and GC Mass Spec evaluation Cuticular waxes described and compared	15 Dec 18 15 Aug 19

Evaluate Germplasm Lines (Variety Trials):

Plants from each replication of all varieties from the two trials with USDA germplasm lines at Bridgestone Eloy were harvested at 11 months-old in March 2019. Samples are being analyzed for dry weight, rubber and resin content and estimated yield per acre. Data will be provided in the next report.

Expression Vectors for Downregulating SEP3 and FT Genes:

Our project seeks to enhance natural rubber content in guayule by downregulation of flowering. Previously, three target genes, all transcription factors related to flowering, were identified. In the last quarter of 2018 and the first quarter of 2019, guayule transformation constructs were completed for the second gene, that is, *SEPATTALA (SEP)* and third gene, that is, *FLOWERING LOCUS T (FT)* genes. As a reminder, the target genes are:

1. **Downregulation** of *APETALA1 (AP1),* which promoted flowering in citrus (Pena *et al.* 2001).
2. **Downregulation** of *SEPATTALA (SEP)* a class E protein that may have a role in all aspects of flower development (sepal identity, petal identity, ovule identity, stamen identity, and carpal identity), in combination with other transcription factors.
3. **Downregulation** of *FLOWERING LOCUS T (FT).* FT2 downregulation in sugar beet resulted in continued vegetative growth without flowering (Pin et al. 2017).

Now that the constructs are prepared, we are also considering a combination of two or more of these approaches.

Plant Transformations using AP1, SEP3, and FT Genes:
Genetic transformation of guayule is known to be difficult (efficiencies under 1%) so many transformation attempts must be made to recover bioengineered plants. In 4Q18-1Q19, leaf disc transformations were conducted using the AZ-2 cultivar. As of the end of March we had 1020 calli growing in culture for the APETALA1 gene (Figure 1A), and 1003 calli growing in culture SEPATTALA3 gene (Figure 2A). Leaf and developing calli from previous attempts, especially our initial candidate gene: *APETAL1,* were subcultured under selection pressure, every two weeks. We are starting to see shoot formation from some of the calli (Figure 1B). We continue to maintain cultures to recover transformed plants from these 3 constructs.

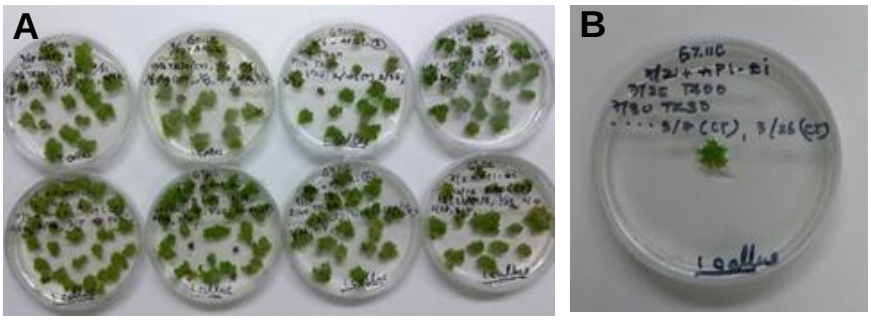

Figure 1. *Calli (A) and shoots (B) emerging from leaf discs transformed with AP1-2i.*

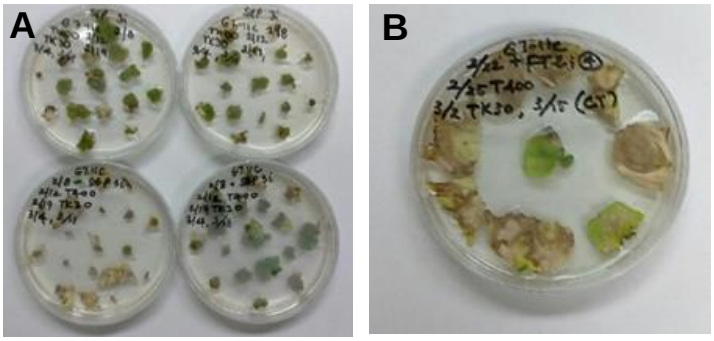

Figure 2. *Calli emerging from leaf discs transformed with (A) SEPATTALA (SEP3) and (B) FLOWERING LOCUS T (FT2).*

Yr1 Growth and Rubber/Resin Content in Guayule Germplasm Lines:
Research associated with this task has been completed; no new data to report.

Root Growth/Architecture Compared to Water Use in Direct Seed and Transplant-Established:
Research is continuing as planned; measurements were not taken this quarter and there are no new data to report.

Cuticular Wax Collection/Evaluation Protocols:
No progress has been made on this task.

Objective 2. Develop high-throughput phenotyping to support crop expansion using remote-sensing methods to create interactive databases/tools.

Task #	Description of Task	Deliverable	Target Completion Date
1 Abdel-H	Phenotypic characterization - Guayule	Collect and analyze available phenotypic data; plant stand and establishment, plant height and width, and flowering time Collect and analyze first set of available high-throughput phenotyping (HTP) parameters: vegetation indices and reflectance	15 Jul 19 15 Jul 19
2 Dierig	Remote sensing evaluation of USDA germplasm lines	Rate of growth comparison between lines completed	31 Aug 19
3 Dierig	Thermogradient table analysis	Germination data completed	31 Oct 18
4 Dierig	Leaf characterization	Trichome and color analysis of leaves from plants of 10 lines in variety trials	30 Sep 18

Phenotypic characterization – Guayule:

A field trial containing 48 USDA guayule accessions were planted at MAC farm, Maricopa, AZ in randomized completed block Design (RCBD) with four replicates each. Each replicate consists of four rows spaced at 40 inches each and 10 -long plots, within each row plants are spaced at 12 inches. Plots are maintained by hand weeding as needed and surface irrigation at bi-weekly interval based on the weather and plant growth stage.

Collect and analyze available field phenotypic data of one-year old plants.
To achieve the agronomical characterization of guayule USDA genotypes under field conditions, plant height was recorded two times traditionally in cm for plants at two-months interval. (Figure 3)

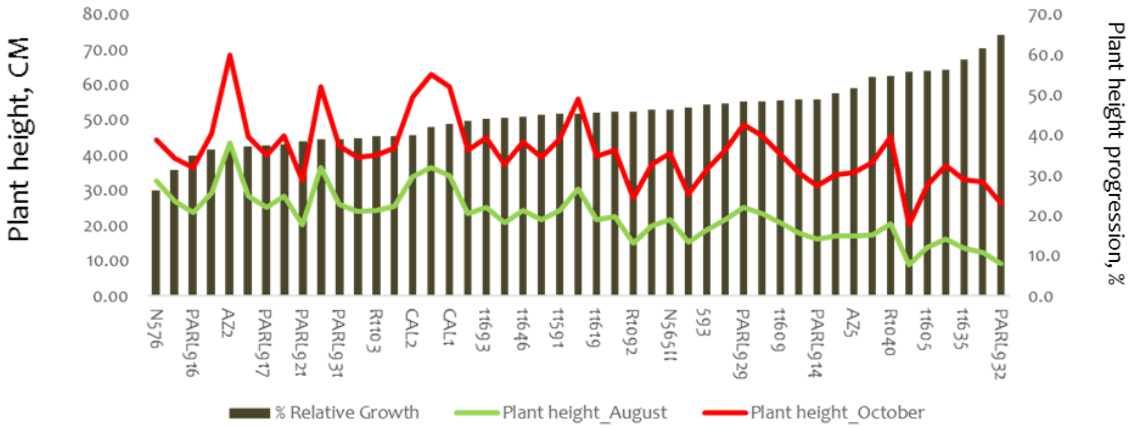

Figure 3. *Plant height for guayule plants meaured at Maricopa Agriculture Center, Maricopa AZ at 2-month intervals.*

Analysis of variance (ANOVA) showed significant differences among guayule genotypes for the plant height at the two measurements, that indicating the high possibility to detect variations in other traits such as rubber content. The tetraploid genotypes such as AZ2 were taller than the diploid (CAL3). It is known that ploidy level could affect plant performance including height and growth. There were significant variations among genotypes in relative plant growth as function of plant heights. These differences among genotypes, could be independent from plant height, and different mechanisms could be controlling plant height and growth rate.

To estimate the rubber and resin contents of one-year guayule genotypes, two plants from each plot were harvested individually, dried, chipped and ground using hummer then Wiley mills. (Photos 1-3) The final ground samples were then prepared for transfer to the Bridgestone Guayule Research Farm in Eloy, AZ for rubber and resin contents using NIRS models.

Photo 1. *Harvesting guayule from the field, Maricopa AZ.*

Photo 3. *Chipping the harvested and dried guayule plants.*

Photo 2. *Grinding chipped guayule plants into a fine powder for final NIRS analysis.*

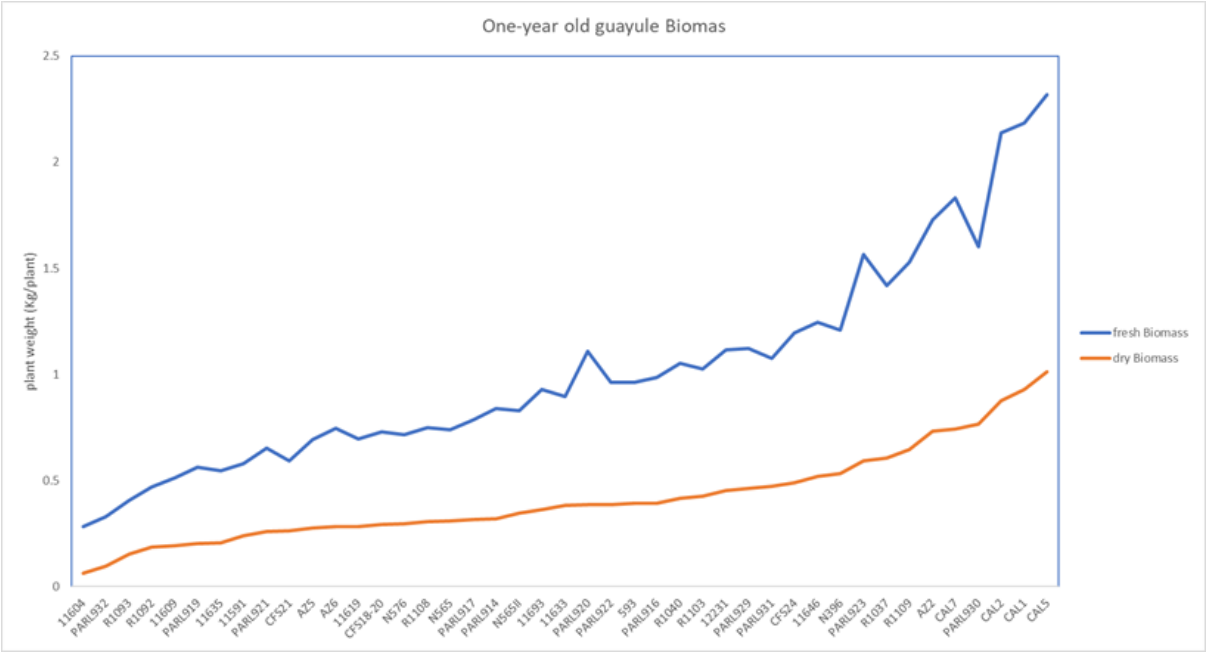

Figure 4. *One-year old guayule biomass for freshly harvested and dried plants.*

The fresh and dry biomasses were assessed for one-year old guayule plants (Figure 4). ANOVA revealed the significant variations in these traits among guayule genotypes. Guayule biomass is important factor in final rubber production determination, phenotypic variations in such traits will allow for selecting high rubber content as well as higher rubber production.

Collect and analyze high-throughput phenotyping (HTP) parameters for one-year old plants.

Photo 4. *A high-clearance tractor used for High-Throughput Phenotyping (HTP) at ALARC in Maricopa, AZ.*

At ALARC, Maricopa, AZ, we developed a high-clearance tractor equipped with proximal sensors mounted on modified LeeAgra AvengerPro spray rig to collect FB-HT data for guayule and other crops (Photo 4). The HTP platform uses proximal data captured from electronic sensors to measure canopy multi-spectral reflectance to estimate different vegetation and chlorophyll content indexes and canopy temperature. Canopy reflectance is recorded at six wavelengths using Holland Scientific ACS-470 CropCircle sensors, which utilize an active pulse-modulated polychromatic light source. Canopy temperature is measured by Apogee SI-131 infrared thermometers. The reflectance data were used to construct vegetation indices (VI) including; Normalized difference vegetation index-red (NDVIR), Normalized difference vegetation index-amber (NDVIA), Physiological reflectance index (PRI), Normalized difference vegetation index-red-red edge (NDRRE), Normalized difference vegetation index-amber-red edge (NDARE), Normalized difference red edge index (NDRE), DATT index, and Meris terrestrial chlorophyll index (MTCI). Beside these indexes, we also collected data for canopy temperature. Data are collected at regular base weekly and will be analyzed during the growing season.

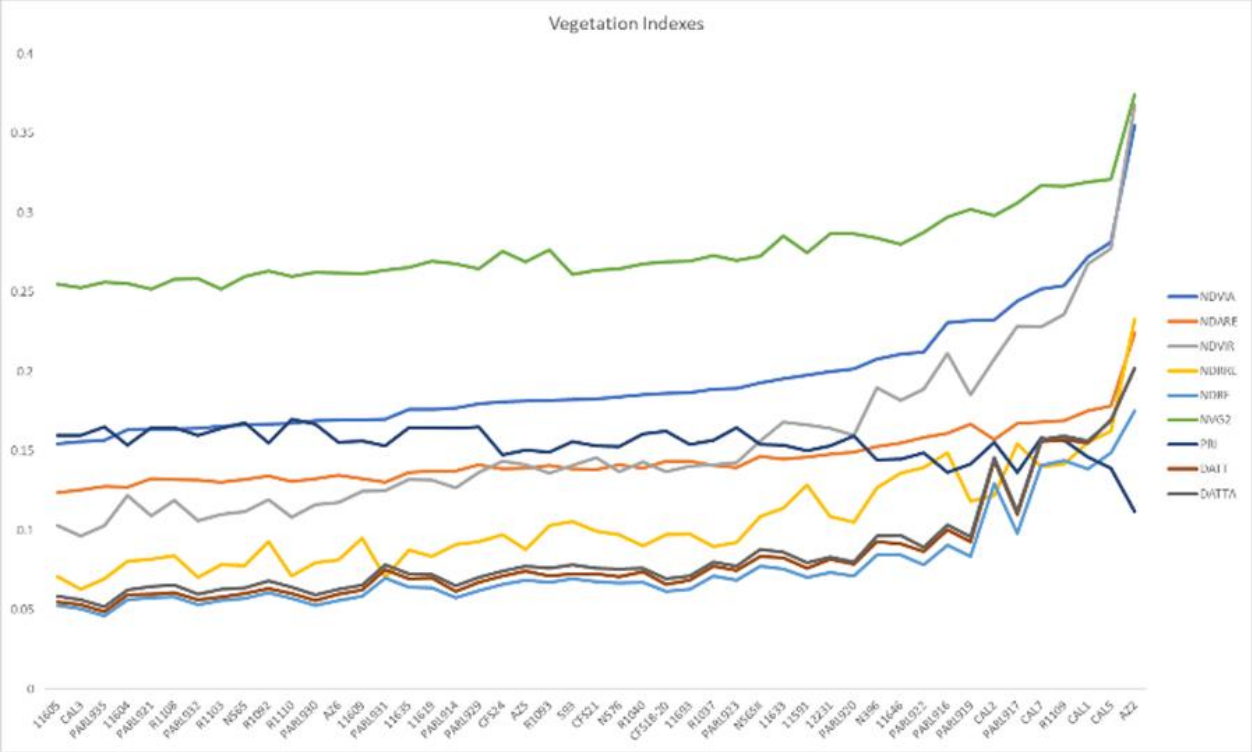

Figure 5. *Vegetation index readings for guayule genotypes at Maricopa Agriculture Center, Maricopa AZ.*

ANOVA indicated significant variations among guayule genotypes for studied vegetation indexes (Figure 5). For example, the NDVI index ranges from 0.15 to 0.36 for studied genotypes. The higher NDVI value indicates the healthier the plant is. Among guayules, highest NDVI were observed in improved germplasm, as general role, as well some wild genotypes showed high in NDVI values as well biomass such as R1109 that is potential candidate for future genetic improvement effort.

Canopy temperature reflects guayule responses to surrounding air temperature and growth conditions. Under our normal trial conditions, guayule genotypes showed significant differences in this trait, indicating the differential responses among guayules to air temperatures and environmental factors (Figure 6).

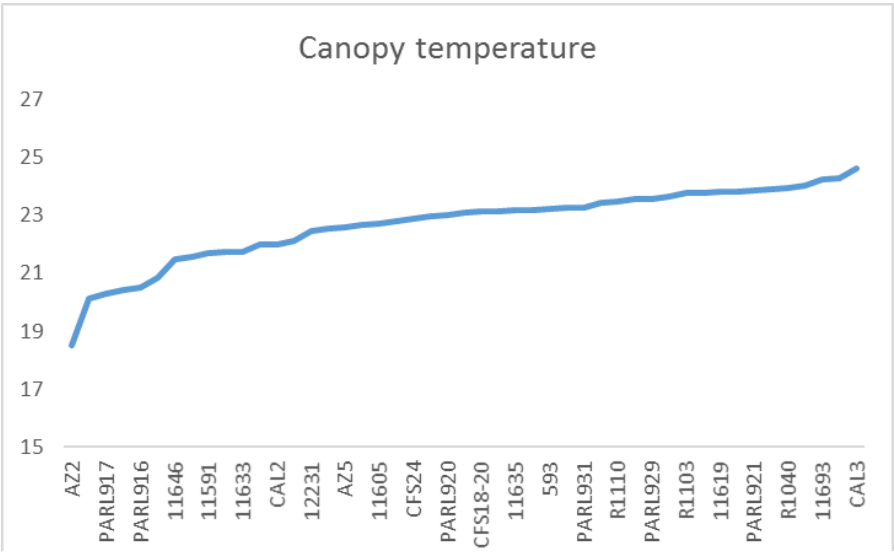

Figure 6. *Canopy temperature (C°) measured at Maricopa Agriculture Center, AZ.*

Remote Sensing Evaluation:
Research is continuing as planned; no measurements were taken this quarter and there are no new data to report.

Thermogradient Table Analysis:
Research is continuing as planned; no new data to report.

Leaf Characterization:
Research is continuing as planned; no new data to report.

Objective 3. Deploy superior genotypes of guayule and guar to regional growers.

Task #	Description of Task	Deliverable	Target Completion Date
1 Angadi	Evaluate guar germplasm in New Mexico high plains environment	Identify guar germplasm suitable for cooler and northern latitudes Summarize data after harvest; present at field day in Clovis, NM	31 Aug 19 31 Aug 19
2 Grover	Multiply guar germplasm lines (increase # of seeds)	Obtain seeds from ~30 guar lines for evaluation Generate report on seed yield and related information learned from multiplication	31 Aug 19 31 Aug 19
3 Ray	Evaluate seed from plants surviving root rot inoculation	Screen seed progeny for increased root rot tolerance	15 Jan 19
4 Ray	Determine root rot tolerance per guayule germplasm	Screen 42 guayule germplasm lines for root rot fungus tolerance Identify survival rate (%) for each germplasm line Complete cuttings from surviving plants to increase seed	15 Jul 19 15 Jul 19 15 Aug 19
5 Ray	Guar yield trials in Tucson, AZ; Las Cruces, NM; and Clovis, NM	Increase guar seed for yield tests Guar seed harvested and cleaned Yield trial protocols established (3 different for comparison) Yield trials planted	15 Nov 18 15 Nov 18 15 Nov 18 15 Jun 19

6 Ray	Guar genetic combination trials	Guar seed from partial male-sterile plants collected and cleaned	15 Nov 18
		Guar seed from crosses of partial male-sterile plants with 2 elite lines planted	15 Jun 19
		Genetic diversity evaluated//flowering time, branching, leaf pubescence, and disease/insect tolerance	15 Oct 19

Guar Germplasm in New Mexico:
Preparing for 2019 field trials. Arranged guar seed supply from Mr. Guy Spears, Agronomist, Guar Resources. Locations for each trial have been identified and preparations have been started to meet the need of each trial.

Discussed with Dr. Dennis Ray and he will let me know about number of guar germplasm lines he can provide for testing in Clovis, NM. Depending on the seed availability, all or part of the germplasm collections from their study will be evaluated at Clovis, NM.

Guar Germplasm Line Multiplication:
Processed plants harvested from the guar germplasm study for threshing and obtaining seeds. Seed yield and yield attributing characteristics measured from the collected samples.

Root Inoculation Results – Seed Evaluation:
The first group of plants was inoculated and are being observed for symptoms. Research for this task is proceeding as planned; no new data to report.

Root Rot Tolerance per Guayule Germplasm:
See above.

Guar Yield Trials in Tucson, AZ; Las Cruces, NM; and Clovis, NM:
Research is continuing as planned; no new data to report.

Guar Combination Trials:
The study fields were being prepared during this quarter with a projected planting date in April 2019.

Objective 4. Deploy agronomic production practices; identify agronomic information for salinity, herbicide, and nutrients to support production; provide irrigation apps using algorithms to growers.

Task #	Description of Task	Deliverable	Target Completion Date
1 Angadi	Conduct guar critical stage based deficit irrigation trial	Identify critical growth stage of guar to reduce irrigation water use	31 Aug 19
		Contribute data for developing guar crop coefficients (Kc) for irrigation management	31 Aug 19
		Present data at regional and national conferences	31 Aug 19
2 Angadi	Conduct incubator study to understand temperature and germination relationships	Identify optimum soil temperature for guar planting for available guar cultivars	31 Aug 19
		Present data/findings at national conference	31 Aug 19
3 Dierig	Density trials in Tucson and Eloy, AZ	Establish trial with different densities in Tucson, AZ	31 Oct 18
		Summarize plant growth, yield performance, and traits for density trial with 2 varieties and 5 densities in Eloy, AZ	30 Apr 22
4 Dierig	Bi-monthly harvest from irrigation trials	Growth data over seasons from two locations	31 Dec 20
5 Grover	Evaluate guar response to moisture stress	Track and collect research data on moisture stress experiment	31 Aug 19
		Generate report/publication from results obtained	31 Aug 19
		Present research results at regional/national conferences	31 Aug 19
6 Grover	Evaluate guar response to planting density	Track and collect research data on guar density experiment	31 Aug 19
		Generate report/publication from results obtained	31 Aug 19
7 McClos	Collaborate with herbicide manufacturers on experiment design and data collection to support 24c SLN registration	Identify herbicide rates, application methods, and application timing for experiments	31 Aug 19
		Prowl H2O (pendimethalin) and Aim (carfentazone) labels expire in 2018; work with BASF and FMC on renewals	31 Jan 19

8 McClos	Conduct guayule herbicide tolerance study, Fall 2018 at Eloy and Maricopa, AZ	Track and collect research data to support 24c SLN preemergence herbicide registrations for metolachlor, bensulide, ethalfluralin, sulfentrazone, and acetochlor Track and collect research data to support 24c SLN postemergence herbicide registrations for clethodim and carfentrazone Generate report/publication from results obtained	31 Jan 19 31 Jan 19 31 Jan 19
9 McClos	Conduct guayule herbicide tolerance studies, Spring 2019 at Eloy and Maricopa, AZ	Track and collect research data to support 24c SLN preemergence herbicide registrations for metolachlor, bensulide, ethalfluralin, sulfentrazone, and acetochlor Track and collect research data to support 24c SLN postemergence herbicide registrations for clethodim and carfentrazone Generate report/publication from results obtained	31 Aug 19 31 Aug 19 31 Aug 19
10 Ogden	Literature review of field/plant level growth models	Complete literature review	31 Dec 18
11 Ogden	Phase 1 growth models developed	Preliminary models developed and shared with project team	1 Aug 19
12 Ray	Plant density trial	Fall trial established for comparison with spring-established trial	15 Sep 18
13 Ray	Biomass drying experiment	Biomass, resin, and rubber content analyzed	30 Sep 18
14 Ray	Guayule trials (direct-seeded and transplant-established)	Compare for root growth/water use Compare a range of N and P application rates Compare N and P utilization and effects of nutrients on biomass, rubber and resin production	15 May 19 31 Dec 18 15 May 19
15 Waller	Install TDR, infrared camera and flowmeter system	Provide data on guayule irrigation experiments Provide data set that can be used to refine the use of	15 Jan 19 15 Jan 19

		sensors for WINDS crop irrigation mgmt. Generate a publication on integration of sensors and WINDS model; present a conference	15 Jan 19
16 Waller	Integrate python MySQL WINDS model with existing tools	Integrate new python model with WINDS (winds.arizona.edu), and in-situ sensors Add crop coefficient method to WINDS Develop educational videos and documents on use of WINDS	15 Apr 19 15 Apr 19 15 Apr 19
17 Waller	Irrigation experiments: Guayule and Guar	Collect data; image collection, neutron probe readings, in-situ sensors, crop coefficient development and destructive plant samples for chemical analysis Document effects of irrigation treatment on plant growth, soil moisture, plant stress, plant chemical response, plant vegetative indices, and crop coefficient Generate a publication on guayule irrigation experiments	15 Jul 19 15 Jul 19 15 Jul 19

Guar Critical Stage-Based Deficit Irrigation Trial:
Triticale planted to deplete soil profile for 2019 deficit irrigation trial location was fertilized and irrigated to stimulate growth and greater depletion of soil profile moisture. Soon triticale will be terminated. The area will be divided into eight blocks and half of them will be pre-irrigated with bubbler pads (to increase soil moisture stored in deeper depths) before planting.

Preliminary analysis of data from deficit irrigation study is showing unique response of guar to pre-season and in season irrigation levels (Table 3). Pre-season irrigation increased average guar seed yield by 27%. This indicates that guar utilized water stored in deeper soil profile for yield formation. Full season irrigation recorded highest guar seed yield. However, stressing at vegetative stage and irrigating after flower initiation (Vstss) reduced seed yield. This indicates that higher water availability during reproductive growth may not help guar in yield formation. Guar is an indeterminate crop and resources available after flowering may stimulate fresh growth and reduce seed yield formation. The lowest harvest index observation in less stressful treatments compared to stressful rainfed treatment support the hypothesis. Averaged over cultivars and pre-season irrigation, not irrigating guar after flower initiation (Rstss) had no effect on seed yield. Soil water extraction data is being analyzed and results will be interpreted soon.

Table 3. *Effect of different water availabilities on yield parameters of guar crop.*

Treatments	Seed yield (kg/ha)	Branches plant^{-1}	Pods plant^{-1}	Seed pod^{-1}	1000 seed wt(g)	HI (%)
Pre	1024.0 a	4.9 a	62.9 a	3.6 a	23.4 b	30.8 a
No-Pre	807.2 b	4.0 b	47.8 a	3.8 a	28.8 a	35.8 a
Critical growth stage based irrigation						
Irr	982.5 a	5.0 a	64.2 a	3.9 a	25.9 ab	29.1 c
Rst	976.5 a	4.8 ab	62.3 a	3.8 a	25.6 ab	34.3 ab
Vst	810.8 b	4.1 bc	47.7 b	3.5 a	24.1 b	32.3 bc
Rainfed	892.8 ab	4.0 c	47.2 b	3.8 a	28.7 a	37.4 a
Cultivars						
Kinman	955.6 a	6.4 a	57.5a	3.5 b	27.7 a	32.0 a
Monument	875.7 b	2.5 b	53.2 a	4.0 a	24.5 b	34.6 a

Remote sensing images collected by Dr. Diaa El-Shikha, are being processed. Initial images are looking really good. Since it was difficult for Diaa to visit Clovis more than two times during the season for remote sensing, I am trying to collaborate with researchers from USDA-ARS, Bushland. If they collect remote sensing data 4-5 times, we will collect matching soil moisture and crop leaf area and biomass data to match those observations.

Incubator Study to Understand Temperature and Germination Relationships:

During the quarter, we initiated temperature and germination study in incubators (Photos 5-6). We have run about 40% of the treatments and some varietal responses to temperature for germination are being observed. We are planning to complete all temperature treatments before planting guar in the field. The results will be very useful in deciding which cultivars to use in northern latitudes or for delayed planting situation.

Photo 5. *Preparing guar seedlings for incubator studies.*

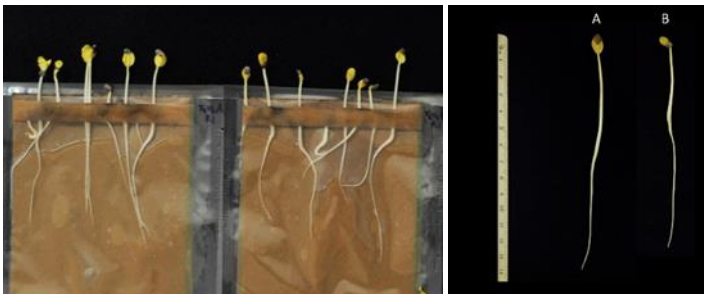

Photo 6. *Germinated guar seeds in the incubator studies.*

Dr. Angadi also had a meeting with Dr. Jim Kiniry, USDA-ARS, Temple TX. He is a crop modeler and has developed Almanac crop model. He is interested in adopting it for new crops growth and yield simulation. We will explore the possibility of using data from guar deficit irrigation trial for simulation modeling.

Density Trials in Tucson and Eloy, AZ:
The densities are 30, 18, 12, 6, 3-inch in-row spacing for density 1, 2, 3, 4, 5 and were harvested in March 2019. Data will be provided in the next quarterly report.

Bi-Monthly Harvest from Irrigation Trials:
Tables 4-10 compare the growth of plants from drip and flood irrigation treatments at 2 locations (MAC and Eloy, AZ). Eloy is a clay soil and MAC is a sandy loam. Plants were harvested at 4, 6, 8, and 10 months of age. Plant dry biomass was similar between the two locations at the March 2019 sampling even though up to the previous sampling from December (8 months) plants at Eloy were substantially higher (~25%). This is likely due to warmer soil temperatures promoting earlier growth at MAC compared to Eloy. Plants at Eloy Farm did not come out of semi-dormancy until later compared to MAC and this allowed biomass production to catch up. We did not see differences between irrigation treatments yet. This will likely take a few more months to be visible.

Table 4. *Shrub dry weight (g/m) (no root) harvested at 4, 6, 8, and 10 months from a replicated irrigation experiment at two locations. Each value is the average of 3 1-m replications.*

Irrigation Treatment	Bridgestone -Eloy Farm (Clay soil) (g/m)				Maricopa- U of A Farm (Sandy loam soil) (g/m)			
	August (4 mo)	October (6 mo)	December (8 mo)	February (10 mo)	August (4 mo)	October (6 mo)	December (8 mo)	February (10 mo)
Drip 50%	572.3	891.8	1472.7	1309.5	335.8	557.5	1368.6	1279.8
Drip 100 %	618.4	1258.8	1652.6	1498.6	310.1	661.6	1225.1	1521.1
Flood 50 %	610.3	909.6	2042.1	1375.5				
Flood 100 %	762.0	973.5	1816.4	1628.5	329.5	638.7	1350.1	1448.6

Table 5. *Eloy Farm. Root dry weight (g/m) and root length (cm) harvested at 4, 6, 8, and 10 months from a replicated irrigation experiment. Each value is the average of 3 1-m replications.*

Irrigation Treatment	Bridgestone -Eloy Farm(Clay soil) (g/m)							
	August (4 mo)		October (6 mo)		December (8 mo)		February (10 mo)	
	Wt (g)	L (cm)	Wt (g)	L (cm)	Wt (g)	L (cm)	Wt (g)	L (cm)
Drip 50 %	148.0	30	214.8	36	250.5	32	328	31
Drip 100 %	140.7	29	214.7	30	237.8	37	350	28
Flood 50 %	128.0	25	179.8	34	291.7	37	317	31
Flood 100 %	141.0	27	169.9	31	250.7	31	338	31

Table 6. *MAC Farm. Root dry weight (g/m) and root length (cm) harvested at 4, 6, 8, and 10 months from a replicated irrigation experiment. Each value is the average of 3 1-m replications.*

Irrigation Treatment	Maricopa U of A Farm (Sandy loam soil) (g/m)							
	August (4 mo)		October (6 mo)		December (8 mo)		February (10 mo)	
	Wt (g)	L (cm)	Wt (g)	L (cm)	Wt (g)	L (cm)	Wt (g)	L (cm)
Drip 50 %	77.7	20	129.3	30	267.4	28	308	31
Drip 100 %	85.3	21	162.5	31	205.8	30	246	31
Flood 50 %								
Flood 100 %	89.3	25	179.2	37	261.4	35	360	29

Table 7. *Eloy Farm. Proportion of flowers (Fls), leaves (Lvs), and stems (St) from each harvest.*

Irrigation Treatment	Bridgestone Eloy Farm (Clay soil) (% of total											
	August (4 mo) (g)			October (6 mo)			December (8 mo)			February (10 mo)		
	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St
Drip 50 %	5	62	21	8	55	28	3	33	46	3	26	50
Drip 100 %	5	64	19	7	61	26	2	42	43	3	28	51
Flood 50 %	4	65	19	9	61	23	3	34	49	3	28	51
Flood 100%	5	63	22	7	59	29	4	39	45	3	24	56

Table 8. *MAC Farm. Proportion of flowers (Fls), leaves (Lvs), and stems (St) from each harvest.*

Irrigation Treatment	Maricopa U of A Farm (Sandy loam soil) (% of total)											
	August (4 mo) (g)			October (6 mo)			December (8 mo)			February (10 mo)		
	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St
Drip 50 %	3	65	21	7	64	17	3	36	41	3	28	49
Drip 100 %	4	64	21	5	67	18	3	37	44	3	30	54
Flood 50 %												
Flood 100%	3	63	22	7	65	17	3	35	43	3	26	50

Table 9. *Eloy Farm. Rubber and resin content (%) of stems (leaves and flowers removed) harvested at 4, 6, 8, and 10 months from a replicated irrigation experiment at two locations. Each value is the average of 3 1-m replications.*

Irrigation Treatment	Bridgestone Eloy Farm (Clay soil) (%)							
Rubber % / Resin %	August (4 mo)		October (6 mo)		December (8 mo)		February (10 mo)	
	Rub	Res	Rub	Res	Rub	Res	Rub	Res
Drip 50 %	0.30	4.3	2.5	5.7	2.0	5.7	2.9	6.2
Drip 100 %	0.39	4.3	1.6	4.4	1.5	4.9	2.5	5.2
Flood 50 %	0.37	3.6	2.2	5.3	2.1	5.7	3.0	6.1
Flood 100 %	0.49	4.2	2.0	4.7	1.8	5.5	2.6	5.6

Table 10. *MAC Farm. Rubber and resin content (%) of stems (leaves and flowers removed) harvested at 4, 6, 8, and 10 months from a replicated irrigation experiment at two locations. Each value is the average of 3 1-m replications.*

Irrigation Treatment	Maricopa U of A Farm (Sandy loam soil) (%)							
Rubber % / Resin %	August (4 mo)		October (6 mo)		December (8 mo)		February (10 mo)	
	Rub	Res	Rub	Res	Rub	Res	Rub	Res
Drip 50 %	0.66	7.6	1.3	7.2	2.1	6.5	3.3	6.4
Drip 100 %	0.78	7.6	1.1	6.5	2.1	6.2	3.4	6.8
Flood 50 %								
Flood 100 %	0.69	7.3	1.1	6.8	2.1	6.5	3.6	6.5

Not much difference in root biomass or length was seen between the treatments or locations. We are only able to harvest coarse roots in this harvest. The proportion of flowers, leaves, and stems changed over time significantly. The proportion of leaves continues to decrease and the proportion of stems increase over time. We measured rubber and resin content of these small plants. Plants have undergone cold induction by February. They are slightly higher at MAC farm. Values are also higher because they are based on dry weight of stems only and not the entire plant. In general, rubber values were about the same in both locations but resin was higher at MAC.

Plants from both MAC and Eloy were harvested in March 2019. Samples are being analyzed for dry weight, rubber and resin content and estimated yield per acre. Data will be provided in the next report.

Guar Response to Moisture Stress:
Analyzed data collected during the crop growth season for guar moisture stress response study. Measured final harvest seed yield and yield attributing characteristics.

Guar Response to Planting Densities:
Collected the in-field crop growth data for guar planting density study. Measured final harvest seed yield and yield attributing characteristics.

Collaboration with Herbicide Manufacturers in Support of 24cSLN Registrations:
Protocols were developed for the spring 2019 Marana, Eloy and Maricopa experiments based in part on data analysis of the fall 2018 experiments at Marana and Maricopa.

The existing Prowl H_2O SLN label was renewed for an additional 5 years and the Aim SLN label did not expire as discussed in the previous quarterly report wh. A revised Prowl H_2O SLN for Prowl use during guayule seedling establishment will be requested through the ADA based on experiments conducted in fall 2018 and spring 2019. FMC has indicated that it would like to see a second Aim (carfentrazone) postemergence study conducted similar to that conducted in spring 2018 at Eloy before moving ahead with new Aim SLN for seedling guayule (see Guayule Herbicide Tolerance Study, Fall 2018 detail below).

Guayule Herbicide Tolerance Study, Fall 2018:
Three preemergence herbicide experiments and three preplant-incorporated experiments (each experiment included two herbicides) were established at MAC in October 2018 and data collection was completed in January 2019. Similarly, three preemergence herbicide experiments were established in Marana at Gary Deen's farm in September 2018 and completed in December 2018 to obtain additional data on a course textured soil. The data collected to date is provided in Table 11.

The postemergence Aim (carfentrazone) and clethodim experiments planned for Fall 2018 in Eloy were not conducted due to fall rains and an abrupt weather change; the experiments were postponed to the spring of 2019.

Table 11. *Data collected from guayule preemergence herbicide experiments in January 2019.*

Spray Date	Chemicals Applied	Location/ Field	Method of Incorporation	ARM File Name / Data Tables?	Data Collected to Date
9/25/2018	Prefar 4-E Prowl H2O	Marana	Sprinkler	PRE-Prowl Prefar Fall2018 Marana	10/8/2018 – Guayule Stand Counts 10/19 – Guayule Stand Counts 10/26 – Guayule Stand Counts 11/7 – Guayule Stand Counts 12/20 –Bulk Sprayed with Aim EC @ 2oz/A
9/25/2018	Dual Magnum Spartan 4F	Marana	Sprinkler	PREE Dual-Spartan Fall2018 Marana	10/8/2018 – Guayule Stand Counts 10/19 – Guayule Stand Counts 10/26 – Guayule Stand Counts 11/7 – Guayule Stand Counts 12/20 –Bulk Sprayed with Aim EC @ 2oz/A
9/25/2018	Warrant Sonalan	Marana	Sprinkler	PREE-Fall2018-Warrant-Sonalan Marana	10/8/2018 – Guayule Stand Counts 10/19 – Guayule Stand Counts 10/26 – Guayule Stand Counts 11/7 – Guayule Stand Counts 12/20 –Bulk Sprayed with Aim EC @ 2oz/A
10/25/2018	Dual Magnum Spartan 4F	MAC / F1 / B36	Sprinkler	Guayule PREE Fall2018 Maricopa Ag Center Dual Spartan	11/15/2018 – Stand Counts 11/28 – Stand Counts 12/10 – Stand Counts 12/13 – Leaf Counts 1/9/19 – Stand Counts 1/15/19 – Nadir Photographs
10/25/2018	Sonalan Prowl H2O	MAC / F1 / B37	Sprinkler	Guayule PREE Prowl Prefar_Maricopa_Ag_Center Fall2018	11/15/2018 – Stand Counts 11/28 – Stand Counts 12/10 – Stand Counts 12/13 – Leaf Counts 1/9/19 – Stand Counts 1/15/19 – Nadir Photographs
10/25/2018	Warrant Prefar	MAC / F1 / B38	Sprinkler	Guayule PREE Fall2018 Warrant Sonalan	11/15/2018 – Stand Counts 11/28 – Stand Counts 12/11 – Stand Counts 12/13 – Leaf Counts 1/11/19 – Stand Counts 1/15/19 – Nadir Photographs
10/25/2018	Dual Magnum Spartan 4F	MAC / F1 / B39	Incorporvator	Guayule PPI Fall2018 Maricopa Ag Center Dual Spartan	11/16/2018 – Stand Counts 11/27 – Stand Counts 12/11 – Stand Counts 12/14 – Leaf Counts 1/11/19 – Stand Counts 1/15/19 – Nadir Photographs
10/25/2018	Sonalan Prowl H2O	MAC / F1 / B40	Incorporvator	Guayule PPI-bedtop Prowl Prefar MAC Fall2018	11/16/2018 – Stand Counts 11/27 – Stand Counts 12/12 – Stand Counts 12/14 – Leaf Counts 1/14/19 – Stand Counts 1/15/19 – Nadir Photographs
10/25/2018	Warrant Prefar	MAC / F1 / B41	Incorporvator	Guayule PPI-Bedtop Warrant Sonalan MAC FALL2018	11/16/2018 – Stand Counts 11/27 – Stand Counts 12/12 – Stand Counts 12/13 – Leaf Counts 1/14/19 – Stand Counts 1/15/19 – Nadir Photographs

Publication of Fall 2018 research reports will be delayed to June 30, 2019 as we did not finish collecting data in the preemergence herbicide experiments until January 2019 and data analysis was not completed until the end of March.

Guayule Herbicide Tolerance Study, Spring2019:
The spring 2019 preemergence herbicide experiments at Maricopa will be initiated in April 2019 with the assistance of Bridgestone.

The grass herbicide (fusillade, sethoxydim and clethodim) experiments will be initiated in April at the Maricopa Ag Center and at Gary Deen's farm in Marana. The spring 2019 Aim experiment was initiated in Maricopa and Eloy in April 2019.

Research technician Bryan Pastor was largely responsible for setting up the experiments, spraying the herbicide treatments, and collecting the data with some help from me. Bryan is (was) also responsible for all data entry into a database program for field research (Agricultural Research Manager; Gylling Data Management, Inc.) and for the analysis of the nadir photographs.

Literature Review for Field/Plant Growth Models:
We are focusing more on the Aquacrop model and working on adapting the model to predict guayule growth.

Phase I Growth Models Developed:
We are making progress in both the AquaCrop and BioCro models

Aquacrop model: The model mainly focuses on the effects of water irrigation on biomass and other products of guayule. We have successfully obtained weather data. We collaborated with team members to work on the model code and focus more on soil, irrigation and plant parameters. We are currently working on the following:

- Studying plant growth parameters
- Obtaining plant growth parameters
- Working on the model code

BioCro model: The model mainly focuses on the effects of carbon dioxide level and temperature on the biomass and other products of guayule. W are studying the database more with the model developer, and we did the experiments to obtain the root ratio. However, the data will be need to be compared with other team members' data. We are currently working on the following:

- Literature review
- Attending workshops
- Studying plant growth parameters

Plant Density Trials:
Research for this objective is complete; no new data to report.

Photo 7. *Dried guayule roots from varying depths below the plant/soil surface.*

Biomass Drying Experiment:
First biomass drying experiment was completed in June 2018, but the experiment will be repeated in June 2019.

Guayule Trials (Direct-Seeded and Transplant-Established):
The guayule plant heights were measured on 2 March 2019, and no significant differences were seen between treatments (Table 12).

Table 12. *Heights of guayule plants in density trial measured on 2 March 2019.*

Level	Number	Mean	Std Dev	Sig
1	40	3.1	1.1	a
2	40	2.8	1.1	a
3	40	3.0	1.1	a
4	40	3.0	1.1	a
5	40	3.1	1.1	a

Installation of TDR, Infrared Cameras, and Flowmeter System:
Maqsood calculated the crop coefficient for the guar study in Clovis (Figure 7). This was based on neutron probe, irrigation, and rainfall data from the summer 2018 experiment in Clovis run by Dr. Sangu Angadi.

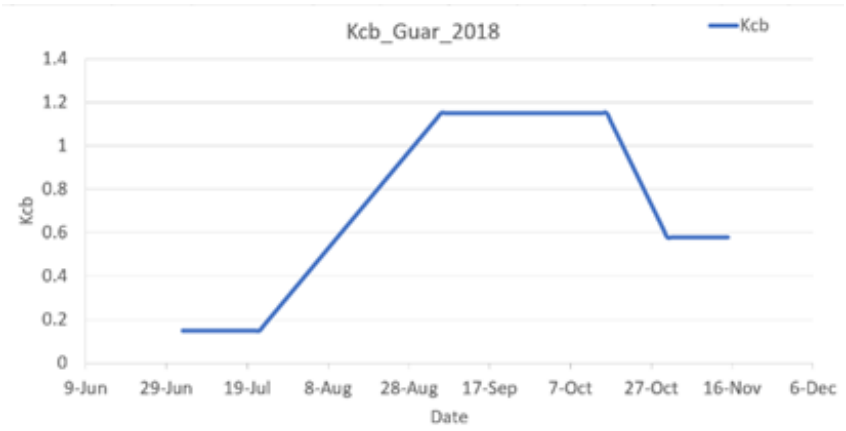

Figure 7. *Guar crop coefficient for Clovis, New Mexico.*

Python MySQL WINDS Model Integration with Existing Tools:
With respect to WINDS model, Maqsood completed the coding of multiple years for online data, soil moisture data formatting for the guayule and guar experiments in Maricopa and Clovis. In progress is the coding for crop coefficient calculation steps and water budgeting within WINDS, and the dual crop coefficient data compilation.

We are also assisting Mimi Pradyawong with data input for the Aquacrops model for the guayule experiments, which is nearly complete.

Irrigation Experiments – Guayule and Guar:
In January 2019-April 2019, we collected plant growth data (height, width, number of plants per meter) in both sites (Eloy and Maricopa). Also, plant samples were collected every other month from the I50 and I100 treatments in both locations. The yearly samples were collected in March 2019, from all plots (3 m/plot) in both locations (MAC and Eloy). Plants were processed, and rubber and resin content and yield data were calculated. Data analysis is in progress.

Neutron probe data was collected every other week until mid-February 2019, then data collection became weekly after that. The collected neutron probe data was used to calculate soil moisture content, which was inserted into the irrigation model to obtain irrigation recommendations (when and how much per irrigation) for furrow and subsurface irrigated plots in Eloy and Maricopa sites. The K_{cb} curves is being developed for year two for the guayule growing under furrow and subsurface drip irrigation. The data collected in the first year is being analyzed and a meeting paper will be published in the annual international meeting of the American Society of Agricultural and Biological Engineers in July 2019. Peer reviewed paper for the data of the first year of guayule growth will be written and submitted by Sept-October 2019.

Matt started to collect weekly plant temperature, near the access tubes, in April, using a hand-held infrared thermometer. Data will be used to develop CWSI and correlations with weekly moisture data. We may be able to collect thermal data using the drone with a FLIR camera onboard.

Drone images, multispectral and RGB, was collected every 7-10 days from the Maricopa site. And this year, we started to collect remote sensing data from Eloy, once a month. All remote sensing images were processed, orthomosaic/VI images were created. Tractor/Hamby remote sensing data was analyzed. Also, ALARC may be receiving a drone carrying active sensors, borrowed for 2 years, sometime in July 2019. Kevin asked me to take the responsibility of flying the drone in his field. I will be able to use the drone/sensor to collect data from the guayule field. This will be the first drone carrying active sensor/s and data will be compared to that obtained from passive sensors that we are using (RGB camera and Rededge sensor).

Other Tasks:
Guayule Resin Applications – According to the last year's pre-test, we have a solid plan to continue further investigation on the adhesion properties of guayule resin, resin (2018-1-1-RES-25), guayule natural rubber (FT-1401-01 CP), miscella terpene, terpenes (SR-1702-01), and terpenes and solvent solution (SP-1702-01 TS) in May 2019. The tested results will be reported in the next quarterly report (Q2 2019).

Objective 5. Develop soil quality and health knowledge critical to environmental sustainability.

Task #	Description of Task	Deliverable	Target Completion Date
1 Maier/ Neilson	Chemical and physical analysis of 108 soil samples	pH, EC, OrgM, NO3-N, P, K, cations, and SAR analysis complete Soil texture characterization complete	1 May 19 1 July 19
2 Maier/ Neilson	DNA extraction of soil samples for microbiome analysis	Quantify available biomass for 108 samples for amplicon sequencing	1 Jun 19
3 Maier/ Neilson	Generate baseline microbiome profile and assess spatial variations	Determine community composition metrics for 108 samples Identify differences within and between field variations in community composition metrics Identify functional gene traits to be quantified in Yr3	30 Jun 19 30 Jun 19 30 Jun 19
4 Maier/ Neilson	Soil sample collection for guayule-microbe winter dormancy studies	Collect and archive soil samples for DNA and RNA analysis from 3 time points (Nov – Mar)	1 Apr 19
5 Maier/ Neilson	Organize and execute Yr2 guayule plant and soil sampling	Plan field sampling day, process and archive samples Coordinate chemical analysis of samples with NMSU	1 Apr 19 1 Apr 19

Chemical and Physical Analysis:

New target completion date (Chemical Analysis) is May 1 2019

Research is being done with NMSU to troubleshoot the % variation for the samples analyzed in 2018. Twelve samples were repeated and the % variation for some reached 88%. It is unlikely that this large variation is due to soil heterogeneity. Work is now being done to identify the cause of this large % CV and to adapt the protocols. Thus, the data presented in the 2018 Q4 report must be revised. The progress is labeled as yellow because the new data shows that further quality control must be done before the data reported last quarter is accepted and analyzed.

New target completion date (Physical Analysis) is July 1 2019

A new undergraduate was hired in Q1 and is being trained to perform the soil texture analysis. She had limited experience with this protocol (only in lab classes) and thus is currently running previously analyzed soil to perfect her technique. We have also decided to order a standard soil

because the data generated in 2018 Q4 for the MAC field is slightly different than data generated by the USDA scientists for the same field. Clay content may be an important variable, thus the accuracy of the soil texture analysis is important and we need to identify the coefficient of variation for this method. Clay content influences soil moisture holding capacity and Dierig also questions whether it will influence guayule pathogen activity.

DNA Extraction for Microbiome Analysis:
New target completion date is June 1 2019

Brown continues to perform DNA extraction and quantification on the Year 1 samples. As with the chemical analysis, Brown is developing quality control standards to evaluate the within sample variation for DNA extracted from a single sample. The clay content of these soils prevents thorough homogenization of soils frozen for DNA extraction. Thus, Brown is performing experiments to quantify effects of extended defrosting procedures. Results will be reported in Q2. Progress is reported as yellow because we did not anticipate the complications associated with DNA extraction from these soils.

Baseline Microbiome Profile and Spatial Variations:
The primary focus for 2019 Q1 was field sampling for Tasks 2 and 3. Field sampling for the irrigation field trials at Eloy and MAC (Task 3) was planned with Dierig, Wang, Ditmar and El-Shikha. Plant and soil samples were collected within the same week and from the same locations. (Photo 7).

Photo 9. *Soil sample collection within guayule field plot. Bridgestone Guayule Research Farm, Eloy, AZ.*

Photo 8. *Soil sample location directly adjacent to harvested guayule plant stem.*

The sampling coordination will allow us to evaluate correlations between plant and soil metrics. All plants were sampled on March 11. Soil sampling was done at Eloy on March 6 and 7, before plant sampling. Samples were collected immediately adjacent to the stem of a plant that would be harvested on March 11 (Photo 8).

Photo 10. *Soil sampling location adjacent to a harvested plant stem.*

Photo 11. *Close-up view of soil harvest location adjacent to harvested plant stem.*

Sampling was done at MAC on March 11 within 5 hours of plant harvest so that the plant exudates would still be present for microbial populations. Soil samples were collected immediately adjacent to a harvested plant stem (Photos 9-10). Soils are currently being dried, ground and prepared for soil chemical analysis. Microbial samples were archived at -80˚C for DNA extraction. This sampling was completed ahead of schedule. The final sampling for this project will be done at the time of harvest in the spring of 2020.

Soil Sampling for Guayule Microbiome Winter Dormancy Studies:

The second soil/plant sampling for the Winter Dormancy Project was coordinated with McMahan and El-Shikha on February 12, 2019. Two plants were harvested from each of the D100 treatments at MAC farm, Maricopa AZ. The six plants were pulled from the ground and soil samples were collected from the rhizosphere region of each plant. Plant tissue was taken by McMahan for further analysis. Soil samples were processed and stored for DNA and RNA extraction and for chemical analysis. Analysis will be completed following the third and final sampling which is scheduled for April 22, 2019.

Year 2 Guayule Plant and Soil Sampling:

Research for this objective is complete; no new data to report.

POST-HARVEST LOGISTICS & CO-PRODUCTS

Project Coordination: The Logistics working group meetings are hosted by NMSU twice monthly. During these meetings, progress reports for all component tasks are provided by team members, issues and challenges are discussed for resolution, and specific tasks are integrated where possible. Data exchange is accommodated via a shared access folder online.

Issues/Risks:
Biomass characterization results have been delayed by about 3 months due to challenges with instrument operation and availability. A proposal for partial purchase of a suitably-sized (for analytical applications) supercritical fluid extraction instrument will be submitted in Q2 for Year 3 funding. Materials for maintenance and consumables are being planned into current orders to reduce sample analysis delays in the future.

Equipment required repairs during period delaying CHNOS analysis and the galactomannan size determination assay. Repairs were managed and arranged, and the potential impact included a delay ~ 1month.

Though we have made improvements on our bagasse evaluation we continue implement modification to the NREL biomass characterization methods with the aide of Dr. Brewer's group on bagasse material. We are continually troubleshooting the process to improve the digestion efficiency. We also have additionally purchased new chromatography columns in an effort to increase the reliability of the data.

Objective 1. Evaluate how seasonality, processing, and storage affect product quality, conversion efficiency, and economics.

Task #	Description of Task	Deliverable	Target Completion Date
1 Brewer	Provide guayule (and guar) bagasse characterization support for ongoing feedstock trials	Capture and collate data on the average variability of bagasse lignocellulosic biomass characteristics	31 Aug 19
2 Holg	Biochemical composition analysis of guayule and respective products	Develop standard operational procedures Composition information and sample extracts completed Generate manuscript on cold tolerance in guayule	31 Aug 19 31 Aug 19 31 Aug 19
3 Holg	Biochemical composition analysis of guar and respective products	Develop standard operational procedures Composition information and sample extracts completed	31 Aug 19 31 Aug 19 31 Aug 19

		Generate manuscript on cold tolerance in guayule	
4 Holg	Analytical evaluation of thermochemical conversion products	Determine composition information and sample extracts	31 Aug 19

Bagasse Characterization Support:
In February, 10 students and other NMSU researchers traveled to Mesa, AZ to tour the Bridgestone facility with the UA teachers, fellows and staff, and to obtain samples of guayule biomass, bagasse and resin, especially resin that had not yet been separated from the solvent and rubber.

In March, we participated in the resin research phone call with Bridgestone and ARS to coordinate efforts. Arrangements are being made for Dehghanizadeh to visit the ARS facility in summer to work with Mealing during her internship there on resin separation and characterization.

Guayule Biochemical Composition Analysis:
We continue to perform biomass characterization methods with Dr. Brewer's group on bagasse material. Through our collaboration with Dr. Jacqueline Jarvis at NMSU we have characterized by FTICR/MS various extraction steps from the Bridgestone plant. Particularly the resin is far more complex than previously thought. Figures 8-9 illustrate the complexity within the samples analyzed.

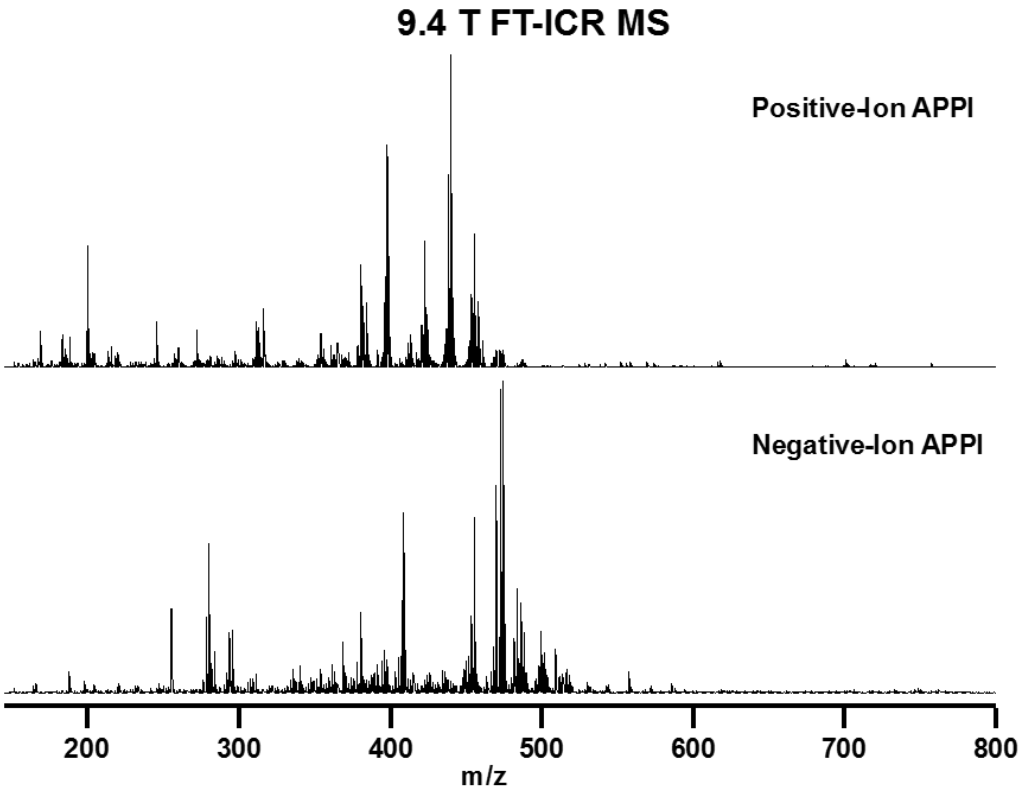

Figure 8. *Ultrahigh resolution and accurate mass FT-ICR MS: ~3,500 peaks in Positive Ion APPI and ~7,200 peaks in Negative Ion APPI.*

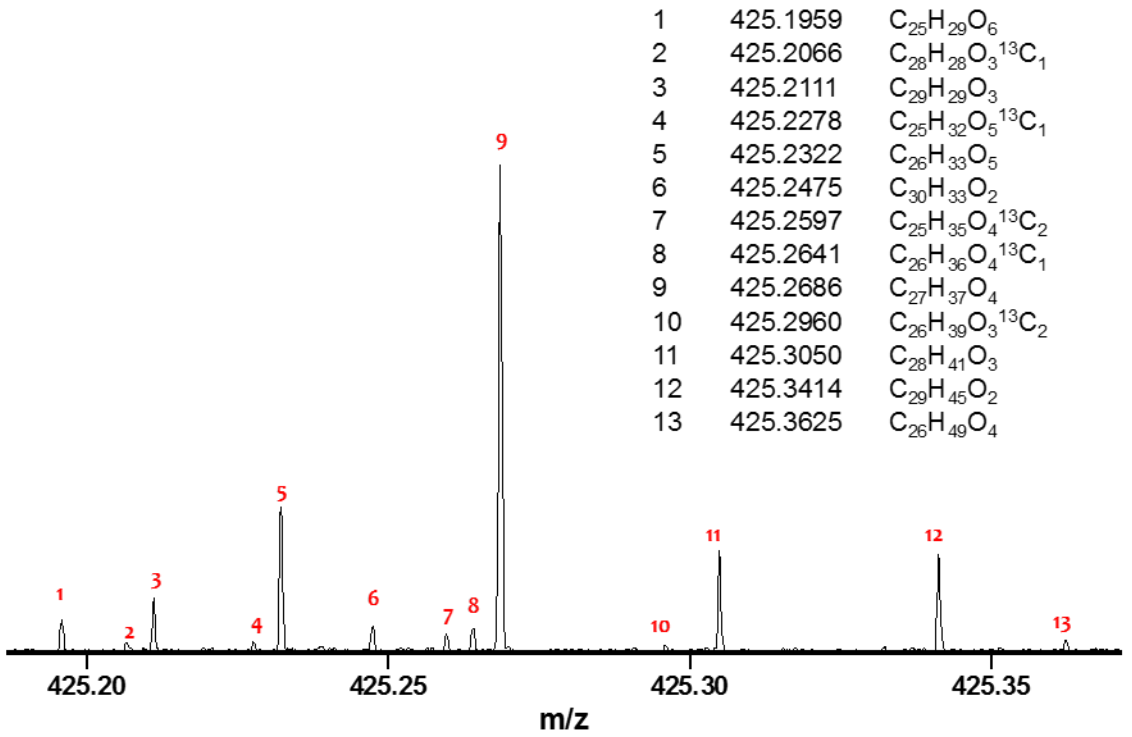

Figure 9. *(-) APPI FT-ICR MS illustrating the complexity at 1 nominal mass unit: 13 Assignments within ~20mDa zoom inset.*

Guar Bagasse Biochemical Composition Analysis:
Thirty-four (34) guar samples have gone through the extraction protocols and we have begun purification. Additionally, a second set of 80 samples has begun extraction. We are continuing the aqueous size exclusion analysis of carbohydrates as well as galactomannans from guar seeds. Additionally, subsets of samples are being submitted for rheology analysis.

Analytical Evaluation of Thermochemical Conversion Products:
Our future work is to perform High Temperature GC-TOF MS followed by NIST library spectra matching, DDA MS2 Acquisition followed by library spectral matching, Unambiguous molecular formula assignment FT-ICR MS and isotopic fine structure, De-novo molecular structure elucidation by fragmentation trees.

Other SBAR Collaborative Work:
Soil Analysis – Soil samples received from Dr. Julie Neilson are greater than 95% complete. We are still lacking NO3 data due to a backlog. Also Dr. Neilson has brought to our attention a discrepancy in the phosphate data that we are evaluating and we running some of the soil samples. We anticipate the full completion of the soil samples prior to the next quarterly report.

Pesticide Analysis – Nipsit Analysis on Guayule leaf and pollen is completed and report table is being generated.

Metabolomics and Biochemical Analysis – We have also continued our work with Dr. Von Mark Cruz and Dr. David Dierig on characterization of cold adaptation of guayule leaf material. We have generated a couple of tables with the most relevant information on how guayule or the previously mentioned plants get acclimated to cold or respond to cold/drought stress.

Identification of metabolic biomarkers from polyploid and diploid guayule (*Parthenium argentatum* (AZ2 and W6-429-32 genotypes) cold-acclimated and no cold-acclimated plants.

Thirty-nine metabolic biomarkers were identified in leaves of guayule no cold-acclimated plants, and thirty-eight in the leaves of cold-acclimated plants (Table 13). Eighteen metabolite markers were identified in both cold-acclimated and no cold-acclimated plants (Figure 10). The metabolic markers are currently putatively identified and need to be verified as some markers have been identified, as compounds not commonly known to exist in biological samples.

Table 13. *Metabolic biomarkers identified in leaves of Parthenium argentatum polyploidy and diploid (AZ2 and W6-429-32) plants, not acclimated to cold and cold-acclimated (PNA/DNA; PA/DA). Metabolic biomarkers with p-values of ~0.05 and below with Log-2 fold change values of 1.0 and above.*

PNA/DNA Set 1	Log 2 Fold-change	PA/DA Set 1	Log 2 Fold-change
Guanidinosuccinic acid	1.68	flavin adenine degrad product	3.0
Ribose	1.61	palmitoleic acid	3.0
Stearic acid	1.46	Norleucine.1	1.54
Urea	1.36	quinic acid	1.44
sulfuric acid	1.35	L-Malic acid	1.42
Xylitol	1.32	linolenic acid	1.31
Lactulose	1.28	Melezitose	1.27
palmitic acid	1.26	isocitric acid	1.26
Monostearin	1.24	serine	1.24
N-Acetyl-L-phenylalanine	1.17	Tricetin	1.22
Octanal	1.17	Galactinol	1.2
alpha-Tocopherol	1.14	fumaric acid	1.2
D-Arabitol	1.14	linoleic acid	1.2
Dehydroascorbic Acid	1.11	Cortexolone	1.2
Gentiobiose	1.09	hydroxylamine	1.15
Carnitine	1.03	Salicylaldehyde	1.14
alpha-Tocopherol.1	1.01	3,7,12-Trihydroxycoprostane	1.0
Gluconic lactone	1.01	phenylacetaldehyde	1.0
methyl hexadecanoate	1.01	oxoproline	1.0
4-hydroxyphenylacetic acid	1.01	3,4-dihydroxycinnamic acid	1.0
Citrulline	1.0		

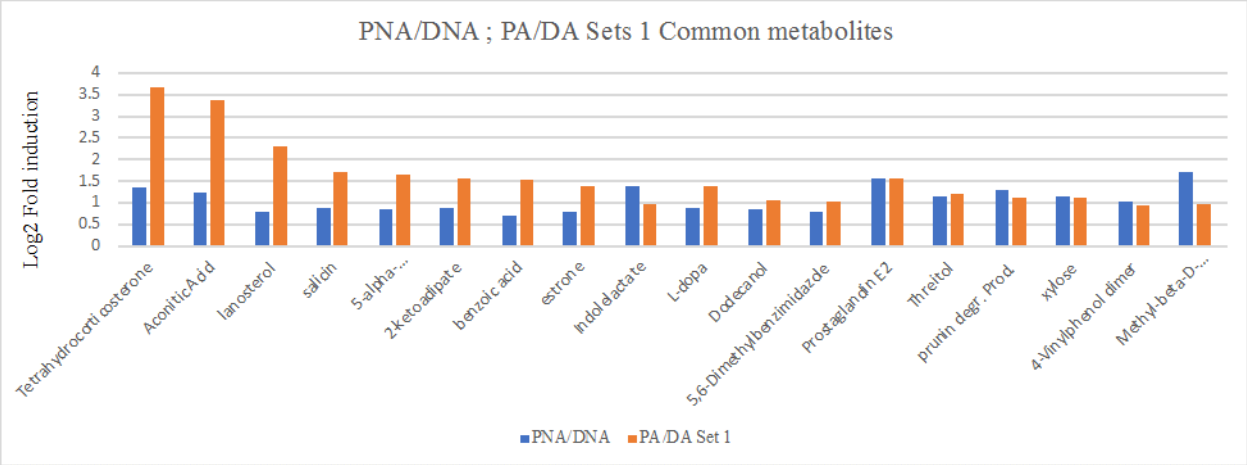

Figure 10. *Common metabolic biomarkers within polyploid no cold-acclimated plants and polyploid cold-acclimated plants.*

Flavin adenine degrad prod., and palmitoleic acid were the metabolic biomarkers with the highest log 2 fold-change (3.0) in polyploid cold-acclimated plants. Flavin is essential for tissue respiration and the generation of energy from the metabolism of carbohydrates, amino acids and fats, palmitoleic acid was the second most abundant biomarker in polyploid cold-acclimated plants and it is involved in the fatty acid biosynthesis pathway. Palmitoleic acid is an omega-7 monounsaturated fatty acid that is found in plants.

Eleven of the common metabolic biomarkers were more concentrated in the polyploid cold-acclimated plants (Figure 10, orange bars) than in the polyploid no cold-acclimated plants (Figure 10, blue bars). The concentration of prostaglandin E2, Threitol, prun deg. Prod., xylose, and 4-Vinylphenol dimer metabolites was similar in polyploid cold-acclimated and no-acclimated plants. A single metabolic biomarker; Methyl-beta-D-galactopyranoside was highly accumulated in the polyploid no cold-acclimated plants.

Pathways represented by the metabolic biomarkers from guayule polyploid no cold-acclimated and cold-acclimated plants

The pathways from the metabolic biomarkers identified in the leaves of polyploid guayule cold-acclimated and no-cold acclimated plants belong to the primary metabolism (Table 14). Primary metabolites perform metabolic roles essential for plant survival and growth. Two metabolic pathways (**Steroid biosynthesis and Stilbenoid diarylheptanoid and gingerol biosynthesis)** from the metabolic biomarkers identified in the polyploid cold acclimated guayule plants belong to the secondary metabolism.

Table 14. *Pathways represented by the metabolic biomarkers identified in leaves of polyploid guayule no-acclimated and cold-acclimated plants.*

PNA/DNA Set 1 Pathways	PA/DA Set 1 Pathways
Purine metabolism	**Citrate cycle (TCA cycle)**
Arginine and proline metabolism	**Glyoxylate and dicarboxylate metabolism**
Fatty acid Biosynthesis	**Galactose metabolism**
Biosynthesis of unsaturated fatty acids	**Tyrosine metabolism**
Fatty acid metabolism	**Biosynthesis of unsaturated fatty acids**
Fatty acid elongation in mitochondria	**Sphingolipid metabolism**
Sulfur metabolism	**Alanine, aspartate and glutamate metabolism**
Steroid biosynthesis	**Steroid biosynthesis**
Citrate cycle (TCA cycle)	**Pyruvate metabolism**
Glyoxylate and dicarboxylate metabolism	**Stilbenoid, diarylheptanoid and gingerol biosynthesis**
Starch and sucrose metabolism	**Fatty acid biosynthesis**
Galactose metabolism	Phenylalanine metabolism
Tyrosine metabolism	Glycine, serine and threonine metabolism
Tryptophan metabolism	Cysteine and methionine metabolism
Lysine degradation	Glutathione metabolism
	alpha-Linolenic acid metabolism
	Aminoacyl-tRNA biosynthesis
	Arginine and proline metabolism
	Sulfur metabolism
	Starch and sucrose metabolism

Pathways for the metabolism of the five amino acids: arginine, proline**,** tyrosine, tryptophan, and lysine degradation were represented in leaves of **polyploid plants no acclimated to low temperatures.** Pathways for the metabolism of ten amino acids including: tyrosine, phenylalanine, alanine, aspartate, glutamate, glycine, serine, threonine, cysteine, methionine, metabolism were represented in the **polyploid cold acclimated plants.** (Table 15)

Table 15. *Pathways represented by the common metabolic biomarkers from the polyploid no acclimated plants and the polyploid cold-acclimated plants.*

PNA/DNA;PA/DA Set 1 Pathways
Isoquinoline alkaloid biosynthesis
Pentose and glucuronate interconversions
Lysine degradation
Tyrosine metabolism
Tryptophan metabolism
Steroid biosynthesis
Glyoxylate and dicarboxylate metabolism
Citrate cycle (TCA cycle)

Detection of free amino acids in plant cells suggest protein degradation or high protein turnover**.** Free amino acids are primarily used as building blocks for protein and peptide synthesis, and as nitrogen sources for the synthesis of other amino acids and other nitrogenous compounds such as nucleotide bases, surplus amino acids are used as metabolic fuel *(reference)*. Most of the amino groups of surplus amino acids are converted into urea through the *urea cycle,* whereas their carbon skeletons are transformed into acetyl CoA, acetoacetyl CoA, pyruvate, or one of the intermediates of the citric acid cycle. *fatty acids, and glucose can be formed from amino acids (reference).*

Eight metabolic pathways were identified for the common metabolic biomarkers from the polypoid no acclimated and cold acclimated plants. Six of them are from the primary metabolism and two from the secondary metabolism (Isoquinoline alkaloid biosynthesis and Steroid biosynthesis).

Identification metabolic biomarker in guayule leaves from no cold acclimated and cold- acclimated polyploid plants after exposure to freezing temperatures (-9°C).

Three metabolite biomarkers: Methyl jasmonate, Norleucine, and Malonic acid were identified for the no cold-acclimated plants exposed to freezing temperatures (-9°C). Six metabolite biomarkers:Norleucine, Methyl jasmonate, 4-Vinylphenol dimer, cuminic alcohol, glutamine, squalene, and D-Glyceric acid were identified for the cold acclimated polyploid plants after exposure to freezing temperatures (-9°C) (Table 16). Norleucine was identified in both no acclimated and cold acclimated plants but its concentration was 80% higher in leaves of cold-acclimated plants. Methyl jasmonate was found also in no acclimated and cold acclimated plants and its concentration was very similar (1.28, 1.4 log 2 Fold-change) in both sets of plants. 4-Vinylphenol, dimer, cuminic alcohol, cuminic alcohol, squalene, and D-Glyceric acid were detected in the cold acclimated plants only.

Table 16. *Metabolic response of no acclimated and cold-acclimated Parthenium argentatum polyploid and diploid (AZ2 and W6-429-32) (PNA/DNA; PA/DA Sets 2) plants to freezing -9C° temperature.*

PNA/DNA Set 2	Log 2 Fold-change	PA/DA Set 2	Log 2 Fold-change
Methyl jasmonate	1.28	Norleucine	2.2
Norleucine	1.22	Methyl jasmonate	1.4
Malonic acid	0.9	4-Vinylphenol dimer	1.2
		cuminic alcohol	1.11
		glutamine	1.04
		squalene	0.95
		D-Glyceric acid	0.95

The polyploid plants that experienced freezing temperatures (-9°C) after cold-acclimation have the metabolic biomarker glutamine. This amino acid represents different pathways including: Aminoacyl-tRNA biosynthesis, purine and pyrimidine metabolism, arginine metabolism, Alanine, aspartate and glutamate metabolism, nitrogen metabolism, and

nitrogen metabolism. These plants also have two pathways from the secondary metabolism: the glycerolipid metabolism, steroid biosynthesis and the steroid biosynthesis.

Pathways represented by the metabolic biomarkers from the polypoid (AZ2) genotype, ***no cold-acclimated plants and polyploid cold acclimated plants exposed to freezing temperatures (-9°C.)***

Two pathways represented by the metabolic biomarkers from the no cold-acclimated plants exposed to freezing temperatures (-9°C): Alpha linolenic acid metabolism, and Valine, leucine, and isoleucine metabolism (Table 17).

Table 17. *Pathways represented by the metabolic biomarkers from the polyploid no cold-acclimated plants and polyploid cold-acclimated plants exposed to freezing temperatures (-9°C).*

PNA/DNA Set 2 Pathways	PA/DA Set 2 Pathways
Alpha linolenic acid metabolism	Alpha linolenic acid metabolism
Valine, leucine, and isoleucine metabolism	Valine, leucine, and isoleucine metabolism
	Aminoacyl-tRNA biosynthesis
	purine and pyrimidine metabolism
	arginine metabolism
	Alanine, aspartate and glutamate metabolism
	nitrogen metabolism
	glycerolipid metabolism
	steroid biosynthesis

Nine Pathways represented within the metabolic biomarkers from the polyploid cold acclimated plants exposed to freezing temperatures (-9°C): Alpha linolenic acid metabolism, and Valine, leucine, and isoleucine metabolism, Aminoacyl-tRNA biosynthesis, purine and pyrimidine metabolism, arginine metabolism, Alanine, aspartate and glutamate metabolism, nitrogen metabolism, glycerolipid metabolism, and steroid biosynthesis (Table 17).

The Alpha linolenic acid metabolism, and Valine, leucine, and isoleucine metabolism were identified in the leaves of both sets of plants no cold-acclimated and cold-acclimated plants.

Metabolism of amino acids Valine, leucine, and isoleucine was observed in both sets of plants, but the cold acclimated plants exposed to freezing temperatures (-9°C) also have the Alanine, aspartate and glutamate metabolism. Detection of free amino acids suggests an increase in protein turnover by acclimation to low temperature in polyploid plants.

The plants that experienced freezing temperatures (-9°C) after cold acclimation have the metabolic biomarker glutamine. This amino acid represents different pathways including: Aminoacyl-tRNA biosynthesis, purine and pyrimidine metabolism, arginine metabolism,

Alanine, aspartate and glutamate metabolism, nitrogen metabolism, and nitrogen metabolism. These plants also have two pathways from the secondary metabolism: the glycerolipid metabolism, steroid biosynthesis and the steroid biosynthesis.

Objective 2. Develop and optimize system-level logistics models for demand-driven harvesting.

Task #	Description of Task	Deliverable	Target Completion Date
1 Fan	Feedstock logistics data collection (farm fields, road networks, water supply, existing facilities, etc.)	Define data and parameter settings for input Preliminary model and algorithm developed	1 Aug 19 1 Aug 19
2 Fan	Integrate and analyze economic benefits and environmental influences within optimization model	Identify parameter settings for optimization model Complete data input within optimization model Complete sensitivity analysis for future model and algorithm development	1 Aug 19 1 Aug 19 1 Aug 19
3 Fan	Develop hybrid optimization models for operations (flexible biomass harvest scheduling, etc.)	Complete hybrid optimization model for operations Present research findings at regional/national conferences Generate publication(s) highlighting research	31 Aug 19 31 Aug 19 31 Aug 19

Feedstock Logistics Data Collection:
Data collection work was almost finalized this quarter. (Figure 11)

Geographic Information System (GIS) data was collected from online databases. We collected land cover types of Arizona and National Hydrography Dataset (NHD) for water supply from USGS, county boundary from US Census Bureau, and transportation network from University of Arizona GIS & Geospatial Database. The transportation distances are measured on the map as road distances within ArcGIS application. Some other input parameters, including cost factors and biomass yield are collected from existing references and our industry partner – Bridgestone.

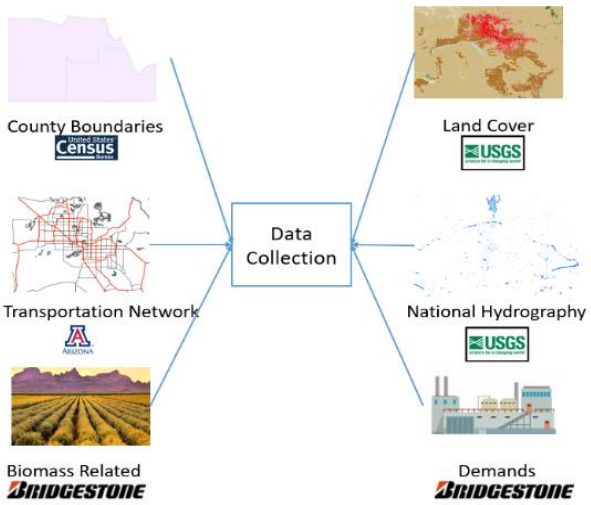

Figure 11. *Feedstock data collection process.*

In the future, we are going to integrate Central Arizona Project (CAP) as natural resource data into our optimization model. And we will see the impact of CAP on the facility location selection decision.

Economic Benefits and Environmental Influences:
We are in the process of integrating environmental and social influences into optimization model. The economic aspect is still the most important consideration in the biomass supply chain configuration and management in order to save total capital cost and operational cost.

With the arising awareness of sustainable issues, people are caring more about the environmental and social impacts of a biomass supply chain. As a result, we are trying to integrate these two aspects into our optimization model and build a cost-competitive, reliable and sustainable biomass supply chain. We are going to use multi-objective optimization method to analyze and formulate the model. By giving different weight of each of the three objectives, we estimate the impacts from economic, environmental, and social together.

For the environmental part, we use Life Cycle Assessment (LCA) to assess the greenhouse gas emissions through the whole process in a supply chain. For the social part, we plan to evaluate the jobs created by the operations of the supply chain, by an input-output multiplier analysis.

In order to analyze the greenhouse emissions in all of the operations in a biomass supply chain, we need to understand clearly about each operations, including collection and harvest, storage, pretreatment, transportation, conversion, and product distribution. We are going to collect information from references, communicate with corresponding partners/ groups to obtain the accuracy of collected data.

Hybrid Optimization Models for Operations:
Developing the hybrid optimization models for different operations is in process.

Using optimization methods and algorithms for strategic (long-term) decisions are well studied and tested in the facility location problem. We are now working on optimization methods and algorithm for tactical/ mid-term decisions, such as inventory level of a storage site, and operational/ short-term decisions, such as short-term harvesting or shipping schedule.

Objective 3. Demonstrate feasibility of farm to fuel conversion of bagasse.

Task #	Description of Task	Deliverable	Target Completion Date
1 Brewer	Prepare 2 manuscripts on guayule/guar bagasse composition, biomass-to-conversion method matching (HTL product yields)	Manuscripts prepared Manuscripts submitted for peer-review process	31 Aug 19 31 Aug 19

Manuscript Preparation:
Cheng and Bayat continued work on the lignocellulose waste material-conversion method review paper; the current length is such that we are discussing splitting the manuscript into multiple review articles for Q2. Cheng and Audu continued work on guar and guayule bagasse sections of the manuscripts in collaboration with the Holguin, Jarvis, and Grover groups. Improvements were made in the biomass characterization (carbohydrates) methods, and Cheng, now full time as a postdoc, has been able to assist with measurements in the Holguin lab across various subprojects.

Objective 4. Identify economic co-products in guayule and guar, e.g., biologically active components.

Task #	Description of Task	Deliverable	Target Completion Date
1 Brewer	Literature review at experiment design/set-up for isolation/purification of guayule resin compounds in commercially relevant quantities	Define research questions for guayule resin separation methods	31 Aug 19
		Preliminary experimental designs defined for guayule resin separation methods	31 Aug 19
2 Gunat	Comprehensive literature search for commercially important small-molecules structurally related to major metabolites of guayule	Identify major metabolites of guayule	30 Sep 18
		Determine conversion ability of metabolites to value-added co-products	30 Sep 18
3 Gunat	Chemical and microbial transformations	Identify and select two major metabolites for experiment	31 Aug 19
		Develop chemical and/or microbial methods for the conversion of guayule by-products into value-added products	31 Aug 19
4 Gunat	Evaluate major metabolites of guayule	Identify promising biologically active metabolites of guayule	30 June 19
		Isolate and characterize potential anticancer and anti-microbial activities of metabolites	30 Jun 19
		Investigate bagasse for polysaccharide coproducts	30 Jun 19
		Investigate terpene solution for useful coproducts	31 Aug 19
		Investigate rubber for low molecular weight constituents	31 Aug 19

5 Gunat	Evaluate extracts and fractions of guayule resin, bagasse, and unusable seeds	Identify promising extracts/fractions for bioactivity guided fractionation to isolate minor biologically active metabolites	31 Aug 19

Literature Review and Experiment Design/Set-up for Isolation/Purification of Guayule Resin Compounds:

Dehghanizadeh continued his literature review and characterization method training on resin. He conducted an evaluation of available extraction equipment at NMSU and found an accelerated solvent extraction (ASE) instrument that can be used for resin removal and separation. The supercritical fluid (CO_2) instrument in storage in chemical engineering proved to be too large and in need of major refurbishing to be useful for this project. During Q2, a statement of work and associated request for funding for resin separation and value-added application will be submitted. Also in March, Jarvis collected high resolution mass spectroscopy data on the heavy (less-volatile) guayule resin samples at the National High Magnetic Field Lab in Tallahassee, FL. These data will be used for comparison against the more-volatile resin molecules that can be characterized by more conventional methods.

Comprehensive Literature Search for Commercially Important Metabolites of Guayule:

Investigation of guayule resin: Additional three minor cycloartane-type tritepenoids, argentatin J (3.2 mg), argentatin I (3.0 mg), and 3β-hydroxy-3-deoxoargentatin C (22.0 mg) (Figure 12) were isolated and characterized. Of these, argentatin J is a new compound and this is the first report of the isolation of 3β-hydroxy-3-deoxoargentatin C from guayule.

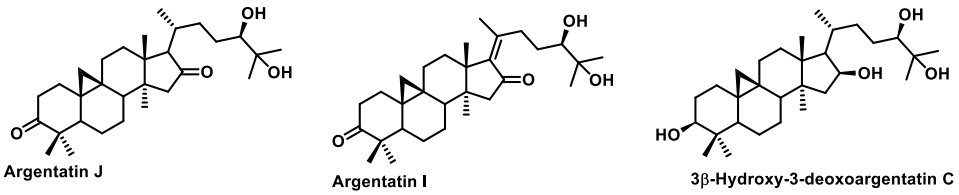

Figure 12. *Chemical structures of some guayule resin constituents.*

Chemical and Microbial Transformations:

Chemical and microbial transformations: The major constituents of guayule resin, argentatins B and C, were subjected to chemical transformations to produce their fused pyrimidine hybrids (Figure 13) with potential biological activity.

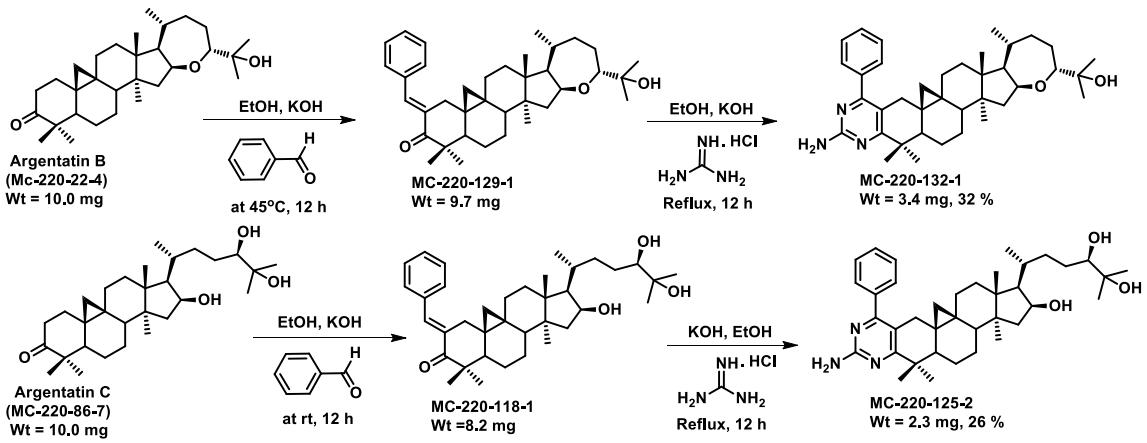

Figure 13. *Chemical transformations of argentatins B and C to their fused pyrimidine hybrids.*

Evaluate Major Metabolites of Guayule:

Investigation of guayule rubber for low-molecular weight constituents: Fractionation of the rubber sample, Yulex GR; ID 252-18, (2.3 g) using a mixture of pentane and acetone (51.5 %: 48.5 % by weight) provided three fractions containing high molecular weight rubber (2.0 g), low molecular weight rubber (187.0 mg), and resin (76.0 mg). The low molecular weight rubber fraction was found to contain mainly *cis*-polyisoprene by ^{1}H and ^{13}C NMR spectroscopic analysis.

SYSTEM PERFORMANCE & SUSTAINABILITY

Project Coordination: Colorado State University (CSU) leads the bi-monthly working group webinar/phone calls. The meetings are leveraged to ensure all team members are on schedule and work can seamlessly integrate across institutions. The focus this quarter has continued to be on the following activities: (1) model integration with a focus on developing scenario and sensitivity analysis coupled with economics and environmental impacts; (2) model integration across the sustainability team; (3) continued development and validation of individual sub-process models for the processing of guar and guayule from agricultural biomass to final products; and (4) development of a sustainability team meeting schedule on a weekly basis in support of model integration. All notes and presentation materials are maintained in a community workspace available to all partners for future reference.

Issues/Risks:
Model fidelity and accuracy represents the largest risk at this point for the sustainability team. CSU is supporting collaborators and critically working through the integrated model to identify areas for focused improvement. In addition, CSU is working with industry partners to verify and validate sub-process models.

Objective 1. Develop a scalable engineering process model for crop production and processing that is coupled with Techno-Economic Analysis (TEA) and Life Cycle Analysis (LCA) to understand the economic impact to rural communities through input-output methods.

Task #	Description of Task	Deliverable	Target Completion Date
1 Gutierr	Functional integration of economic analysis into system model	Gather information for farm level scenarios using different avg. farm sizes, irrigation, and acreages	30 Jun 19
		Complete economic impact of guar and guayule at the farm level on employment, labor income, taxes and household spending (among others)	30 Jun 19
		Validate preliminary analysis; finalize farm level analysis	30 Jun 19
		Generate publication on the economic analysis for guar and guayule	30 Jun 19
2 Landis	First order LCA model	Complete preliminary LCA	30 Sep 18
3 Landis	LCA first order model integration	Integrated modular model in collaboration with broader team	31 Dec 18

4 Landis	Collect agricultural data from field trials	Update agriculture model inputs Re-run model with new information	31 Mar 19 31 Mar 19
5 Landis	Clarify social sustainability metrics	Develop overview of sustainability tools and list of potential metrics Generate publication/presentation for conference proceedings	30 Jun 19 30 Jun 19
6 Quinn	Techno-economic and Life Cycle Assessment results	Update/finalize economic and environmental impact results	1 Aug 19
7 Seav	Co-develop enterprise budgets that contain costs/returns of growing current cropping system and new crops that include outputs for LCA	Completed budgets for integration into Sustainability model	28 Jan 19
8 Seav	Develop financial ratios and performance measures for representative farms in AZ and NM	Meet with area lenders and accountants to gather info Complete two whole-farm case studies (AZ and NM) Case study info integrated into Sustainability model	31 Mar 19 31 Mar 19 31 Mar 19
9 Teeg	Facilitate working agreement between Tribal Farms and Bridgestone to establish experimental plots	Signed agreement established between Gila River Farms and Bridgestone Experimental plots established on Tribal lands	1 Jan 19 1 Jan 19
10 Teeg	Co-develop enterprise budgets that contain costs/returns of growing current cropping system and new crops that include outputs for LCA	Completed budgets for integration into Sustainability model	28 Jan 19
11 Teeg	Develop financial ratios and performance measures for representative farms in AZ and NM	Meet with area lenders and accountants to gather info Complete two whole-farm case studies (AZ and NM) Case study info integrated into Sustainability model	31 Mar 19 31 Mar 19 31 Mar 19

Functional Integration of Economic Analysis into System Model:

The current status of the project in meeting defined milestones for the recent quarter (Q1), 2019 is on schedule. The proactive bi-weekly meetings with project partners motivated the team to meet the identified task and set targets.

The goal of identifying farm level inputs to be used in the integrated systems model was accomplished. The first draft of the farm level economics has been integrated into the systems model. NMSU has been in collaboration with OSU and UA in developing the farm level model.

The whole farm level economic analysis has been successfully developed for integration into system model.

First Order LCA Model:
Existing guayule data and knowledge was used to setup a preliminary guayule excel model as well as outline a guar excel model. An LCA mini-workshop/tutorial was also led by Dr. Eranki to assist with the setup of the model. Additional research on general agricultural models was completed to explore simple to complex model options that may benefit this project, specific to field emission simulations. Preliminary results were produced for guar ag impacts from the excel based model. Refinement of model inputs was completed, and new results were produced.

LCA First Order Model Integration:
Inputs to both LCA and cost models are very similar; as such the teams have collaborated to ensure that the models are harmonized with one streamlined inputs location. All teams have contributed to the inputs tab and refined the overlapping inputs. For the cost model, costs and breakeven prices are based on whole-farm, long-term scenarios that include changes to labor, fuel, repairs and maintenance costs for tractors and equipment as crops are planted or adopted. Some outputs from the cost model can be used as inputs for the LCA, and include hours of labor, amounts of fertilizer and chemical inputs, irrigation water usage, and tractor and equipment fuel requirements, and replacement costs. The LCA model estimates environmental impacts by creating process models and coupling them with life cycle inventory databases, with environmental impacts calculated via the EPA TRACI model. The first round of full team model integration is complete, and the refining process of the integrated model is still in progress. Validation of agricultural processes is in progress with planned communication with Guar Resources and their associated farmers.

Collect Agricultural Data from Field Trials:
No progress made this quarter.

Clarify Social Sustainability Metrics:
Initial social sustainability literature review was completed. Presented on the social sustainability assessment review and its application to emerging technology (like guar & guayule) at the International Conference on Environmental, Cultural, Economic and Social Sustainability conference in Vancouver, Canada. Informative request has been sent out to other SBAR teams to see what our social sustainability efforts have been across the project and plan for upcoming next steps with regards to social sustainability assessment and information.

Techno-economic and Life Cycle Assessment Results:
Research for this objective is complete; no new data to report.

Enterprise Budget Development:
With the help of the economics team, we have completed the initial phase of the integrated model. Machine costs as well as adjusting certain inputs can be modified for a sensitivity analysis. The commodities included in the model are guar, guayule, cotton, corn, sorghum, barley, wheat and alfalfa hay. The user can modify the total number of acres of a farm, the percent of crops grown, modify prices received, crop yields, irrigation, fertilizer, and pesticide inputs for each crop.

Continue enhancement to the farm level scenarios using different average farm sizes, irrigation technologies and different crop mix is in progress for both New Mexico and Arizona.

Development of Financial Ratios and Performance Measures for Representative Farms in AZ and NM:
We are making contact with lenders in Arizona and New Mexico to explain the whole farm concept and gathering information about acceptable liquidity, debt-to-asset and repayment capacity measures for varying farm sizes with crop rotations included in the integrated model.

Working Agreements between Tribal Farms and Bridgestone to Establish Experimental Plots:
Continue to assist in securing experimental plots on at least two tribal farms. 1) Connect Bridgestone and CRIT farms for experimental acreage agreement, establish introduction meeting and started contract negotiations 2) Connecting Bridgestone and Fort McDowell Farm for experimental acreage agreement. Started the conversation and in the process of setting up the first meeting with both farms.

Objective 2. Integrate regionally appropriate metrics and combine results from SBAR-developed data into sustainability models to provide a path to commercialization of biofuels and bioproducts.

Task #	Description of Task	Deliverable	Target Completion Date
1 Quinn	Model integration	Integration of upstream and downstream modeling efforts	1 Jan 19
2 Quinn	Sensitivity analysis	Generate results for sensitivity analysis Present results of sensitivity analysis to SBAR LEADS for feedback	1 Apr 19 1 Apr 19
3 Quinn	Process modeling	Improve downstream process modeling fidelity Re-run results for further analysis (and to identify next steps)	1 Jun 19 1 Jun 19

Model Integration:
A critical aspect moving forward is the integration of modeling efforts across the teams. CSU has lead the integration effort with the development of a modeling framework to support the integration of the research across all research groups. As previously reported, an integrated model has been developed and the CSU team continues to work with collaborators in improving the fidelity of individual components of that model. The integration effort has identified areas that have required improvement from various partners and CSU continues to support the seamless integration of those components.

Engineering Process modeling:
Guar: Model development has focused on continued integration and verification of results. Harmonization efforts occurred within the life cycle portion of the guar model to ensure accurate methodology. We will be working with Guar Resources to validate several process models in the near future. The baseline integrated Guar model is now ready for the structural development of scenario and sensitivity analyses. The team will be focused on developing these tools to identify variables that significantly impact results and evaluate farm level impact.

Guayule: Model validation with Bridgestone has focused on two key elements related to rubber extraction. 1) The solvent recovery sub-process has been refined to reflect more realistic industrial solvent and mineral oil recovery efficiencies. 2) The economic modeling for the full rubber extraction process has been reviewed to ensure realistic results for different scenarios including sale of downstream bagasse and resin at a set value. The combined impacts of elements 1 and 2 have reduced expected selling price of rubber significantly. Work has started on implementing these and other scenarios within the full integrated model. Evaluating these scenarios across the integrated model will allow us to evaluate the impact of different guayule biomass selling prices on farm economics.

Objective 3. Interface with regional growers to de-risk US production of guayule and guar while evaluating social impacts.

Task #	Description of Task	Deliverable	Target Completion Date

NO PLANNED ACTIVITIES FOR THIS OBJECTIVE IN YEAR 2.

EXTENSION & OUTREACH

Project Coordination: Dr. O. John Idowu (New Mexico State University) continues to serve as the lead for the Extension & Outreach working team. When the larger Education and Extension & Outreach components jointly meet, Dr. Idowu works with Dr. Chavarria to draft meeting agendas.

The Extension & Outreach team has two main foci – youth development (through 4-H activities and STEM summer camps), and grower education/outreach. These two sub-groups meet at least once per month to discuss tasks and to improve component integration. The combined Education and Extension & Outreach teams meet once monthly to provide updates and address larger concerns regarding tasks and project implementation in Arizona and New Mexico.

Issues/Risks:
Inoculum of plant growth promoting microbes/rhizobium mix (Micronoc, Sono Ag, Brownfield TX) did not show significant impact at all demonstration locations. We are modifying the strategy for a new demonstration.

Objective 1. Produce Extension bulletins and web materials to inform growers of agronomic and irrigation requirements.

Task #	Description of Task	Deliverable	Target Completion Date
1 Angadi	Arrange guar field day/field walks at Agricultural Science Center, Clovis NM	Present guar crop info to ~100 producers in the region	31 Aug 19
		Visit guar farmers' fields to identify future research needs	31 Aug 19
		Visit Guar Resources to identify research needs	31 Aug 19
2 Angadi	Guar phosphorus and rhizobium study	Gather/analyze data; develop peer-reviewed paper on guar Phosphorus and rhizobium needs	31 Aug 19
		Train graduate students in guar agronomic management	31 Aug 19
3 Angadi	Guar deficit irrigation study	Gather/analyze data; develop peer-reviewed paper on guar deficit irrigation management	31 Aug 19
		Analyze/present results at regional and national meetings	31 Aug 19
4 Evan	Produce guayule newsletter articles	At least 2 guayule articles drafted and published – targeting AZ growers	31 Aug 19

5 Fields	Design/schedule evaluation tools, protocols, and metrics for all Extension & Outreach activities	Fall tools developed/refined; evaluation data gathered Spring tools developed/refined; evaluation data gathered Summer tools developed/ refined; evaluation data gathered Data synthesized; evaluation report generated	31 Dec 18 31 May 19 31 Jul 19 31 Aug 19
6 Grover	Establish guar trial and showcase guar as potential crop in NM	Host field day Collect data; results synthesized Generate peer-reviewed Extension publication	31 Aug 19 31 Aug 19 31 Aug 19
7 Gutierr	Develop producer-level partial budget analysis for guayule and guar	Generate Extension bulletin reporting cost of production for guayule and guar	15 Mar 19
8 Idowu	Travel to conferences	Present SBAR info/materials at 4-5 grower commodity conferences	31 Aug 19
9 Idowu	Distribute Needs Assessment to farmers in NM	Compile survey information for at least 100 farmers/growers in NM Analyze/synthesize results Identify gaps for future SBAR work in NM	31 Aug 19 31 Aug 19 31 Aug 19
10 Idowu	Establish guayule and guar trials in Las Cruces, NM and Los Lunas, NM	Showcase trial experiments at field days Gather data/synthesize results (toward generating an Extension bulletin) Generate first year trial summary (published on SBAR website)	31 Aug 19 31 Aug 19 31 Aug 19
11 Idowu	Design/schedule/implement E&O evaluation	Fall evaluation data gathered Spring evaluation data gathered Summer eval data gathered Eval info synthesized; report generated	31 Dec 18 31 May 19 31 Jul 19 31 Aug 19
12 Rock	Deploy stakeholder needs assessment survey in AZ	Survey results collected from grower stakeholders in AZ	31 Dec 18
13 Rock	Survey results from Arizona	Summarize survey results; generate Extension publication	31 Mar 19

		Generate peer-reviewed manuscript using AZ survey results	31 May 19
14 Seav	Generate updated cost-production budgets for current cropping systems (guayule and guar)	Develop 5 enterprise budgets showcasing different scenarios Generate summary; publish results (SBAR website)	30 Jun 19 30 Jun 19
15 Seav	Participate in Extension meetings; disseminate economic info for guar and guayule	Provide 2 presentations to growers in NM Provide 2 presentations to growers in AZ	31 Aug 19 31 Aug 19
16 Teeg	Generate updated cost-production budgets for current cropping systems (guayule and guar)	Develop 5 enterprise budgets showcasing different scenarios Generate summary; publish results (SBAR website)	30 Jun 19 30 Jun 19
17 Teeg	Participate in Extension meetings; disseminate economic info for guar and guayule	Provide 2 presentations to growers in NM Provide 2 presentations to growers in AZ	31 Aug 19 31 Aug 19
18 Teeg	Develop input tool to identify potential adoption rates of guayule and guar in AZ and NM	Gather data for adoption potential during Extension meetings Synthesize data; generate report highlighting adoption probability in AZ and NM	31 Aug 19 31 Aug 19

Field Days and Site Visits:

Dr. Angadi's team is planning for a large demonstration of guar on farmer's field. They have talked to the agronomist (Mr. Guy Spears) from Guar Resources for seeds. Have been talking to farmers to get a good collaborator. Our guar research and demonstration will be show cased in ASC Clovis annual summer field day. In addition, field tour will be arranged for interested farmers to the large scale demonstration trial. We will also visit some of the guar farms nearby, research projects of other scientists and interact with experienced farmers. Understanding research needs of guar farmers in the region will be ascertained.

Dr. Angadi's team has started working on developing high quality visuals and videos of guar plant development, the assignment accepted during the SBAR-EEO meeting at Las Cruces, NM. Angadi has procured a few cameras for the purpose and has shot some trial videos. Initial videos are quite encouraging. We are learning to improve quality by adjusting planting material, light conditions, background, time lapse scheduling and exposure, and focus on objective. We will have some videos in the field also. We hope to develop a few quality videos by the next annual retreat.

Guar Phosphorus Rhizobium Study:
Results from P fertilization and plant growth promoting microbes/rhizobium mix (Micronoc, Sono Ag, Brownfield TX) is not showing useful treatment effects. Probably, the inoculant is not working in our environment or guar is not responding to it. Therefore, we are modifying the demonstration trial to include N and P.

Guar Deficit Irrigation Study:
Preliminary results of the deficit irrigation trial from 2018 were compiled as a chapter in the 2018 annual report of Agricultural Science Center of Clovis. A poster was presented in ACES-Open House on April 6, 2019, which was meant for communicating our research work to public and school children. We also setup SBAR Display and distributed guar and guayule handouts in Spring Field Day at Clovis, NM on April 11, 2019.

Produce Guayule Newsletter Articles:
One newsletter has been written and will be in the next Pinal County Cooperative Extension Quarterly Newsletter.

Design and Implement Evaluation Tools:
For the grower-focused extension group, based on feedback received during the Las Cruces meeting, the evaluator drafted a simple (paper) tool that is meant to assist the team in better capturing comprehensive information about their outreach efforts and reach. The first version of the tool was shared with the extension team in February for their comments and initial use to inform revisions. A check in with the team will occur in Q2 to determine if this tool has helped them document the types of outreach being done, the variety of stakeholders being reached (i.e. growers, industry, general public, K-12, etc.), and the overall impact (estimated numbers reached and demographics.)

In a meeting with the extension team, we discussed and looked at the changes made on the education side of the website and discussed the ways that the extension team can make similar changes to better meet the needs of their stakeholders. In Q2, the evaluator will work with the extension group (including both grower focused and 4-H) on ways that they can customize the content and formatting of their web pages to better meet their needs.

Showcase Guar as Potential Crop in New Mexico:
Dr. Grover's group visited grower fields, presented information related to guar, and discussed the potential of guar for production and demonstration in Anthony, New Mexico. Data continues to be collected from on-station guar demonstrations.

Develop Producer-Level Partial Budget Analysis for Guayule and Guar:
Enterprise budgets and narrative detailing the ergonomic and cultural practices in production of guar and guayule have been developed in draft form. These enterprise/budget analysis fact sheets will be used in grower meetings to help inform producers of the cost and returns associated with guar and/or guayule production. First drafts are completed and under peer review by members of the NM, AZ and Oregon SBAR team.

Related to development of producer education information and material, the team has successfully connected with county extension agents in 7 southern New Mexico counties in

order to meet with producers and distribute a needs assessment survey to producers. Some survey results have been collected and the team is in contact with extension agents to collect all of the surveys distributed. The needs assessment survey will help in decision making on questions that producers desire to have answered using the systems model as well as identify accurate potential for adoption of biofuel crops. The team is connecting with county extension agents to collect all of the survey results. After results are collected the team will analyze the survey data and use the information to create extension bulletins to answer producer's questions on sustainability and production of guar and guayule in southern New Mexico.

Travel to Conferences:
An SBAR tabling event took place at the NM Cotton Conference on January 23rd, 2019 in Ruidoso, NM. About 80 participants had the opportunity to visit SBAR table and learn about the project. There was another SBAR table display at the NM Organic Farming Conference that took place from February 15th – 16th, 2019 in Albuquerque, NM. About 300 of the conference participants visited the SBAR table with some expressing interest to know more about the SBAR project. We collected the contact information of those interested in learning more about the SBAR project.

Distribute Needs Assessment to farmers in New Mexico:
Distribution of the guar needs assessment survey to NM growers was concluded in February of 2019. About 60 growers completed the survey. We are currently in the process of analyzing the surveys and compiling the summary results.

Dr. Gutierrez's team has collected a total of 54 needs assessment have been completed and collected from producers in NM and have been summarized for analysis.

Establish Guayule and Guar Trials in New Mexico:
The guayule cold tolerance study that started in the fall of 2018 at Leyendecker Plant Science Center in collaboration with scientists from Bridgestone is still ongoing. The first year of trial will be concluded in May 2019.

Graduate student/technician (Darien Pruitt) has actively participated in outreach activities and supervised the field trials at the research stations. She has also designed her graduate experiments that will focus on mycorrhizal colonization of guar roots as affected by different organic amendments and biorational products. She will be starting a laboratory/greenhouse trial in May.

Design and Implement Extension & Outreach Evaluation:
Based on request by the grower-focused EEO members of the SBAR team, the evaluation specialist designed a template sheet that can be used to capture our contacts at SBAR events. The template was used to capture the contacts that visited the SBAR informational table displays at the NM Cotton and NM Organic Farming Conferences.

Stakeholder Needs Assessment in Arizona:
This task is complete.

Cost-Production Budgets for Current Cropping Systems:
We are working with New Mexico team members to develop a guar enterprise budget. No new data to report.

Completed the estimation of crop adoption estimates for AZ for both Guayule and Guar. Estimates will be for Maricopa, Pima and Pinal counties.

Dissemination of Guayule and Guar Economic Information through Extension Meetings:
The results from Sustainability integrated models will provide Extension faculty an interactive tool that generates the costs to grow and harvest guayule and guar to be used in meetings in AZ and NM.

Input Tool for Potential Adoption Rates in Arizona and New Mexico:
Preparing Whole Farm analysis and crop budget information to be adapted to extension publications with the extension outreach group. Continue to refine the AZ and NM whole farm scenarios, and we are near finalization of the baseline for whole farm analysis and presentation for extension/outreach activities.

Objective 2. Hold workshops throughout the region on sustainable practices to expand crop production to new rural regions and Native Nation lands.

Task #	Description of Task	Deliverable	Target Completion Date
1 Evan	Hold workshops and present information to growers in Arizona	Host two presentations on guayule agronomic production and irrigation at regional extension events	31 Aug 19
		Present guayule production to Native American farming communities	31 Aug 19
		Collect needs assessment information directly from Native American farming communities	31 Aug 19
2 Grover	Hold workshops and present information to growers	Host 2 presentations on guar agronomic production as an interim step to bulletin	31 Aug 19
		Present SBAR project information and materials	31 Aug 19

Grower Workshops in Arizona:
PowerPoint presentations to growers at grower meeting. 8/31/19 Green- Completed, presentation has been created that highlights the history of guayule, current research that is ongoing and the market outlook for guayule production. This presentation was given at grower meetings in January in Marana and Casa Grande.

Contact has been made with 2 Native American farming communities to discuss the potential of guayule production on their land. Both are interested and discussions have commenced about the requirements required for guayule production. Trent Teegerstrom, U of A Native American Liaison, and David Dierig Bridgestone, were also involved with these conversations and we are working towards installing acreage with one community as early as 2019. Meetings with Native American communities will continue throughout the year.

Collect survey data and add to needs assessment survey. 8/31/19 Green- Relationships are being built with Native American communities, when it feels appropriate I will approach them about filling out the survey.

Grower Workshops in New Mexico:
Grover participated in monthly SBAR Guar focus group, SBAR EEO group, and SBAR NMSU group meetings with colleagues on the project. Grover also served on advisory committee of Western Sustainable Agricultural Research and Education (WSARE) and helped plan for the NM Sustainable Agriculture Field Day to be held in summer 2019 at Las Cruces, NM.

Grover met several potential (guar) growers at the New Mexico Chili Conference and the New Mexico Organic Farming Conference, informally presented information on SBAR project and guar production. A number of SBAR guar surveys were also collected at these events.

Objective 3. Involve youth in internships, 4-H projects, and STEM summer camps.

Task #	Description of Task	Deliverable	Target Completion Date
1 Gutierr	Develop/improve SBAR 4-H Camp curriculum	Adapt camp curriculum for use in NM (train-the-trainer and 4-H camps)	31 May 19
2 Gutierr	SBAR 4-H Day camps and/or mini-camps	Plan/Host 6 SBAR 4-H Day camps and/or mini-camps targeting Hispanic and Native youth in Southern and Northern NM	31 Aug 19
3 Lopez	Order equipment/supplies for biofuel activities	4-H Biofuel outreach activities prepped/ready for implementation Summer camp curriculum finalized	30 Apr 19 30 Apr 19
4 Lopez	Provide 4-H biofuel activities to 4-H youth	Hold 2 biofuel activities (at least one reaching rural 4-H youth)	31 Jul 19
5 Lopez	Expand 4-H biofuel camp	Host a biofuel-focused 4-H summer camp Increase participation to 20 students	31 Jul 19 31 Jul 19
6 Lopez	Refine evaluation instrument for the BYOE program	Revised and updated evaluation instrument available for SBAR biofuel activities	31 Jul 19

		Revised and updated evaluation instrument available for SBAR biofuel summer camp	31 Jul 19
7 Rock	Develop SBAR internal factsheets on *Project Puente*	Generate *Project Puente* resource document(s) for SBAR faculty	28 Feb 19
8 Rock	Recruit students for summer *Project Puente* internships	Update application materials to highlight on-going SBAR research opportunities Recruit 6 students for Yr2 cohort of *Project Puente* interns	1 May 19 1 May 19
9 Rock	*Project Puente* student project development and deployment	Work with SBAR faculty to identify appropriate internship projects (research and extension) Facilitate SBAR internship projects; final poster presentations highlighting student work	26 Jul 19 31 Aug 19

SBAR 4-H Camp Curriculum:
Developmental work continues; no new details to report this period.

SBAR 4-H Day Camps or Mini-Camps:
Developmental work continues; no new details to report this period.

Biofuel Activities Supplies:
UA and NMSU 4-H Team held 5 planning meeting total; we have continued to identify activities/ideas that would integrate the research components: Feedstock Development & Production, Post-Harvest Logistics & Co-Products and System Performance & Sustainability into the biofuel summer camp in 2019; UA 4-H team has also been integrating Dr. Laura Rodriguez-Uribe's and Dr. Catie Brewer's activities into the 4-H Biofuel camp; Dr. Rodriguez-Uribe is collaborating with 4-H agents and teachers in New Mexico to plan SBAR activities. Rodriguez-Uribe and Brewer have both developed separate activities for the 3 day train the trainer camp in NM.

4-H Biofuel Activities to Youth:
UA undergraduate students Jasmine Lopez – AmeriCorp member, Shiara Perez and Kaitlyn Benally have held five 1-hour sessions at Pueblo High School chemistry club to provide Biofuel activities, on average 8 students have participated in each. Dr. Gutierrez is working with the NM state 4-H office to host biofuel activities.

Expand 4-H Biofuel Camp:
Dr. Lopez, Jasmine Lopez, Shiara Perez and Kaitlyn Benally have met with Pueblo High School students to share about and recruit for the Biofuel summer camp. Students seem very interested in doing the biofuel activities and participating in the biofuel during the summer. Dr.

Lopez and Daniela Cabrera have reached out to the 4-H Extension Program to advertise the program with 4-H Agents as well as have sent it out to parent/student list serves. Dr. Gutierrez (NM) is working with the NM 4-H state office to recruit agents and volunteers for the train the trainer workshop in July. Dr. Laura Rodriguez-Uribe is working local middle school teachers and 4-H program to promote summer train the trainer program. Cabrera has prepared the art contest for industrial crops and have sent it out to AZ 4-H county Agents list serve and has sent flyer to Dr. Gutierrez to circulate in NM 4-H program and to schools in NM. A web page for the biofuel camp has been established on the SBAR website. Links have also been provided on the UA Cooperative Extension STEM for the biofuel camp and Art contest.

Refine Evaluation Instrument for the BYOE Program:
Dr. Lopez, Cabrera, and Dr. Gutierrez have completed reviewing the Bioenergy Youth Outreach and Engagement (BYOE) evaluation for the SBAR 4-H Biofuel Summer Camp and are using this feedback to guide the planning for this year's summer camp at the UA and the train the trainer workshop at NMSU.

Internal Factsheets on *Project Puente* Internships:
See description below.

Project Puente Internship Recruitment:
During this quarter, the Arizona Extension team worked alongside Central Arizona College to recruitment of *Project Puente* student interns to participate in in the SBAR internship program for Summer 2019. Outreach materials and flyers have been developed as resources for potential students interested in the program as well as SBAR faculty interested in mentoring students.

Student interns will be located at the Maricopa Agricultural Center or the USDA Arid Land Agricultural Research Center in Maricopa, as well as on campus at the University of Arizona in Tucson. Student interns will work on both research and Extension projects related to the focal areas of SBAR and were able to interact with SBAR industry members, faculty, staff and students as part of their project(s). Each student will work on projects for a total of 6 weeks under the director of a SBAR faculty mentor and will share their findings at a culmination event in July of 2019 at the Maricopa Agricultural Center with the faculty mentors, teachers, and families. The Extension team aims to increase year two summer interns from 4 to 6 total interns.

Project Puente Student Project Development and Deployment:
In order to better facilitate meaningful student intern experiences the extension team has partnered with 4H STEM specialist Dr. Jerry Lopez. Dr. Lopez is currently working to recruit a local High school teacher in Tucson to serve as a faculty mentor for the local Tucson-based interns. Additionally, in-order to aid in information transfer to student interns, we have arranged for Zoom classroom sessions that will link Maricopa and Phoenix-based students with those in Tucson. If successful, this would be a model for future engagement of students in New Mexico in year 2020.

EDUCATION

Project Coordination: Dr. Sara Chavarria (University of Arizona) serves as the lead for the Education Team, which meets at least twice monthly to cover broader topics related to specific Education objectives and tasks. Smaller working groups meet weekly for specific action items (such as planning and coordinating the weekly SBAR Fellow Seminar). The Education Team also meets monthly with the Extension & Outreach Team to ensure that selected curriculum and activities is integrated for 4-H workshops and camps.

Issues/Risks:
Activities are continuing as planned; no issues/risks identified this quarter.

Objective 1. Train teams of students and teachers with focus on rural and under-represented groups.

Task #	Description of Task	Deliverable	Target Completion Date
1 Brewer	Supervise/Assist NM SBAR Fellows and Teacher Mentors through 2018-2019 school year	Design/deliver after school program for middle school Design/vet STEM activities	31 May 19 31 May 19
2 Brewer	Recruit and train SBAR Fellows and Teachers for 2019-2020 school year	Identify 2 new NM SBAR Fellows and any replacements, as necessary Identify 2 new NM SBAR Middle school teachers Identify 1 PhD student for education component; provide training	31 Jul 19 31 Jul 19 31 Jul 19
2 *cont* Chav	Recruit and train SBAR Fellows and Teachers for 2019-2020 school year	Identify 2 new AZ SBAR Fellows and any replacements, as necessary Identify 2 new AZ SBAR Middle school teachers	31 Jul 19 31 Jul 19
3 Chav	Plan/Design/Coordinate Fall 2018 and Spring 2019 SBAR Fellow seminar	Plan Fall 2018 seminar content Plan Spring 2019 seminar content Generate education products on SBAR Fellow activities (digital publications)	31 Aug 18 31 Dec 18 31 Jul 19
4 Chav	Visit classrooms for observations (Teacher delivery of SBAR content)	Implement Fall 2018 teacher observation	30 Nov 18 30 Nov 18

		Implement Fall 2018 SBAR Fellow observation Implement Spring 2019 teacher observation	30 Apr 19
5 Fields	Design/Schedule evaluation tools, protocols and metrics for all Education activities	Fall tools developed/refined; evaluation data gathered Spring tools developed/refined; evaluation data gathered Summer tools developed/ refined; evaluation data gathered Data synthesized; evaluation report generated	31 Dec 18 31 May 19 31 Jul 19 31 Aug 19

New Mexico SBAR Fellows and Teacher Mentors (2018-2019):
The fellows and teachers continued the SBAR-based afterschool program, *Guardians of the Biosphere*, where they had approximately 10 students in a given week. Both pairs also conducted activities during the school day in their respective classrooms. In March, Dehghanizadeh and Audu participated in the visit to the Bridgestone facility in Mesa, AZ with teachers and fellows from Arizona. Both fellows attended and participated (virtually) in the fellows' course at UA, and with the SBAR group meetings at NMSU.

Brewer met several times with Rodriguez-Uribe and Gutierrez to coordinate plans for the 4-H/PD Train the Trainers workshop, as well as support from the SBAR fellows for other 4-H and College of Engineering outreach activities. Locations for the Train the Trainers workshop and the Teacher/Fellow PD were identified and reserved, including synchronous distance communication capabilities to enable participation from those unable to travel.

Recruit and Train SBAR Fellows and Teachers (2019-2020):
Recruitment notices were shared with faculty in the Colleges of Agricultural, Consumer & Environmental Sciences (ACES), Engineering, and Education to recruit three new SBAR fellows (Audu will return as a PhD student), and a PhD student in science education. Recruitment notices were sent to the Las Cruces and several neighboring school districts to middle school STEM teachers and administrators, as well as through individual networks of contacts, to recruit two new teachers to join our two continuing teachers.

Two of the 2018-2019 SBAR fellows are graduating, Holly Barton and Ashton Leo. With two fellows leaving the program, four fellows will need to be recruited for Fall 2019. Applications for open fellow positions were received in April of 2019 and selected fellows will be notified the week of 4/15/19.

To address the teacher recruitment challenges identified in the Q4 report of recruiting Native American teachers, Sara Chavarria has been networking and meeting with indigenous communities. This has led to productive meetings with potential applicant, Valentina (Tina) Andrews, whose interest and experience has highlighted the need for indigenous representation

in the SBAR project. Teacher applications were received in April 2019 and selected teachers will be notified the week of 4/15/19.

SBAR Fellow Seminar (Fall 2018 and Spring 2019):
The second semester of the seminar is underway and going well. Knox and Anderson were in charge of the ongoing seminar planning with administrative support from Duncan. The weekly seminar meetings took place on Thursdays from 4:30-5:30 pm and the sessions alternated between staff presentations on relevant education topics, guest speakers on topics such as classroom management techniques and video recording/editing techniques and hands-on work on lesson plans components and presentations/discussions by fellows based on their needs.

Weekly seminar planning meetings took place on Thursdays at 3:30-4:30pm to discuss presentations, arranging of speakers, assignments, and lesson design support. Some highlights from the seminar include: translating academic article for middle school age students and developing fictional stories that serve as an additional resource to last semester's lesson plans, developing and strategizing of short videos to add to lesson plans and attending the February 28th presentation of SBAR fellow, Ashton Leo at Science Talks on his plant research and experience as an SBAR fellow. A February 22nd fieldtrip was taken to Bridgestone with Education team: Dr. Chavarria, staff, Anderson, 1 SBAR Teacher (Camero), and two SBAR fellows (Barton and Leo). We were joined on the fieldtrip by NM researchers, students and SBAR fellows, which allowed for joint learning and team building with the NM team.

Classroom Observations:
All activities continue as planned; no new information to report.

Design and Implement Evaluation Tools:
The evaluator continued to participate in team meetings as much as possible to better understand each team's planned activities for year 2, any changes in personnel, any concerns, and document the process as part of the formative evaluation. But more so, the evaluator met/communicated individually with team leads to go over the evaluation findings from year one in order to inform potential programmatic improvements to either processes or products for year 2. This is particularly true for the UA outreach/4-H component of the EEO effort. A number of strategies have been discussed for the summer camp offering as a result of year one findings. The first conversations centered around the target audience and type of camp (week-long, residential, combined with existing 4-H camp infrastructure.) It became clear that working within the existing 4-H camp infrastructure would not allow for enough time dedicated to SBAR content. Then, significant work was done to try to engage specifically Native American partners and create a summer camp that exclusively served Native American students and partnered with two local tribal education offices (Tohono O'Odham and Pascua Yaqui). Although this direction is still being pursued for future SBAR camps, it became clear that enough progress would not be made in time for this summer. Therefore the decision has been made to offer a residential, one-week camp in June and that recruitment would happen statewide through 4-H/extension offices, with emphasis on recruitment of Hispanic and Native American students. The evaluator reviewed the application and recruitment materials and provided feedback to the team based on issues that arose from last year's recruitment and application strategy. Now, the 4-H team's attention will turn to curriculum adaptions and development of new activities, in conjunction with NMSU and their planned 'Train-the-Trainers' workshop. Again, the team will

utilize evaluation findings from Year 1 to inform the selection of activities to keep, refine, or eliminate from the camp offerings.

The evaluator also worked with the education lead and team members to inform the design of evaluation questions that will be asked of teachers and SBAR fellows as the first year comes to a close. The evaluator planned on a focus group interview with teachers during the Bridgestone and farm tour in January, but an unexpected snow storm contributed to low teacher attendance and the decision was made to instead pursue individual interviews with teachers, which the evaluator is in the process of scheduling. Reaching teachers can be difficult given their schedules and lack of access to them during the school day. The intent of the interviews is to garner information about their experience during the first year with their graduate fellow partner, challenges and opportunities in implementing SBAR content in their classrooms, resources and materials developed to date and needs for additional support from the SBAR team. The evaluator will also gather feedback that can help to inform the design of the summer 2019 teacher PD and teacher-fellow pairings and assignments. The long-range goal is a curricular module around a sustainable bioeconomy in arid lands that is engaging, fits with middle or early high school standards, is cost effective, and can be implemented by teachers without a graduate fellow, so all information collected attempts to streamline the processes and products that will result in the development of that curriculum. Important feedback from teachers will be understanding the best fit of SBAR content with standards and existing curriculum so that the final product will be more likely to be used in classrooms. One outcome of the EEO team meeting in Las Cruces was the idea that centering the curriculum around an ‘arid lands’ lens might be the best fit, so evaluation questions will look at that aspect as well.

A two-part evaluation for the graduate fellows was designed in March. One tool in the final stages of development is a survey that asks fellows about the logistical elements of the program – expectations, timing, training, stipends, etc. The second will be a focus group interview after the final seminar course to discuss the fellowship and how it has impacted the fellows’ own future career directions, learning, networking, etc.

Q2 will include development of new evaluation tools and/or refinement of year one tools to document EEO activities for formative evaluation and to collect data towards summative outcomes. This will involve close work with each team to ensure the evaluation tools and timeline for implementation work with their schedules and meet their needs. In particular, much of the work with be new with the NMSU 4-H team who did not have active camp or trainer programs last year. Of particular interest is looking at the two different models between UA and NMSU to try to determine the extent of the reach and impact.

Another issue that was addressed involved the SBAR website and concerns that it may not be responsive to some of the EEO stakeholder’s needs. A meeting was arranged by the Project Director with the Education team and the website designer to discuss some possible solutions. The intervention was well received and changes to the education portion of the SBAR website were made very quickly to accommodate their needs. As with any change, there were a few hiccups along the way but generally the changes have been viewed positively by the Education team.

Objective 2. Develop and disseminate agricultural bioenergy and bioproduct K-12 modules.

Task #	Description of Task	Deliverable	Target Completion Date
1 Brewer	Develop/Offer train-the-trainer biofuels education program for 4-H agents/volunteers and teachers/fellows	Develop/Host 3-day summer train-the-trainer program at NMSU Recruit 4-H youth and GK-12 participants	31 Jul 19 31 Jul 19
2 Chav	Connect with 4-H Team to ensure lesson transfer to teachers	Lessons posted on Schoolology	30 Sep 18

Design and Implement Train-the-Trainer Education Program for 4-H Youth Development:
All activities continue as planned; no new information to report.

4-H Team Connection:
All activities continue as planned; no new information to report.

Objective 3. Develop a biofuel certificate program at the university level.

Task #	Description of Task	Deliverable	Target Completion Date
1 Molnar	Develop MS and/or PhD education opportunities within the University of Arizona around the theme of “Sustainable Bioeconomy”	At least 2 tracks (study concentration areas) within UA GIDPs	31 Dec 19

Development of Education Opportunities:
All activities for this task are complete.

PRODUCTS GENERATED.
September 2017 – March 2019

PUBLICATIONS, CONFERENCE PAPERS AND PRESENTATIONS

Publications

1. **Abdell-Haleem H.*; Luo Z.; Ray, D. 2019.** Genetic improvement of guayule (*Parthenium argentatum* A. Gray): An Alternative Rubber Crop. *In.* J. Al-Khayri (ed.). Advances in Plant Breeding Strategies, Volume 4; Nut and Industrial Crops. Springer Nature Switzerland AG (Invited Book Chapter, In press).

Conference Papers

None this reporting period.

Scholarly Presentations

1. **Angadi, S.V. 2018.** *Sustainable Bio-economy for Arid Regions: Growing Guar.* Extension Field Day. Clovis, New Mexico. 9 August.
2. **Angadi, S.V.*; Begna, S.H.; Singh, S.; Katuwal, K.; Singh, J.; Gowda, P.; Ghimire R. 2018.** *Multiple Approaches to Sustain Ogallala Aquifer in the Southern Great Plains of the United States of America*. Agrosym 2018. Jahorina, Bosnia. 4-7 December.
3. **Angadi, S.V.*; Begna, S.H.; Umesh, M.R. 2018.** *Crop diversification for sustainable soil and water resources use in semi-arid regions of USA*. XXI Biennial National Symposium of Indian Society of Agronomy, Udaipur, India. 24-26 October.
4. **Angadi, S.V.*; Singh, J.; Begna, S.H. 2019.** Crop growth stage based deficit irrigation management in guar crop. Annual Report, Agricultural Science Center at Clovis, New Mexico. 20 February.
5. **Audu, M.*; Dehghanizadeh, M.; Cheng F.; Bayat H.; Holguin, O.; Jena U.; Brewer, C.E. 2019.** *Co-Products and Biofuels from Guar and Guayule Processing Residues*. ASABE Annual International Meeting, Boston, Massachusetts, 7-10 July.
6. **Brewer, C.E. 2018**. *Pairing biomass residues with conversion technologies*. Advanced Bioeconomy Leadership Conference, Washington, D.C. 28 February.
7. **Brewer, C.E. 2018**. *Polymerization and guar gum bubbles*. Outreach event activity. New Mexico 4-H State Conference. 11 July.
8. **Brewer, C.E. 2018**. *Identifying Co-Products from Guar and Guayule Processing Residues*. 2018 American Institute of Chemical Engineers Annual Meeting. Pittsburgh, Pennsylvania. 30 October.
9. **Brown, K.S.*; Neilson, J.W.; Waller, P.M.; Ray D.T.; Dierig, D.; Maier, R.M. 2018.** *Microbial contributions to soil health: Optimizing guayule (Parthenium argentatum) production in an arid environment*. SWESx Earthday Symposium. Tucson, Arizona. 15 April. [poster]
10. **Brown, K.S.*; Neilson, J.W. 2018.** *Microbial contributions*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. April.
11. **Brown, K.S.*; Neilson, J.W.; Waller, P.M.; Ray D.T.; Dierig, D.; El-Shikha, D.;Maier, R.M. 2019.** *Microbial contributions to soil health: Optimizing guayule (Parthenium argentatum) production in an arid environment*. SWESx Earthday Symposium. Tucson, Arizona. 27 March. [poster]

12. **Cheng, F.*; Audu, M.; Dehghanizadeh, M.; Treftz, B.; Le-Doux, T.; Jena, U.; Brewer, C.E. 2018.** *Characterization and Conversion of Guar and Guayule Bagasse as Potential Resources for Biofuels Production.* Symposium on Thermal and Catalytic Sciences for Biofuels and Biobased Products. Auburn, Alabama. 9 October.
13. **Cheng, F.; Le-Doux, T.; Jena, U.; Brewer, C.E.* 2018.** *Characterization and Conversion of Guar Bagasse.* Symposium on Thermal and Catalytic Sciences for Biofuels and Biobased Products. Auburn, Alabama. 9 October.
14. **Cheng, F. 2018.** *Hydrothermal Liquefaction of Microalgae in Batch and Continuous Flow Reactors.* PhD Dissertation Defense. New Mexico State University, Las Cruces, New Mexico. 24 October.
15. **Cheng, F.*; Rosalez, R.; Dehghanizadeh, M.; Brewer, C.E. 2019.** *Co-Hydrothermal Liquefaction of Guayule Bagasse and Wastewater Treatment Microalgae*. AIChE Annual Meeting, Orlando, Florida. 10-15 November.
16. **Cheng, F.*; Le-Doux, T.; Treftz, B.; Woolf, S.; Guillen, S.; Usrey, J.; Martinez Bejarano, C.; Bayat, H.; Jena, U.; Brewer, C.E. 2018.** *Characterization of Flow and Heat Transfer Parameters in a Continuous Flow Hydrothermal Liquefaction Reactor.* 2018 American Institute of Chemical Engineers Annual Meeting, Pittsburg, Pennsylvania. 1 November.
17. **Deirig, D. 2017.** *Bridgestone's perspective on a domestic source of natural rubber in the desert.* Invited Speaker at the New Mexico Sustainable Agriculture Conference. Los Lunas, New Mexico. 13 December.
18. **El-Shikha, D. 2018.** *Update – Guayule irrigation experiments at Maricopa Agricultural Center*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 12 September.
19. **Evancho, B.*; Teetor, V.H.; Willmon, J.; Bennett, M.C.; Montes, M.; Schmaltzel, C.; Ray, D.T. 2018.** *Root structure differentiation between common guayule planting methods.* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 2 August. [poster]
20. **Evancho, B. 2018.** *Guayule Fuels the Future*. IES – Energy Talks Seminar, Sky Bar, Tucson, Arizona. 9 October.
21. **Evancho, B. 2019.** *Guayule: How Close Are We?* Marana Winter Field Crops Clinic. Marana, Arizona. 10 January.
22. **Evancho, B. 2019.** *Guayule: How Close Are We?* Casa Grande Winter Field Crops Clinic. Casa Grande, Arizona. 15 January.
23. **Fan, N. 2018.** *Review on Optimization Methods for Biomass Supply Chain*. SBAR UA Research Team Seminar. University of Arizona, Tucson, Arizona. 28 November.
24. **Garcia, A.*; Grover, K.; Stringam, B.; Schutte, B.; VanLeeuwen, D. 2018.** *Growth and performance of guar (Cyamoposis tetragonoloba L.) under various irrigation regimes in semi-arid region of New Mexico*. 73rd SWCS International Annual Conference, Albuquerque, New Mexico. 29 July – 1 August.
25. **Garcia, A.*; Grover, K.; Stringam, B.; Schutte, B.; VanLeeuwen, D. 2018.** *Growth and performance of guar under various irrigation regimes in semi-arid region of New Mexico*. Annual SBAR Retreat, University of Arizona, Tucson, Arizona. 1-3 August.
26. **Garcia, A.*; Grover, K.; Stringam, B.; Schutte, B.; VanLeeuwen, D. 2018.** *Performance of guar under various irrigation regimes in southern New Mexico*. Extension Field Day, New Mexico State University Agricultural Science Center, Artesia, New Mexico. 23 August.

27. **Garcia, A.*; Grover, K.; Stringam, B.; Schutte, B.; VanLeeuwen, D. 2018**. *Performance of guar under various irrigation regimes in southern New Mexico.* New Mexico Sustainable Agriculture Science Conference, Los Lunas, New Mexico. 12 December.
28. **Garcia, A.*; Grover, K.; Schutte, B.; Stringam, B.; VanLeeuwen, D. 2018.** Growth and p*erformance of guar under various irrigation regimes*. Proceedings of the 2018 Annual Meeting of the American Society of Agronomy, Crop Science Society of America and the Soil Science Society of America. Baltimore, Maryland. 4-7 November.
29. **Gloria, T.*; Grover, K.; Garcia, A. 2018.** *Guar: a potential alternative crop in New Mexico*. Annual SBAR Retreat, University of Arizona, Tucson, Arizona. 1-3 August. [poster]
30. **Gloria, T.*; Grover, K.; Garcia, A. 2018.** *Guar: a potential alternative crop in New Mexico*. Extension Field Day, New Mexico State University Agricultural Science Center, Artesia, New Mexico. 23 August.
31. **Gloria, T.*; Grover, K.; Garcia, A. 2018.** *Guar: a potential alternative crop in New Mexico.* New Mexico Sustainable Agriculture Science Conference, Los Lunas, New Mexico. 12 December.
32. **Godfrey, D.J; Bennett, M.C.*; Willmon, J.; Waltz, Q.; Coronado, G.; Teetor, V.H.; Schmalzel, C.; Ray, D.T. 2018**. *Vegetative propagation of Parthenium argentatum (Guayule).* SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 2 August. [poster] Won first place for undergraduate posters.
33. **Godfrey, D.*; Willmon, J.; Teetor, V.H.; Schmalzel, C.; Ray, D.T. 2018.** *Vegetative propagation of guayule*. 2018 Annual Conference, American Society for Horticultural Science, Washington D.C. 30 July – 3 August 2018.
34. **Grover, K. 2017.** *Guar as a potential alternative crop in New Mexico*. Invited Speaker at the New Mexico Sustainable Agriculture Conference. Los Lunas, New Mexico. 13 December.
35. **Grover, K. 2018.** *Sustainable agriculture and guar production in New Mexico*. New Mexico State 4-H Conference, Las Cruces, New Mexico. 10 July.
36. **Grover, K. 2018**. *An overview of guar and other research in the Plant and Environmental Sciences Department*. A presentation to student ambassadors of College of Agriculture, Consumer and Environmental Sciences, New Mexico State University, Las Cruces, New Mexico. 8 August.
37. **Grover, K. 2018**. *Guar as an alternative crop in New Mexico.* Extension Field Day, New Mexico State University Agriculture Science Center, Clovis, New Mexico. 9 August.
38. **Grover, K. 2018**. *Guar as an alternative crop in New Mexico.* Extension Field Day, New Mexico State University Agriculture Science Center, Artesia, New Mexico. 23 August.
39. **Grover, K. 2018**. *Guar and Sustainable Crop Production.* An invited presentation to students of *AGRO/HORT 100 Introductory Plant Sciences*. New Mexico State University, Las Cruces, New Mexico. 31 August.
40. **Grover, K. 2018**. *Guar and Sustainable Crop Production.* An invited presentation to students of *AXED 466V: "John Muir: Lessons in Sustainability."* New Mexico State University, Las Cruces, New Mexico. 25 September.
41. **Grover, K. 2019.** *Guar as an alternative rotation crop in the chili production system of New Mexico.* New Mexico Chili Industry and Researcher Meeting, Las Cruces, New Mexico. 5 February.

42. **Grover, K. 2019.** *Guar: A potential alternative crop in New Mexico.* Climate Change Strategies for a Changing World Workshop, New Mexico State University, Las Cruces, NM. 5 February. [invited speaker]
43. **Grover, K.; Garcia, A. 2018.** *Evaluating guar as a potential alternative crop in New Mexico*. University Research Council Meeting, New Mexico State University. Las Cruces, New Mexico. 15 February.
44. **Hoare, D.M. 2018.** *Irrigation Sensors and the WINDS Model.* SBAR UA Research Team Seminar Series, Tucson, Arizona. 26 September.
45. **Idowu, O.J. 2018.** *Introduction to the SBAR Project*. Las Cruces, New Mexico. 6 Feb.
46. **Idowu, O.J. 2018.** *Sustainable Bio-economy for Arid Regions: Update*. Extension Field Day, Clovis, New Mexico. 9 August.
47. **Idowu, O.J. 2018.** *Sustainable Bio-economy for Arid Regions: Guar and Guayule*. Extension Field Day, New Mexico State University Agricultural Science Center, Artesia, New Mexico. 23 August.
48. **Khanal, S.*; Gutierrez, P.; Robbs, J.; Acharya, R. 2019.** *The Economic Potential of Producing Guayule in the Southwest.* Department of Agricultural Economics and Agricultural Business, New Mexico State University, Las Cruces, New Mexico. [poster]
49. **Leo, A. 2019.** *Microbial adaptations for arid regions and middle schoolers*. Institute for Energy Solutions (IES) Energy Talks public lecture series, Sky Bar, Tucson, Arizona. 14 March.
50. **Lopez, E. 2018.** *Sustainable Bioeconomy for Arid Regions: Activities for education, extension and outreach*. American Institute of Chemical Engineers Rocky Mountain Regional Student Conference. Provo, Utah. 23 March.
51. **Lopez, E.; Fox, S.; Brewer, C.E. 2018.** *GK-12 Lesson Documentation Spreadsheet*. American Institute of Chemical Engineers Annual Meeting, Pittsburg, Pennsylvania. 29 October.
52. **Maqsood, H. 2018.** *Guar Crop Coefficient Development for New Mexico Environments*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 7 November.
53. **McCloskey, W. 2018.** *Weed Trial Results for Guayule*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 14 November.
54. **McMahan, C. 2018.** *Flowering Reduction in Guayule*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 19 September.
55. **McMahan, C. 2019.** *USDA-ARS Rubber Lab Update*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 27 March.
56. **Mealing, V. 2018.** *An overview of sustainability analysis methods of a new biofuel feedstock: bagasse from guar*. 6th Colorado School of Mines Graduate and Discovery Symposium. Golden, Colorado. 5 April.
57. **Mealing, V. 2019.** *Criteria, Methods, Opportunities, and Needs for Social Sustainability of Emerging Technology*. 7th Colorado School of Mines Graduate Research and Discovery Symposium. Golden, Colorado. April.
58. **Mealing, V.*; Harris, T.; Landis, A.E. 2019.** *Criteria, Methods, Opportunities, and Needs for Social Sustainability of Emerging Technology*. 15th International Conference on Environmental, Cultural, Economic and Social Sustainability. Vancouver, Canada. February.
59. **Mealing, V.*; Summers, H.M.; Sproul, E.; Eranki, P.L.; Landis, A.E.; Quinn, J.C. 2018.** *Life Cycle Assessment of Cultivating Guar in the American Southwest*. LCA XVIII

Conference. Fort Collins, Colorado. October [poster] Won second place in graduate student posters.

60. **Mealing, V.*; Summers, H.M.; Sproul, E.; Eranki, P.L.; Quinn, J.C.; Landis, A.E.. 2018.** *Life Cycle Assessment of Cultivating Guar in the American Southwest.* National Society of Black Engineers, Fall Regional Conference. Las Vegas, Nevada. November [poster]
61. **Mi, W.*; Teetor, V.H.; Ray, D.T. 2018.** *Rubber and Resin Extraction of Differentially Treated Biomass in Guayule (Parthenium argentatum)*. SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 2 August. [poster]
62. **Willmon, J.; Montes, M.*; Coronado, G.; Bennett, M.C.; Teetor, V.H.; Hu, J.; Ray, D.T. 2018**. *Screening Parthenium argentatum for Resistance to Phymatotrichum omnivora*. SBAR Annual Retreat, University of Arizona, Tucson, Arizona. 2 August. [poster]
63. **Niu, D., 2018.** *Partial cloning of APETALA1 (AP1) gene from guayule*. cDNA Lab Seminar, USDA-ARS Western Regional Research Laboratory. 28 March.
64. **Ogden, K. 2017**. *Introducing new USDA NIFA CAP grant awardees – Developing regional AJF supply chains: Sustainable Bioeconomy for Arid Regions*. CAAFI-SOAP Jet Webinar. Hosted online. 13 October. [invited speaker]
65. **Ogden, K. 2017.** *Sustainable Bioeconomy for Arid Regions*. Biomass Research and Development Technical Advisory Board Meeting. 15 November. [invited speaker]
66. **Ogden, K. 2018.** *Sustainable Bio-economy for Arid Regions*. Southwest Indian Agricultural Association Meeting. Laughlin, Nevada. 16-18 January.
67. **Ogden, K. 2018.** *Potential of the Bioproducts and Biofuels Economy*. AIChE Annual Meeting, Pittsburg, Pennsylvania. October [invited speaker]
68. **Ogden, K.*, White, R., Brewer, C.E. 2018.** *Public Private Partnerships*. ABLC Conference. Washington, D.C. 27-28 February.
69. **Rock, C.*, Brassill, N. 2018.** *Importance of Cooperative Extension in University Research*. University of Arizona, Tucson, Arizona. 14 March.
70. **Rogstad, A. 2018.** *Real World Supply Chain Development: USDA Coordinated Agriculture Projects. SBAR Overview*. CAAFI Biennial General Meeting and Integrated ASCENT Symposium. Washington, D.C. 4-6 December. [invited speaker]
71. **Singh, J**.*; **Angadi, S.V.; Begna, S.H. 2018**. *Crop Growth Stage Based Deficit Irrigation Management in Guar Crop.* The Western Sustainable Agriculture Conference (WSARE), University of New Mexico – Valencia Campus, Los Lunas, New Mexico. 12 December [poster]
72. **Singh, J.*; Angadi, S.V.; Begna, S.H.; Guzman, I.; and Idowu, J. 2019.** *Sustaining water resources using guar crop under different irrigation practices.* ACES-Open House, New Mexico State University, Las Cruces, New Mexico. 6 April. [poster]
73. **Skuse, K.*; Dery, J.; Zozaya, S.; Brassill, N.; Rock, C. 2018.** *Public interest in guayule being used as a biofuel.* University of Arizona, Maricopa Agricultural Center, Maricopa, Arizona. 26 July. [poster]
74. **Skuse, K.*; Dery, J.; Zozaya, S.; Brassill, N.; Rock, C. 2018.** *Public interest in guayule being used as a biofuel.* Oral presentation of student internship work. University of Arizona, Maricopa Agricultural Center, Maricopa, Arizona. 26 July.
75. **Sun, O. 2018.** *GIS-Based Two-stage Stochastic Facility Location Considering Planting Plan Uncertainty*. INFORMS Annual Meeting, Phoenix, Arizona. 5 November.

76. **Sun, O. 2018.** *GIS-Based Two-stage Stochastic Facility Location Considering Planting Plan Uncertainty*. SBAR UA Research Team Seminar. University of Arizona, Tucson, Arizona. 28 November.
77. **Sun, O. 2019.** *Optimization of a Biomass Supply chain from Economic, Environmental, and Social Perspectives*. Dr. Fan's Group Meeting, University of Arizona, Tucson, Arizona. 13 March.
78. **Sun, O. 2019.** *Biomass Supply Chain Configuration and Management*. SBAR UA Research Team Seminar. University of Arizona, Tucson, Arizona. 10 April.
79. **Sun, O.; Fan, N. 2018.** *Harvest scheduling*. SBAR Logistics Team Group Meeting. (webinar) New Mexico State University. Las Cruces, New Mexico. 5 February.
80. **Sun, O.; Fan, N. 2018.** *Optimization of feedstock logistics*. SBAR UA Research Seminar. University of Arizona. Tucson, Arizona. 14 February.
81. **Sun, O.; Fan, N. 2018.** *Optimally locating biorefineries*. SBAR Sustainability Working Group Seminar. (webinar) Colorado State University. Lakewood, Colorado. 8 March.
82. **Summers, H.M., Sproul, E., Johnson, J., Quinn, J.C. 2017.** *Sustainability assessment of bioproducts from southwest arid crops*. 21st Century Energy Transition Symposium, Colorado State University, Fort Collins, Colorado. October.
83. **Summers, H.M., Sproul, E., Johnson, J., Quinn, J.C. 2017.** *Sustainability assessment of bioproducts from southwest arid crops*. Colorado State University Graduate Student Showcase, Colorado State University, Fort Collins, Colorado. November.
84. **Summers, H.M.*; Sproul, E.; Johnson, J.; Quinn, J.C. 2018**. *Economic Viability and Environmental Impact of processing arid crops in the American Southwest.* International Congress on Environmental Modelling and Software. Colorado State University, Fort Collins, Colorado. June.
85. **Summers, H.M.*; Sproul, E.; Johnson, J.; Quinn, J.C. 2019.** *Economic and Environmental Impact Assessments of Drought Tolerant Crops in the American Southwest*. 21st Century Energy Transition Symposium, Denver, Colorado. April.
86. **Summers, H.M.*; Sproul, E.; Mealing, V.; Eranki, P.L.; Landis, A.E.; Quinn, J.C. 2018**. *Process Modeling and Life Cycle Assessment of Rubber from Guayule.* LCA XVIII Conference, Fort Collins, Colorado. October.
87. **Waller, P. 2018.** *WINDS Model: A status report and connection to SBAR research*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 10 October.
88. **Willmon, J.*, Hu, J., Teetor, V.H., and Ray, D.T. 2018.** *Screening Parthenium argentatum for resistance to Phymatotrichum omnivorum*. 2018 Annual Conference, American Society for Horticultural Science, Washington, D.C. 30 July – 3 August.

Total Audience Demographics for Project-Related Presentations (when captured)

Audience Demographic Parameter	Previous Total (Cumulative)	This Quarter Total	Cumulative Project Total
Gender			
Males	824	50	***874***
Females	363	4	***367***
Race/Ethnicity			
Hispanic	173	1	***174***
Asian	106	1	***107***
Native American	174	0	***174***

African American	41	0	***41***
Anglo/White	693	52	***745***

Audience Cumulative Total *(when captured)****: 1,241 ppl***

WEBSITE(S) OR INTERNET SITE(S)

SBAR Project Website

1. .https://sbar.arizona.edu

NEW TECHNOLOGIES OR TECHNIQUES GENERATED

None this reporting period.

INVENTIONS, PATENT APPLICATIONS, AND/OR LICENSES

1. **Dec 2017.** 24c SLN Label for Gramoxone SL 2.0 Herbicide (Paraquat dichloride), for control of weeds in guayule. SLN Registration Number: AZ120005. Expiration: 31 Dec 2022. Arizona Department of Agriculture, Environmental Services Division.

2. **Dec 2017.** 24c SLN Label for Fusilade DX Herbicide (*Propanoic acid, 2-(4-((5-(trifluoromethyl)-2-pyridinyl)oxy)phenoxy)-, butyl ester, (R)-*), for control of emerged weeds in guayule. SLN Registration Number: AZ070006. Expiration: 31 Dec 2022. Arizona Department of Agriculture, Environmental Services Division.

OTHER PRODUCTS GENERATED

Brochures, Factsheets, and Flyers

1. **Duncan, C.M. 2018.** SBAR USDA-NIFA graduate student fellowship: UA Students. One page promotional flyer. February and March.
2. **Duncan, C.M. 2018.** SBAR USDA-NIFA graduate student fellowship: NMSU Students. One page promotional flyer. February and March.
3. **Duncan, C.M. 2018.** SBAR call for middle and high school science teachers. One page promotional flyer. February and March.
4. **Duncan, C.M. 2018.** SBAR 4-H summer camp: Biofuels powering your world. One page promotional flyer. March.
5. **Duncan, C.M. 2019.** SBAR Call for Middle & High School Science Teachers. One page promotional flyer. March.
6. **Duncan, C.M. 2019.** SBAR USDA-NIFA graduate student fellowship: UA Students. One page promotional flyer. March.
7. **Duncan, C.M. 2019.** SBAR USDA-NIFA graduate student fellowship: NMSU Students. One page promotional flyer. March.
8. **Grover, K. 2018**. Guar – A potential alternative crop in New Mexico. Two page informational handout. January.

9. **Kiela, C. 2018.** Guayule. SBAR Project two-page fact sheet. March.
10. **Kiela, C. 2018.** Guar. SBAR Project two-page fact sheet. April.
11. **Kiela, C. 2018.** History of Guayule. SBAR Project two-page fact sheet. April.
12. **Rogstad, A. 2017.** SBAR – Sustainable Bioeconomy for Arid Regions. One-page informational and promotional card. November.

Press Releases and News Articles

1. 26 Sep 2017. "As NIFA awards $21.1M to grow the bioeconomy, CABLE debuts to bridge students and industry." BiofuelsDigest. http://www.biofuelsdigest.com/bdigest/2017/09/26/as-nifa-awards-21-1m-to-grow-the-bioeconomy-cable-debuts-to-bridge-students-and-industry/

2. 16 Oct 2017. "UA to Head New Center Focusing on Biofuels and Bioproducts." UA News. https://uanews.arizona.edu/story/ua-head-new-center-focusing-biofuels-and-bioproducts

3. 4 Nov 2017. "Biofuels, bioproducts, and an Arizona bioeconomy?" Arizona Daily Wildcat. http://www.wildcat.arizona.edu/article/2017/11/science-biofuels-and-bioproducts

4. 29 Nov 2017. "NMSU to host state sustainable agriculture conference in Los Lunas." News Bulletin. http://www.news-bulletin.com/news/nmsu-to-host-state-sustainable-agriculture-conference-in-los-lunas/article_a45281f6-d540-11e7-9530-27dc93258a79.html

5. 16 Jan 2018. "Dr. Quinn's Sustainability Expertise Recruited for Multi-Million Dollar DOE and USDA Grants." Colorado State University, Mechanical Engineering Featured Projects. http://www.engr.colostate.edu/me/2018/01/16/dr-quinns-sustainability-expertise-recruited-for-multi-million-dollar-doe-and-usda-grants/

6. 21 Feb 2018. "NMSU collaborating in Sustainable Bio-economy for Arid Regions project." New Mexico State University News Center. http://newscenter.nmsu.edu/Articles/view/12961/nmsu-collaborating-in-sustainable-bio-economy-for-arid-regions-project

7. 27 Feb 2018. "Bridgestone receives guayule research grant from USDA." The Smithers Report - A daily and weekly tire industry news source. (4,500 daily subscribers) https://www.smithersrapra.com/publications/the-smithers-report

8. 27 Feb 2018. "Bridgestone and research partners earn $15 Million grant for guayule work." MTD (Modern Tire Dealer). UMV: 62,085. http://www.moderntiredealer.com/news/728673/bridgestone-and-research-partners-earn-15-million-grant-for-guayule-work

Tabling Events and Workshops – Marketing and Outreach

1. 14 July 2017. New Mexico Cotton Ginners Conference. New Mexico.
2. 17 Aug 2017. SBAR Project Kick-off Meeting. Tucson, Arizona.

3. 28 Oct 2017. Rocky Mountain Zone Summit (sustainability focus). Denver, Colorado.
4. 05 Dec 2017. Valencia County (New Mexico) Forage Conference. New Mexico.
5. 13 Dec 2017. New Mexico Sustainable Agriculture Conference. Los Lunas, New Mexico.
6. 15-17 Feb 2018. SBAR Display Table. New Mexico Organic Farming Conference. Albuquerque, New Mexico.
7. 24 Feb 2018. Farm Science Day. USDA-ARS, Arid-Land Agricultural Resource Center. Maricopa, Arizona.
8. 24 Feb 2018. 2018 Engineering Fair – Recycled papermaking and guar gum bubbles activity. Las Cruces Museum of Science and Nature. Las Cruces, New Mexico.
9. 15 Mar 2018. Zia Middle School Project – Lead the Way NMSU College of Engineering Day. Recycled papermaking and guar gum bubbles activity. Las Cruces, New Mexico.
10. 22-24 Feb 2018. Southwest Ag Summit. Yuma, Arizona.
11. 19 Mar 2018. Roosevelt Irrigation District Board Meeting. Buckeye, Arizona.
12. 28 Mar 2018. Alfalfa and Forage Workshop. Maricopa, Arizona.
13. 11 Jul 2018. New Mexico 4-H State Conference – Polymerization and guar gum bubbles activity. Albuquerque, New Mexico.
14. 9 Aug 2018. Extension Field Day, New Mexico State University Agricultural Science Center, Clovis, New Mexico.
15. 23 Aug 2018. Extension Field Day, New Mexico State University Agricultural Science Center, Artesia, New Mexico.
16. 12 Dec 2018. New Mexico Sustainable Agriculture Conference, Las Cruces, New Mexico.
17. 10 Jan 2019. Marana Winter Field Crop Clinic. University of Arizona Cooperative Extension, Marana, Arizona.
18. 15 Jan 2019. Casa Grande Winter Field Crop Clinic. University of Arizona Cooperative Extension, Casa Grande, Arizona.
19. 23 Jan 2019. New Mexico Cotton Growers Association Conference, Ruidoso, New Mexico.
20. 13 Feb 2019. Desert Hills S.T.E.A.M. Night. (Science, Technology, Engineering, Art, and Math) Desert Hills Elementary School, Las Cruces, New Mexico.
21. 15-16 Apr 2019. New Mexico Organic Farming Conference, Albuquerque, New Mexico.
22. 11 Apr 2019. Spring Extension Field Day, New Mexico State University Agricultural Science Center, Clovis, New Mexico.

→*Total Reach via Tabling Events and Workshops (when captured):* ***2,028 participants***

YOUTH ACTIVITIES

Biofuel Lessons in Classrooms (SBAR Teacher/Fellow Cohort 2018-2019)

1. Apollo Middle School, Tucson, Arizona.
2. Mesilla Valley Leadership Academy, Las Cruces, New Mexico.
3. Pueblo High School, Tucson, Arizona.
4. Quail Run Elementary School, Marana, Arizona.
5. Sierra Middle School, Las Cruces, New Mexico.
6. Valencia Middle School, Tucson, Arizona.

7. Walter Douglas Elementary School, Tucson, Arizona.

Biofuel Lessons in Classrooms (SBAR Teacher/Fellow Cohort 2019-2020)

1. Apollo Middle School, Tucson, Arizona.
2. Camino Real Middle School, Las Cruces, New Mexico.
3. Mesilla Valley Leadership Academy, Las Cruces, New Mexico.
4. Quail Run Elementary School, Marana, Arizona.
5. Pueblo High School, Tucson, Arizona.
6. Saguaro National Park Environmental Education, Tucson, Arizona.
7. Santa Rosa Ranch School, Sells, Arizona.
8. Sierra Middle School, Las Cruces, New Mexico.
9. Walter Douglas Elementary School, Tucson, Arizona.

Youth Participation Demographics for Project-Related Activities (when captured)

Youth Participation Demographic Parameter	**Previous Total (Cumulative)**	**This Quarter Total**	**Cumulative Project Total**
Age Level			
11-13 years	-	503	***503***
14-16 years	-	64	***64***
Gender			
Males	-	281	***281***
Females	-	286	***286***
Race/Ethnicity			
Hispanic	-	303	***303***
Asian	-	1	***1***
Native American	-	8	***8***
African American	-	6	***6***
Anglo/White	-	66	***66***

Youth Cumulative Total *(when captured)****: 567 ppl***

PARTICIPANTS AND COLLABORATING ORGANIZATIONS. September 2017 – March 2019

PARTNER ORGANIZATIONS

Organization Person*	Project Role	Project Component
Bridgestone Americas,		
Von Mark Cruz	Professional	Feedstock Development & Production
David Dierig	Key Collaborator	Feedstock Development & Production
Stefan Dittmar	Professional	Feedstock Development & Production
Amber Lynch	Professional	Feedstock Development & Production
Russell Prock	Professional	Feedstock Development & Production
Theresa Sullivan	Professional	Feedstock Development & Production
Sam Wang	Professional	Feedstock Development & Production
Jocelyn Zhu	*Intern*	*Feedstock Development & Production*
Colorado School of Mines		
Pragnya Eranki	*Post-doc*	*System Performance & Sustainability*
Amy Landis	Key Collaborator	System Performance & Sustainability
VeeAnder Mealing	Graduate Student	System Performance & Sustainability
Colorado State University		
Jack Johnson	*Undergrad Student*	*System Performance & Sustainability*
Jason Quinn	Key Collaborator	System Performance & Sustainability
Evan Sproul	Graduate Student	System Performance & Sustainability
Hailey Summers	Graduate Student	System Performance & Sustainability
New Mexico State University		
Ram Acharya	Professional	System Performance & Sustainability
Sarah Acquah	*Post-doc*	*Extension & Outreach* *System Performance & Sustainability*
Sangu Angadi	Key Collaborator	Extension & Outreach Feedstock Development & Production
Matt Armijo	Undergrad Student	Post-Harvest Logistics & Co-Products
Meshack Audu	Graduate Student	Education Post-Harvest Logistics & Co-Products
Valerie Bailey	Undergrad Student	Feedstock Development & Production
Hengameh Bayat	Graduate Student	Post-Harvest Logistics & Co-Products
Sultan Begna	Professional	Feedstock Development & Production
Cesar Martinez Bejarano	Undergrad Student	Post-Harvest Logistics & Co-Products
Geneva Ben	Undergrad Student	Feedstock Development & Production
Pratima Bhandari	Graduate Student	System Performance & Sustainability
Catherine E. Brewer	Key Collaborator	Education Post-Harvest Logistics & Co-Products
Nico Carrero-Little	Undergrad Student	Post-Harvest Logistics & Co-Products
Pedro Castillo	Undergrad Student	Feedstock Development & Production
Feng Cheng	Graduate Student	Post-Harvest Logistics & Co-Products
Mostafa Dehghanizadeh	Graduate Student	Post-Harvest Logistics & Co-Products

Barry Dungan	Professional	Post-Harvest Logistics & Co-Products
Sarah Fox	*Undergrad Student*	*Post-Harvest Logistics & Co-Products*
Alonso Garcia	Graduate Student	Feedstock Development & Production
Saba Gill	Graduate Student	Post-Harvest Logistics & Co-Products
Thomas Gloria	Undergrad Student	Feedstock Development & Production
Kulbhushan Grover	Key Collaborator	Extension & Outreach Feedstock Development & Production
Erin Gutierrez	Undergrad Student	Post-Harvest Logistics & Co-Products
Paul H Gutierrez	Key Collaborator	Extension & Outreach System Performance & Sustainability
Befekadu Habteyes	*Professional*	*System Performance & Sustainability*
F. Omar Holguin	Key Collaborator	Post-Harvest Logistics & Co-Products
John Idowu	Key Collaborator	Extension & Outreach
Jackie Jarvis	Professional	Post-Harvest Logistics & Co-Products
Umakanta Jena	Professional	System Performance & Sustainability
Sita Khanal	Graduate Student	System Performance & Sustainability
Kelly Laje	Graduate Student	Post-Harvest Logistics & Co-Products
Travis Le-Doux	*Undergrad Student*	*Post-Harvest Logistics & Co-Products*
Esai Lopez	*Undergrad Student*	*Education*
Alberto Lorenzo	Undergrad Student	Feedstock Development & Production
Sicilee Macklin	*Undergrad Student*	*Education* *Post-Harvest Logistics & Co-Products*
Cesar Martinez-Bejarano	Undergrad Student	Post-Harvest Logistics & Co-Products
Sa'Rae Montoya	Graduate Student	Post-Harvest Logistics & Co-Products
Kyle Moore	Undergrad Student	Feedstock Development & Production
Jasmine Paquin	Graduate Student	Extension & Outreach
Kaavya Polisetti	Graduate Student	Post-Harvest Logistics & Co-Products
Camila Prieto	Undergrad Student	Extension & Outreach
Darien Pruitt	Undergrad Student	Extension & Outreach
Joram Robbs	Graduate Student	Extension & Outreach System Performance & Sustainability
Laura Rodriguez-Uribe	Professional	Extension & Outreach Post-Harvest Logistics & Co-Products
Rodrigo Rosalez	Graduate Student	Education
Kimberly Salinas	Undergrad Student	Extension & Outreach
Nathan Schavz	Undergrad Student	Post-Harvest Logistics & Co-Products
Tarah Schuman	*Undergrad Student*	*Post-Harvest Logistics & Co-Products*
Jagdeep Singh	Graduate Student	Feedstock Development & Production
Peter Skelton	Professional	Extension & Outreach
Nicolas Soliz	Undergrad Student	Post-Harvest Logistics & Co-Products
Stephen Taylor	Undergrad Student	Education
Brian Treftz	*Graduate Student*	*Education* *Post-Harvest Logistics & Co-Products*
Jacob Usrey	Undergrad Student	Post-Harvest Logistics & Co-Products
Victoria Valenzuela	Undergrad Student	Feedstock Development & Production
Stephanie Willette	*Graduate Student*	*Post-Harvest Logistics & Co-Products*
April Wright	Undergrad Student	Post-Harvest Logistics & Co-Products
Scott Woolf	*Undergrad Student*	*Post-Harvest Logistics & Co-Products*
Other		
Jennifer Fields	Professional	Education Extension & Outreach
Clark Seavert	Professional	System Performance & Sustainability Extension & Outreach

University of Arizona		
Torran Anderson	Professional	Education Extension & Outreach
Nick Ashley	*Graduate Student*	*Feedstock Development & Production*
Craig Bal	*Graduate Student*	*Education* *Extension & Outreach*
Armando Barreto	Professional	Feedstock Development & Production
Holly Barton	Graduate Student Fellow	Education
Megan Bennett	Undergrad Student	Feedstock Development & Production
Natalie Brassill	Professional	Extension & Outreach
Kyle Brown	Graduate Student	Feedstock Development & Production
Daniela Cabrera	Professional	Extension & Outreach
Madasu Chandrashekar	Professional	Post-Harvest Logistics & Co-Products
Sara Chavarria	Key Collaborator	Education
German Coronado	Undergrad Student	Feedstock Development & Production
Kamel Didan	Professional	Feedstock Development & Production
Cara Duncan	Professional	Education Extension & Outreach
Diaa El-Shikha	Post-doc	Feedstock Development & Production
Blase Evancho	Key Collaborator Graduate Student	Extension & Outreach Feedstock Development & Production
Neng Fan	Key Collaborator	Post-Harvest Logistics & Co-Products
Krista Farmer	*Undergrad Student*	*Feedstock Development & Production*
Charles Ferini	Undergrad Student	Feedstock Development & Production
Daryan Godfrey	*Undergrad Student*	*Feedstock Development & Production*
Leslie Gunatilaka	Key Collaborator	Post-Harvest Logistics & Co-Products
Wolfgang Grunberg	Professional	ALL AREAS
Matthew Harmon	Undergrad Student	Feedstock Development & Production
Danielle Hoare	Graduate Student	Feedstock Development & Production
Stephanie Honeker	*Undergrad Student*	*Feedstock Development & Production*
Jessica Ledesma	Undergrad Student	Feedstock Development & Production
Ashton Leo	Graduate Student Fellow	Education
Arisbeth Ibarra Nieblas	Graduate Student Fellow	Education
Pujan Kafle	*Graduate Student*	*System Performance & Sustainability*
Matthew Katterman	Graduate Student Fellow	Education Extension & Outreach Feedstock Development & Production
C. Kasia Kiela	*Undergrad Student*	*ALL AREAS*
Corey Knox	Graduate Student	Education
Ashton Leo	Graduate Student Fellow	Education
Manping Liu	Professional	Post-Harvest Logistics & Co-Products
Patrick Lohr	Graduate Student	Feedstock Development & Production
Gerardo Lopez	Key Collaborator	Extension & Outreach
Jasmine Lopez	Undergrad Student	Extension & Outreach
Raina Maier	Key Collaborator	Feedstock Development & Production
Hadiqa Maqsood	Graduate Student	Feedstock Development & Production
William McCloskey	Key Collaborator	Feedstock Development & Production
Wenzhe Mi	*Intern*	*Feedstock Development & Production*
Istvan Molnar	Key Collaborator	Education
Madison Montes	*Undergrad Student*	*Feedstock Development & Production*

Leobardo Moreno	Undergrad Student	Feedstock Development & Production
Madison Morris	Undergrad Student	Feedstock Development & Production
Julie Neilson	Professional	Feedstock Development & Production
Andrew Nelson	Post-doc	Feedstock Development & Production
Kim Ogden	Key Collaborator	ALL AREAS
Bryan Pastor	Professional	Feedstock Development & Production
Duke Pauli	Key Collaborator	Feedstock Development & Production
Shaira Perez	Undergrad Student	Extension & Outreach
Sam Pernu	Undergrad Student	Feedstock Development & Production
Sarocha Pradyawong	Post-doc	Feedstock Development & Production
Dennis Ray	Key Collaborator	Feedstock Development & Production
Jaspreet Rekhi	*Professional*	*Post-Harvest Logistics & Co-Products*
Channah Rock	Key Collaborator	Extension & Outreach
Alix Rogstad	Professional	ALL AREAS
Luis Anguiano Sanchez	Professional	Feedstock Development & Production
Carl Schmalzel	Professional	Feedstock Development & Production
Stephanie Sikora	Professional	Education
Ou Sun	Graduate Student	System Performance & Sustainability
Trent Teegerstrom	Key Collaborator	Extension & Outreach System Performance & Sustainability
Valerie Teetor	Professional	Feedstock Development & Production
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Christine Toering	Undergrad Student	Feedstock Development & Production
Peter Waller	Key Collaborator	Feedstock Development & Production
Quinn Waltz	*Undergrad Student*	*Feedstock Development & Production*
John Willmon	Undergrad Student	Feedstock Development & Production
Ya-ming Xu	Post-doc	Post-Harvest Logistics & Co-Products
Stevi Zozaya	Undergrad Student	Extension & Outreach
USDA Agriculture Research Service – US Arid Lands Research Center, Maricopa AZ		
Hussein Abdel-Haleem	Key Collaborator	Feedstock Development & Production
Adrianna Chambers	Undergrad Student	Feedstock Development & Production
Amber Dearstyne	Undergrad Student	Feedstock Development & Production
Greg Leake	Professional	Feedstock Development & Production
Aaron Szczepanek	Professional	Feedstock Development & Production
Brandon Vera	Undergrad Student	Feedstock Development & Production
USDA Agriculture Research Service – Western Regional Research Center, Albany CA		
Sheyla Aucar	Professional	Feedstock Development & Production
Matthew Canonizado	Professional	Feedstock Development & Production
George Chong	Professional	Feedstock Development & Production
Chen Dong	Professional	Feedstock Development & Production
Niu Dong	Professional	Feedstock Development & Production
Trinh Huynh	Professional	Feedstock Development & Production
Colleen McMahan	Key Collaborator	Feedstock Development & Production
Grisel Ponciano	Professional	Feedstock Development & Production
Dante Placido	Professional	Feedstock Development & Production

** Individuals no longer actively working on the SBAR project appear in italic.*

Total Key Collaborators: ***25***
Total Professional Staff: ***43***
Total Postdoctoral Researchers: ***6***
Total Graduate Students: ***35***
Total Undergraduate Students: ***50***
Total Fellows/Interns: ***7***

COLLABORATIONS AND OTHER CONTACTS

Collaborations:

Academic Institutions:	CSM (Colorado School of Mines) - Dept. of Civil and Environmental Engineering CSU (Colorado State University) - Dept. of Mechanical Engineering FSU (Florida State University - National High Magnetic Field Laboratory NMSU (New Mexico State University) - Cooperative Extension - Dept. of Agricultural Economics and Agricultural Business - Dept. of Chemical Engineering - Dept. of Plant and Environmental Sciences UA (University of Arizona) - Agricultural and Biosystems Engineering - College of Education - Cooperative Extension - Dept. of Agriculture and Resource Economics - Dept. of Chemical and Environmental Engineering - Dept. of Soil, Water and Environmental Sciences - Dept. of Systems and Industrial Engineering - Natural Products Center - School of Natural Resources and the Environment - School of Plant Sciences
Nonprofits:	
Industrial or Commercial Firms:	BASF Bridgestone Americas, Inc. Central Arizona Project (CAP) FMC Guar Resources Syngenta

Federal Government	Saguaro National Park (West), Tucson AZ - Environmental Education Department USDA – Agricultural Research Service, Western Regional Research Center, Albany CA - Chemistry (Bioproducts) - Plant Genetics USDA – Agricultural Research Service, Grassland Soil and Water Research Laboratory, Temple TX - Crop Modeling
State or Local Governments:	Arizona Department of Agriculture, Environmental Services Division
Tribal Governments:	
Schools or School Systems:	**BASIS Charter Schools**, BASIS Tucson North (high school), Tucson, Arizona **Flowing Wells Unified District**, Walter Douglas Elementary School, Tucson, Arizona **Las Cruces Public Schools**, Camino Real Middle School, Mesilla Valley Leadership Academy, and Sierra Middle School, Las Cruces, New Mexico **Marana Unified School District**, Quail Run Elementary School, Marana, Arizona **Tucson Unified School District**, Pueblo High School, and Valencia Middle School, Tucson, Arizona **Santa Rosa Ranch School District**, Santa Rosa Ranch School, Sells, Arizona **Sunnyside Unified School District**, Apollo Middle School, Tucson, Arizona
Other Organizations (foreign or domestic):	

Other Contacts:

Contacts with others within recipient's organization (interdepartmental or interdisciplinary collaborations):	UA (University of Arizona) - Applied Biosciences - Arid Lands Resource Sciences - College of Agriculture and Life Sciences - Institute of the Environment - Water Resources Research Center

Contacts with others outside the organization:	Denver Museum of Nature and Science, Denver Colorado Central Arizona College
Contacts with others outside the United States or with an international organization:	