SUSTAINABLE BIOECONOMY FOR ARID REGIONS (SBAR)

Summary Report – Quarter 4, 2018

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

USDA Cover Page

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Name of Submitting Official	*Signature / Date*

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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 was developed and approved by the Leadership Team in mid-July 2018. The evaluation plan is a living document that will change over the project life to reflect revised research questions, project goals and big-picture, overall objectives. The plan clarifies three distinct levels of evaluation (Table 1), responsible parties for each, and feedback loops that allow for adjustments and realignment of actions.

Table 1. *Evaluation process for SBAR-related activities.*

Evaluation Level – description and purpose	Person(s) Responsible	Frequency
Level 1 / Self-evaluation - Ranking of current progress (Green, Yellow, Red; issues and risks) - Minor adjustments	PI/Co-PI	Quarterly (Quarterly Reports)
Level 2 / Detail program evaluation - Specific activity evaluation; education, extension and outreach - Debrief after action; document progress, change or improvement	PI/Co-PI; Evaluator as needed	On-going
Level 2 / Peer Review - Presentation and evaluation of progress - Medium to Major adjustments	PI/Co-PI	Annually (Annual Meeting)
Level 3 / Big Picture - Target/Mission evaluation… is the project meeting main target - Major adjustments; re-aligning project direction to meet current conditions	Advisory Board	Annually (Annual Meeting)
Level 3 / 360° Review - Feedback received - Adjustments and realignment suggestions	PI/Co-PI	Annually (After annual meeting)

Advisory Board

Following discussions regarding research from the SBAR Annual Retreat, each of the SBAR Advisory Board members was requested to complete and submit a non-disclosure agreement (NDA) to ensure confidentiality of research data, information, and conclusions for the duration of the project. 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 5 NDAs are pending. Two advisors rolled off of the board during this reporting period; possible replacements are being identified and will be invited to join the board in the future.

Budget and Financial Management

General budget management activities are ongoing, where all project expenditures are tracked for reporting purposes. 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 now 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 16 times for over 12.5 hours. An additional 10 meetings were hosted during the same timeframe that did not require the virtual meeting space.

Photo 1. *Education Component Team - meeting at New Mexico State University, Las Cruces in December 2018.*

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. Mr. Blase Evancho joined the LEADS Team (as the Extension and Outreach component co-lead, based in Arizona) in November 2018. This change occurred to better address Extension and Outreach needs in Arizona as the project gets fully implemented. Evancho will help facilitate Extension and Outreach work across Arizona, as well as help to better integrate the research and extension activities.

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 provides 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) was updated and maintained to serve as the "face" of the SBAR Center. There were 476 unique sessions reported from October – December 2018, representing 18 different countries (top two: USA and India). There have been a total of 1051 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.

The Leadership Team generated a list of SBAR-specific hashtags in December (Table 2), encouraging their use in all future social media posts regarding SBAR research or activity. The goal of encouraging their use is to facilitate and broaden project outreach and searchability within the social media platforms.

Table 2. *SBAR hashtags for social media posts.*

Hashtag	When to Use
#SBAR	**Always** Use this whenever you post to social media regarding an SBAR-related activity, event, or research (as appropriate).
#bioeconomy #SWIndustrialCrops #Guayule #Guar	**Use one or more** Use these whenever your post is specifically related to developing the bioeconomy or an SBAR-related key crop.
#Education #4H #Extension #SustainableAgriculture	**Optional; As Desired** Use these (or others of your preference) when you want to draw attention to another facet of your SBAR-related activity, event, or research (as appropriate).

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:
Some aspects of the research have experienced some set-backs due to the USDA furlough and government shut-down. Plants in the field were not affected, but some laboratory experiments were adversely affected and/or lost. Experiments under Objective 4 were interrupted when all of the plants died in the greenhouse as a result of a temperature control failure. The experiments will be restarted in January.

The rainfall received in late September and early October 2018 and accompanying cool temperatures delayed start of the Eloy and Maricopa herbicide 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.

There is a 3 month delay in completion of the soil chemical, texture and biomass analysis. The soil chemical analysis was delayed due to the graduation of a doctoral student managing the work. The work is now being supervised by Omar Holguin and will be completed this quarter. The soil texture analysis was delayed due to the departure of an undergrad student. The undergrad has been replaced and the new student will be trained and the work completed during the coming quarter. The DNA extraction work has proceeded slower than anticipated because Kyle Brown had no experience with this work and needed time to develop the needed laboratory skills. He has now mastered the required techniques and is on schedule to complete the Year 1 DNA extractions by March 1, 2019. This schedule will allow us to evaluate all year 1 data prior to finalizing the year 2 sampling design.

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 Complete construct for transformation work on FLOWERING LOCUS T	30 Nov 18 31 Mar 19
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):

Plant growth monitored from two variety trials by hand measurements and high throughput sensor-mounted tractor measurements. Table 3 shows for each variety the average height, standard deviation, and standard error ranked from high to low plant height. The varieties in the second trial corresponded in rank with those in common from the first trial planted 1 month earlier. AZ-2 ranked the highest and is the one currently being used in production fields.

Table 3. *Average plant height, standard error by line taken on Nov. 19, 2018 from 55 USDA varieties in a replicated trial at Bridgestone America Guayule Research Farm, Eloy, AZ planted in April and May 2018.*

Plant Heights 11/19/2018 both fields

	Planting 1 DOP April 11, 2018				Planting 2 DOP May 16, 2018			
	Average of 4 reps per Entry							
Pedigree	Avg Height Entry	StdDev Entry	StdErr Entry	Plants/ Entry	Avg Height Entry	StdDev by entry	Std error by entry	Plants/ Entry
AZ2	72	11.02	0.97	130	61	8.31	0.71	139
CAL7	71	10.45	1.28	67	61	8.63	0.79	119
R1109	67	15.72	1.71	84	53	12.02	1.21	98
CAL2	66	7.65	1.12	47	53	6.45	0.64	102
PARL 934	65	10.12	1.88	29	53	18.34	8.20	5
CAL5	65	8.18	0.95	74	53	8.58	0.84	105
CAL1	62	10.25	1.41	53				
PARL 930	52	11.34	1.94	34	40	4.57	0.44	109

CFS18-2005	48	16.85	2.93	33	32	4.73	0.47	102
R1040	47	6.23	0.93	45				
R1096	46	5.21	0.60	75				
11604	44	10.65	2.09	26				
R1110	44	16.02	2.83	32				
R1037	43	7.66	1.60	23	28	9.58	1.29	55
11693	43	7.64	1.02	56	35	5.87	0.93	40
PARL 929	43	8.77	1.23	51				
11619	43	8.76	1.31	45	35	10.68	1.98	29
PARL 923	42	10.48	1.38	58				
11591	42	6.89	0.88	62				
PARL 931	42	7.20	1.20	36	39	5.13	0.47	119
PARL 922	41	9.36	1.01	86				
PARL 921	41	20.63	5.00	17	27	3.81	0.63	37
AZ6	41	10.33	1.72	36				
11646	40	7.51	0.99	57	33	7.60	1.41	29
N565	40	7.31	1.49	24	31	4.03	1.08	14
PARL 919	40	8.40	0.90	88	34	6.37	0.68	88
AZ5	40	9.54	1.49	41	33	7.82	0.95	68
N565 II	40	6.83	0.83	67	33	5.95	0.91	43
N396	39	4.84	0.56	75				
11609	39	5.23	0.94	31	34	3.78	0.42	81
R1103	39	5.86	1.09	29				
R1044	39	5.78	0.76	58				
N576	38	7.08	1.29	30				
CFS24	38	10.40	1.67	39				
12231	38	4.74	0.70	46	36	5.68	0.58	95
PARL 917	38	4.99	0.52	91	31	5.59	0.67	70
11633	38	4.44	0.62	52	33	3.77	0.43	76

PARL 920	38	7.65	0.97	62	34	7.35	0.93	63
PARL 916	38	4.26	0.40	111	31	5.08	0.51	100
4265-X	37	10.52	1.15	84				
R1108	37	3.91	0.70	31				
CFS21	37	5.48	0.55	98	31	5.19	0.62	70
PARL 924	36	4.11	0.51	64				
11635	36	8.55	1.34	41	28	7.36	0.91	66
PARL 935	35	2.47	0.68	13	31	6.10	2.31	7
CAL3 (2x)	35	6.02	1.90	10				
11605	34	10.85	2.43	20				
PARL 914	32	7.42	1.35	30				
593	32	3.87	0.52	55				
PARL 915	32	5.50	0.92	36				
PARL 932	31	10.85	2.05	28	25	3.96	0.40	99
R1092	28	3.96	0.54	53	24	4.36	0.60	52
R1093	26	2.62	0.37	50				

Expression Vectors for Downregulating SEP3 and FT Genes:
Research is continuing as planned. Downregulation of *FLOWERING LOCUS T* continues, and the construct preparation is in the final stages. We expect final results to be available in February 2019.

Plant Transformations using AP1, SEP3, and FT Genes:
Research is continuing as planned. Transformation of guayule AZ-2 to downregulate *APETALA1* gene resulted in 1020 callli growing in the culture. Transformation of guayule AZ-2 to downregulate *SEPATTALA3* gene resulted in 1003 calli growing in the culture.

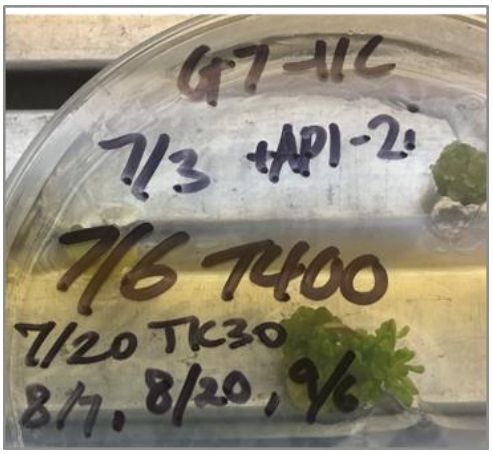

Photo 2. *Lab samples for guayule gene downregulation and transformations.*

Yr1 Growth and Rubber/Resin Content in Guayule Germplasm Lines:
Research for this objective is complete; no new data to report.

Root Growth/Architecture Compared to Water Use in Direct-Seed and Transplant-Established:
Research is continuing as planned; no new data to report.

Cuticular Wax Collection/Evaluation Protocols:
Characterization of leaf waxes was to begin in Fall 2018, but has been suspended due to the USDA furlough. No progress has been made on this objective.

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:
Research is continuing as planned. There are significant phenotypic variations, e.g., plant height, within the USDA guayule accessions and more variations in other traits. The rate of growth is also different among accessions, and independent from plant height, indicating different mechanisms could control plant height and growth rate (Figure 1).

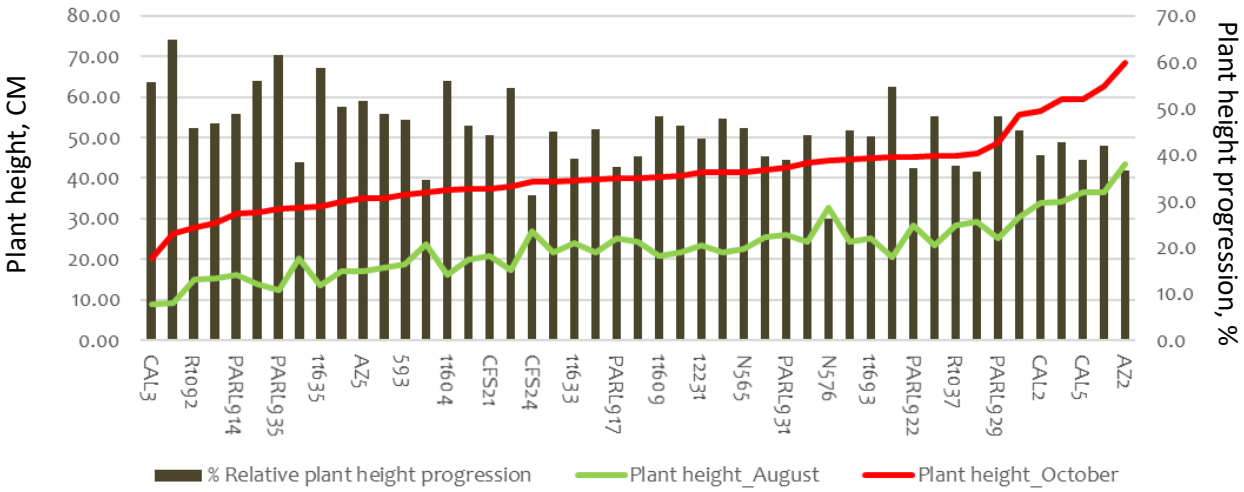

Figure 1. *Phenotypic variations within guayule accessions.*

Remote Sensing Evaluation:

Figure 2 shows NDVI measured from July to October. The two top lines are AZ-2 that were transplanted and are not shown in the table. The third top line is AZ-2.

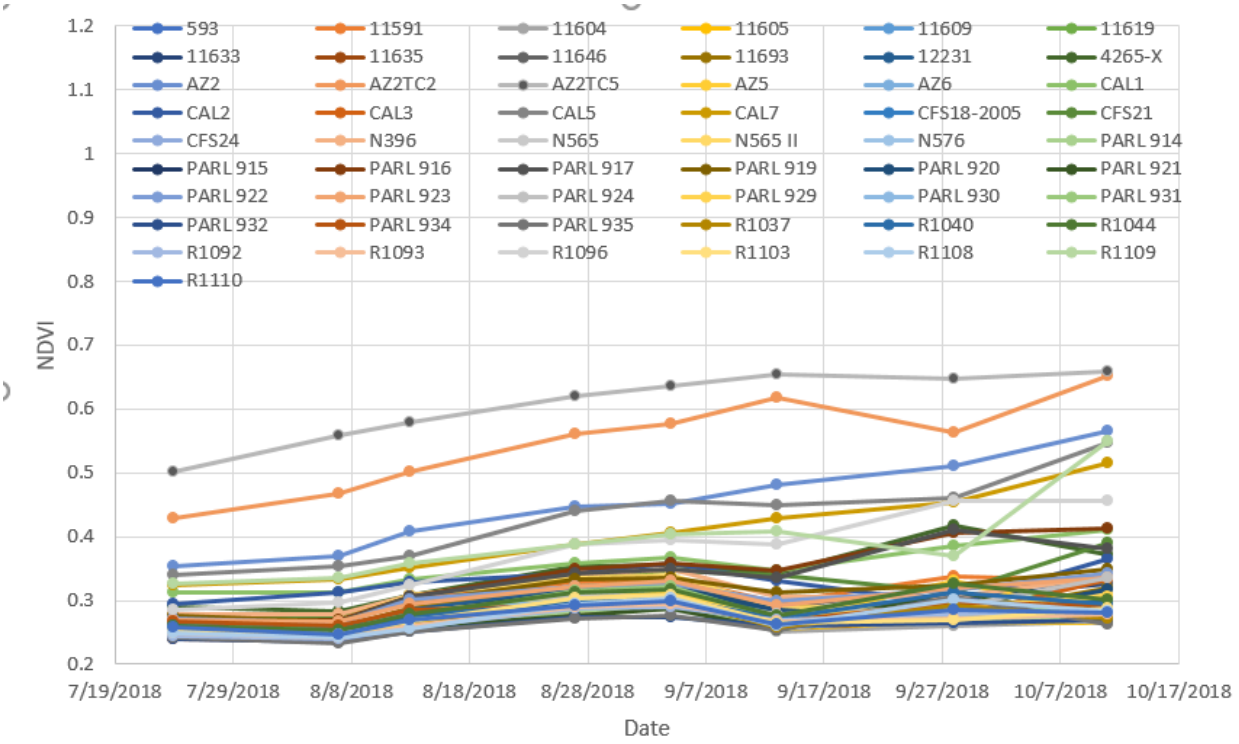

Figure 2. *NDVI of 55 USDA varieties in a replicated trial at Bridgestone America Guayule Research Farm, Eloy, AZ planted in April 2018. Measurements occurred from July until mid-October.*

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 Guar seed from crosses of partial male-sterile plants with 2 elite lines planted	15 Nov 18 15 Jun 19

		Genetic diversity evaluated//flowering time, branching, leaf pubescence, and disease/insect tolerance	15 Oct 19

Guar Germplasm in New Mexico:
Locations for trials in 2019 have been identified and land preparation has been started. Area where deficit irrigation trial will be conducted is planted with triticale to make soil moisture depleted and uniform. Before, the trial is planted the field 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).

Germplasm evaluation study will use seeds from Drs. Ray and Grover's studies conducted in 2018. Depending on the seed increase, all or part of the germplasm from their study will be evaluated.

Guar Germplasm Line Multiplication:
Guar germplasm study was harvested and seeds obtained. Plant samples were collected for measuring final harvest data.

Photo 3. *Guayule: direct-seeded roots at four months.*

Root Inoculation Results – Seed Evaluation:
Seed from thirty-four new accessions were treated with 500ppm gibberellic acid solution and planted in the greenhouse. Seedlings will be moved from trays to pots and inoculated when roots are developed.

Root Rot Tolerance per Guayule Germplasm:
See information above.

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

Photo 4. *Guar: non-branched, upright, good pod to biomass ratio.*

Guar Combination Trials:
Plant measurements and characterizations are completed. Seed from all accessions collected in November and December (Table 4). Threshing (to remove seed pods) is ongoing.

Table 4. *Guar accession characteristics.*

PLOT	ACCESSION	AVE HT (CM)	PLANTS[1]	STEMS[2]	MATURITY[3]	LODGING?	COMMENTS
G1	PI 176377	71.4	P (not very)	BR	LATE		lots of biomass:pods
G2	PI 179926	64.6	P	BR to BA	MID		basal branching looks good
G3	PI 180434	80.4	P	BR	LATE		Lots of biomass:pods
G4	PI 186477	79.8	P	NON BR	EARLY	LOTS	good ratio biomass:pods
G5	PI 217923	99.0	P	NON BR	EARLY	SOME	some basal branching; good pod set
G6	PI 253182	105.0	P	BR	LATE	SOME	some off-types early; most branching; few pods
G7	PI 250360	98.6	P	NON BR	EARLY	SOME	good pod set
G8	PI 253186	98.8	P	NON BR	EARLY		some basal branching; lot of pods
G9	PI 253187	101.4	P	M (BA & NON BR)	EARLY	SOME	good pod set; basal branching
G10	PI 262152	81.6	P	BR	LATE	LOTS	lot of biomass
G11	PI 268229	100.4	P	BR	LATE		lots of biomass:pods
G12	PI 288377	111.2	P	BR	LATE		lots of biomass:pods
G13	PI 537281	94.2	P	BR	LATE		lots of biomass:pods
G14	PI 542608	99.0	G	BR	MID		many off types; ok pod set; some basal br
G15	PI 158125	96.4	P	M	MID/LATE		non-branching mid; branching late
G16	PI 158126	91.2	P	BR	LATE		non-branching early (good pod set); branching late (few pods)
G17	PI 164486	102.6	P	BR	LATE		upright; high biomass:pods
G18	PI 263406	85.2	G	BR	LATE	SOME	not great biomass:pods
G19	PI 263698	97.0	P	BR	LATE		
G20	PI 338745	93.0	P	M	MID/LATE		non-branching mid; branching late
G21	PI 338796	104.6	P	BR	LATE		high biomass:pods
G22	PI 338811	93.2	P	BR	LATE	SOME	not great biomass:pods
G23	PI 340261	91.8	P	M	MID		branched and non-branched
G24	PI 547070	121.6	G	NON BR	EARLY/MID		MS/GOOD ARCHITECTURE for crossing; early but keeps flowering
G25	PI 549164	80.0	P	M	EARLY/LOTS		PMS; early but keeps flowering; poor pod set
G26	PI 593048	77.2	G	BR	EARLY		
G27	PI 593049	87.2	G	BR	MID		average biomass:pods
G28	PI 593058	81.6	P	BR	MID		nice upright
G29	PI 593059	92.2	G	M	EARLY		has potential
G30	SANTA CRUZ	85.0	G	BR	MID		good yield

G31	MATADOR	59.8	P	BR	MID		small nice looking plants
G32	LEWIS	80.0	G	BA BR	EARLY		excellent biomass:pods

[1]PLANT MORPHOLOGY: PUBESCENT (P); GLABROUS (G); MIXED (M)

[2]STEM MORPHOLOGY: BRANCHED (BR); BASAL (BA); MIXED (M)
[3]MATURITY: EARLY (90-100 DAYS AFTER PLANTING); MID (100-120); LATE (>120)

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
			31 Aug 19

		Generate report/publication from results obtained	
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 Prowl H2O (pendimethalin) and Aim (carfentazone) labels expire in 2018; work with BASF and FMC on renewals	31 Aug 19 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	15 May 19 31 Dec 18

		Compare N and P utilization and effects of nutrients on biomass, rubber and resin production	15 May 19
15 Waller	Install TDR, infrared camera and flowmeter system	Provide data on guayule irrigation experiments	15 Jan 19
		Provide data set that can be used to refine the use of sensors for WINDS crop irrigation mgmt.	15 Jan 19
		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	15 Apr 19
		Add crop coefficient method to WINDS	15 Apr 19
		Develop educational videos and documents on use of WINDS	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	15 Jul 19
		Document effects of irrigation treatment on plant growth, soil moisture, plant stress, plant chemical response, plant vegetative indices, and crop coefficient	15 Jul 19
		Generate a publication on guayule irrigation experiments	15 Jul 19

Guar Critical Stage-Based Deficit Irrigation Trial:
In general, alternative crops cannot compete with traditional crops grown in New Mexico like corn and forage sorghum for irrigation water due to difference in profitability. Therefore, understanding seed yield formation of alternative crops under range of water availabilities and also water availabilities at different growth stages are very important in management decisions. Desert adapted crop like guar has ability to use water from greater depth and also ability to use water more judiciously. It is often told that if guar receives more water after flowering its seed yield reduces. Therefore, the trial focuses on the ability of guar to utilize water stored in deeper soil profile for yield formation. Second aspect assesses when stressing guar least affects its seed yield formation.

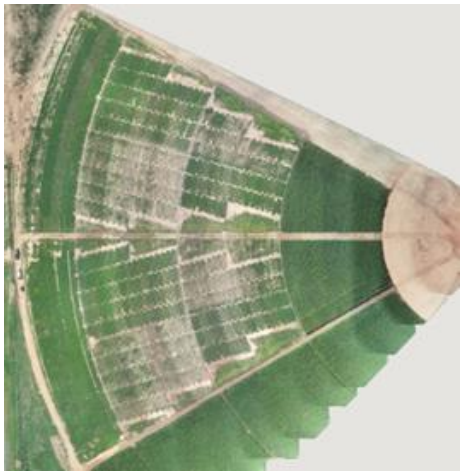

Photo 5. *Aerial view of deficit irrigation trial, Clovis, New Mexico.*

Preliminary analysis of the data from the first year of the trial indicated that refilling soil profile with pre-irrigation increased seed yield by 28%. Observation of critical stage based irrigation indicated that skipping irrigation during reproductive stage was less critical compared to stressing at vegetative stage. Seasonal biomass observation suggested that relieving stress at reproductive with irrigation increased biomass production. But, all of it may not transfer into seed yield. Data on seed yield components is still being processed. Effect of drought on source and sink will be assessed. Seasonal soil moisture to a depth of 1.40m was measured at different growth stages to assess role of soil moisture extraction on yield and yield components. Data on seasonal soil moisture will be processed after neutron probe calibration is completed. The trial is also being used for crop coefficients development. After graduate students returned to classes for fall semester, weekly neutron probe data was collected on limited treatments by Dr. Sultan Begna. With the help of Dr. Diaa El-Shikha, we collected remote sensing data from irrigation studies at Clovis. Visual assessments of the results indicate interesting results. We feel that remote sensing for only two times is not sufficient. We are exploring the possibility of extending collaboration to collect remote sensing data more than four times.

Incubator Study to Understand Temperature and Germination Relationships:
Recently, we received both temperature controlled incubators. We also have seeds of all guar cultivars. We will initiate study to assess temperature effect on guar germination. We are also developing protocol for the study. This trial will provide much needed information on what cultivars can be used in northern latitudes or for delayed planting. This will help in increasing guar acreage in the US and local production of guar gum.

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 direct seeded in April and then thinned to the desired spacing. A 1 m plot was harvested in October from each plot with 4 reps per treatment to assess biomass yield. Figure 3 shows that AZ-2 had more plants per area than Sel-1 due to the high vigor of AZ-2 but in general, each variety had

increasing numbers from treatment 1 to 5 on a per acre basis. The top right figure shows the same trend but treatments Sel-1-4 and Sel-1-5 were about the same. This affected the biomass results shown in the bottom figure where those treatments are similar (and equal to treatment Sel-1-3). AZ-2 treatments corresponded in biomass increases and treatments 1 to 5. This indicates at this age, the more plants per acres the more biomass. The bottom right figure indicates that at this age, AZ-2 plants do not compete with each other but Sel-1 plants do.

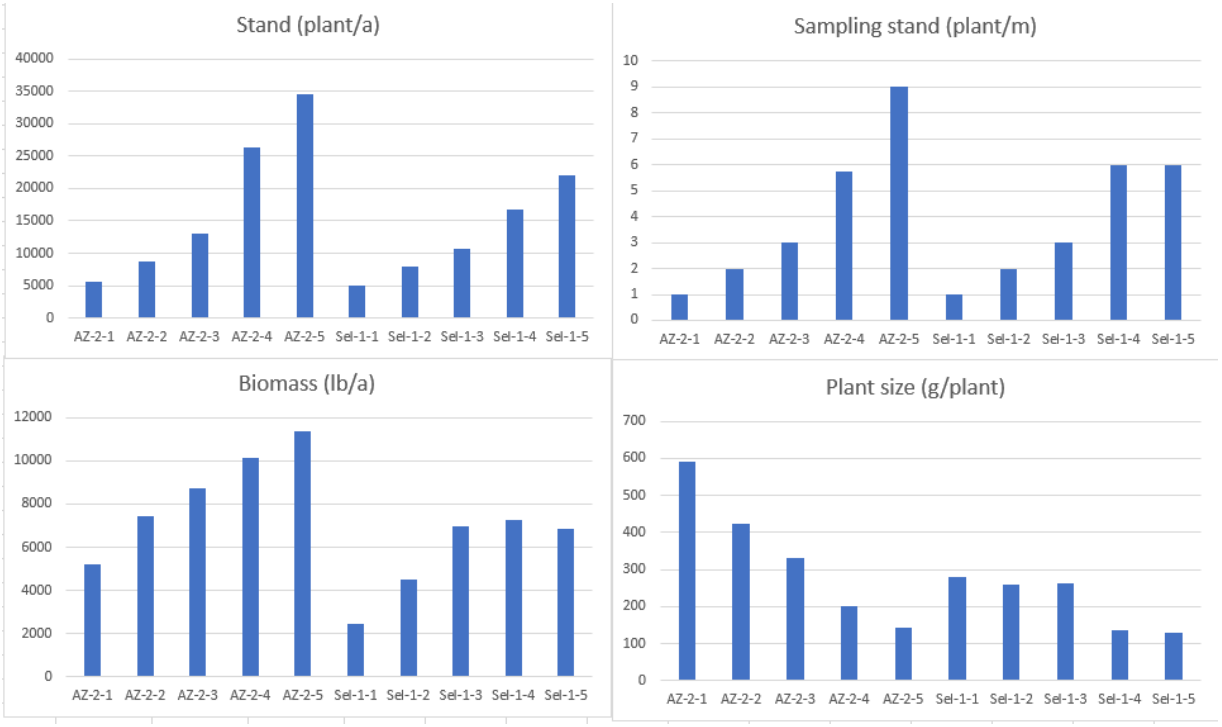

Figure 3. *Biomass (lbs/ac) by density (plants/ac) for two varieties at 6 months of age.*

The NDVI shows the ranking of increased biomass by treatment very well (Figure 4). There is a low correlation between NDVI and the biomass values due to the closing gap as plant get older (Figure 5). However, the ranking is still valid at 6 months of age.

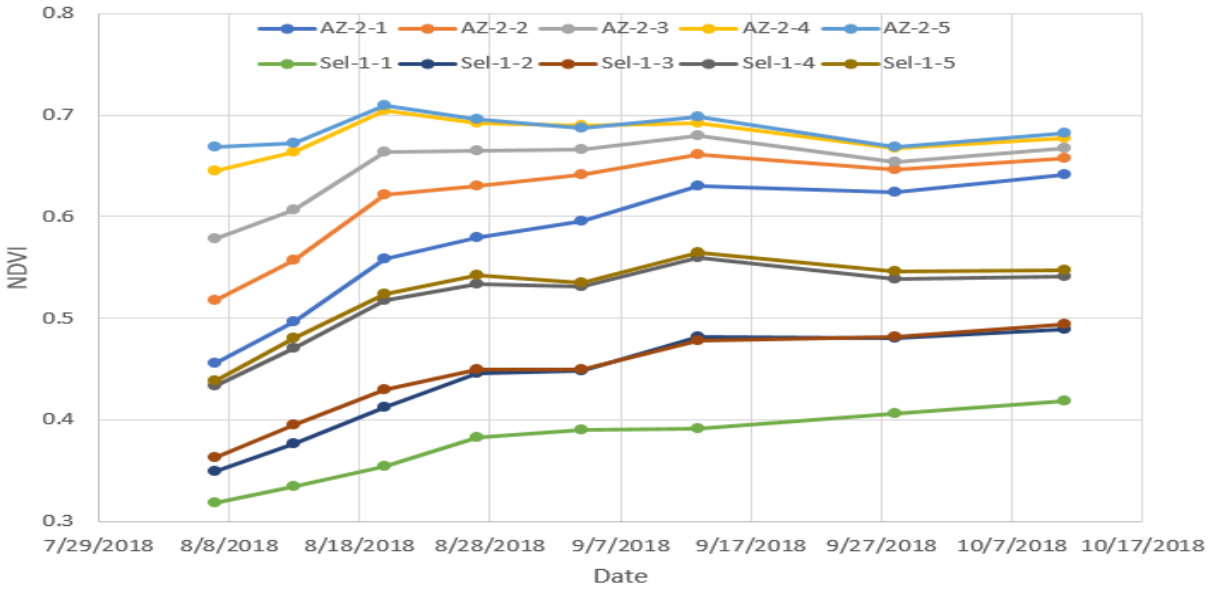

Figure 4. *Relationship between NDVI and actual plant biomass measurements.*

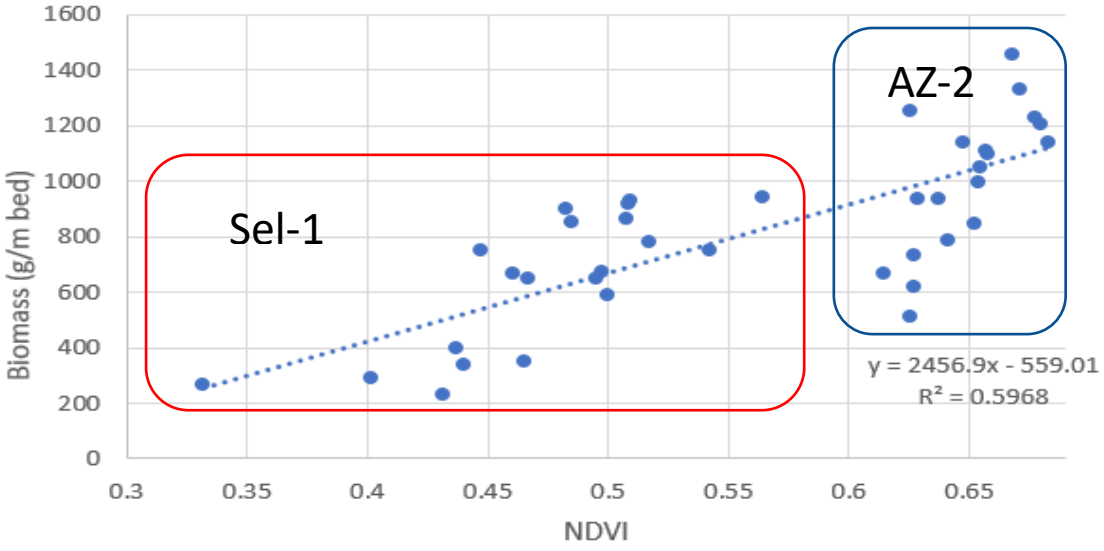

Figure 5. *Correlation between plant biomass at age 6 months and NDVI of two guayule varieties.*

Bi-Monthly Harvest from Irrigation Trials:

Tables 5-10 compare the growth of plants from drip and flood irrigation treatments at 2 locations.

Table 5. *Shrub dry weight (g/m) (no root) harvested at 4, 6, and 8 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)**	**August (4 mo)**	**October (6 mo)**	**December (8 mo)**
Drip 50%	572.3	891.8	1472.7	335.8	557.5	1368.6
Drip 100 %	618.4	1258.8	1652.6	310.1	661.6	1225.1
Flood 50 %	610.3	909.6	2042.1			
Flood 100 %	762.0	973.5	1816.4	329.5	638.7	1350.1

Table 6. *Root dry weight (g/m) harvested at 4, 6, and 8 months from 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)**	**August (4 mo)**	**October (6 mo)**	**December (8 mo)**
Drip 50 %	148.0	214.8	250.5	77.7	129.3	267.4
Drip 100 %	140.7	214.7	237.8	85.3	162.5	205.8
Flood 50 %	128.0	179.8	291.7			
Flood 100 %	141.0	169.9	250.7	89.3	179.2	261.4

Table 7. *Average root length (cm) harvested at 4, 6, and 8 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) (cm)**			**Maricopa U of A Farm (Sandy loam soil) (cm)**		
	August (4 mo)	**October (6 mo)**	**December (8 mo)**	**August (4 mo)**	**October (6 mo)**	**December (8 mo)**
Drip 50 %	29.6	35.8	31.6	20.4	30.1	28.3
Drip 100 %	28.9	30.0	37.3	21.4	31.5	30.5
Flood 50 %	25.1	33.8	36.8			
Flood 100 %	26.8	30.7	31.4	24.7	36.7	35.2

Eloy is a clay soil and MAC is a sandy loam. Plants were harvested at 4, 6, and 8 months. Higher biomass was produced at Eloy on the clay soil regardless of irrigation treatment. On average, the biomass yield was 25% higher in Eloy. In Eloy differences were starting to show higher growth in flood treatments compared to drip on the clay soil, but not at MAC. Not much difference in root biomass was seen between the treatments or locations. We are only able to harvest coarse roots in this harvest. Root length of the main taproot did not show significant differences yet. The proportion of flowers, leaves, and stems changed over time significantly. Leaves decreased from August to December by about 20% as stems increased over that time. We measured rubber and resin content of these small plants. It is important to remember they have not undergone cold induction yet at any of the 3 harvest dates. 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. Resin values appear to be near maturity at 8 months of age compared to rubber, which still needs cold induction.

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

Irrigation Treatment	Bridgestone Eloy Farm (Clay soil) (% of total									Maricopa U of A Farm (Sandy loam soil) (% of total)								
	August (4 mo) (g)			October (6 mo)			December (8 mo)			August (4 mo)			October (6 mo)			December (8 mo)		
	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St	Fls	Lvs	St
Drip 50 %	5	62	21	8	55	28	3	33	46	3	65	21	7	64	17	3	36	41
Drip 100 %	5	64	19	7	61	26	2	42	43	4	64	21	5	67	18	3	37	44
Flood 50 %	4	65	19	9	61	23	3	34	49									
Flood 100%	5	63	22	7	59	29	4	39	45	3	63	22	7	65	17	3	35	43

Table 9. *Rubber and resin content (%) of stems (leaves and flowers removed) harvested at 4, 6, and 8 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) (kg/ha)			Maricopa U of A Farm (Sandy loam soil) (kg/ha)		
Rubber Yield (shrub + roots)	August (4 mo)	October (6 mo)	December (8 mo)	August (4 mo)	October (6 mo)	December (8 mo)
Drip 50 %	29.5	133.9	335.6	33.7	93.8	378.0
Drip 100 %	7.9	114.2	250.6	39.2	92.3	302.2
Flood 50 %	2.9	106.9	463.5			
Flood 100 %	4.6	111.4	364.2	33.6	99.4	379.5

Table 10. *Rubber yield (kg/ha) based on stems and roots harvested at 4, 6, and 8 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) (%)						Maricopa U of A Farm (Sandy loam soil) (%)					
Rubber % / Resin %	August (4 mo)		October (6 mo)		December (8 mo)		August (4 mo)		October (6 mo)		December (8 mo)	
	Rub	Res	Rub	Res	Rub	Res	Rub	Res	Rub	Res	Rub	Res
Drip 50 %	0.30	4.3	2.5	5.7	2.0	5.7	0.66	7.6	1.3	7.2	2.1	6.5
Drip 100 %	0.39	4.3	1.6	4.4	1.5	4.9	0.78	7.6	1.1	6.5	2.1	6.2
Flood 50 %	0.37	3.6	2.2	5.3	2.1	5.7						
Flood 100 %	0.49	4.2	2.0	4.7	1.8	5.5	0.69	7.3	1.1	6.8	2.1	6.5

Guar Response to Moisture Stress:
In-field crop growth data were tracked and collected for guar moisture stress response study. Plant samples were collected for final harvest seed yield and yield attributing characteristics. Preliminary results were presented at scientific meetings.

Guar Response to Planting Densities:
In-field crop growth data were tracked and collected for guar planting density study. Plant samples were collected for final harvest seed yield and yield attributing characteristics.

Collaboration with Herbicide Manufacturers in Support of 24cSLN Registrations:
The protocols were developed and used to conduct the guayule herbicide tolerance experiments.

I wrote a letter to Jack Peterson, Associate Director ADA and head of the Environmental Services Division, supporting the renewal of the Prowl 24c SLN for use of Prowl in transplanted guayule and established guayule fields. BASF submitted the materials required to the ADA and the SLN was renewed for a period of 5 years. During conversations with BASF, it was decided to wait for the results of the Fall 2018 and Spring 2019 pendimethalin preemergence and preplant incorporated experiments and then submit the data to BASF and begin the process of obtaining BASF's support for a Prowl H_2O 24c SLN for directed seeded guayule and all other existing guayule uses. Our goal is to submit materials to the ADA in the Fall of 2019 to obtain a new SLN. With regard to the Aim 24c SLN, through a quirk and a change of process at the EPA and ADA there is no expiration date on the Aim SLN for transplanted and established guayule. However, Jack Peterson (ADA) would like to see a new submission for a guayule 24c SLN so that the Aim SLN can be given an end date. We (FMC, U of A, and Bridgestone) will use this opportunity obtain a new Aim SLN that includes Aim uses in seedling guayule in addition to existing uses. FMC has indicated that it would like to see a second Aim postemergence study conducted similar to the one I conducted in spring 2018 at Eloy before moving ahead with an SLN.

Guayule Herbicide Tolerance Study:
Three preemergence herbicide experiments and three preplant-incorporated experiments (each experiment included two herbicides) were established at MAC in October and data were collected through the end of the quarter. (Photos 6-7) Some data will be collected in January 2019 and then the experiments will be terminated. Similarly, three preemergence herbicide experiments were established in Marana at Gary Deen's farm in September to obtain additional data on a course textured soil. (Table 11).

Photo 6. *Nadir photograph to measure early seedling growth following preemergence herbicide treatments.*

Photo 7. *Leaf counts per plant at Maricopa Agriculture Center following preemergence herbicide treatments.*

Table 11. *Data captured from the herbicide tolerance experiments.*

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
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
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
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
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

Spray Date	Chemicals Applied	Location/ Field	Method of Incorporation	ARM File Name / Data Tables?	Data Collected to Date
					12/14 – Leaf Counts
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

The postemergence Aim 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.

Publication of research reports will be delayed to March 31, 2019 as the preemergence herbicide experiments were not completed until the end of January 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:

In our literature review, we reviewed both the most current published data on guayule and general plant growth models. During our review, we found that AquaCrop and BioCro plant growth models show promise.

Guayule information is needed to simulate the growth models, AquaCrop and BioCro. Therefore, the detail studies are needed to collect more guayule information. We are obtaining guayule information in the fields, MAC and Eloy. We have already measured the specific leaf area index from different irrigation treatments (Table 12). The following experiment is to obtain other guayule information that will be conducted in the future.

Table 12. *Specific leaf area index of guayule treated with different water irrigation treatments.*

Treatments	row	Ave. wt. (g)/leaf		Ave area	Specific leaf area	mg/cm^2
		Fresh	Dry	cm^2/leaf	cm^2/g	
D50R3	P14	0.37	0.07	9.57	101.58	9.84
D75R3	P16	0.36	0.07	8.85	88.49	11.30
D100R1	P3	0.44	0.06	10.38	90.72	11.02
D100R2	P11	0.38	0.06	9.38	97.80	10.22
D100R3	P15	0.39	0.06	9.95	92.29	10.84
D125R3	P13	0.40	0.05	9.00	92.89	10.77
D150R3	P18	0.34	0.07	9.92	125.07	8.00
F100R3	P17	0.26	0.07	7.04	115.61	8.65

Phase I Growth Models Developed:

We have studied the project detail and find suitable plant growth models for guayule. We recently focused on 2 plant growth models, AquaCrop and BioCro.

1. AquaCrop model: The model mainly focuses on the effects of water irrigation on the biomass and other products of guayule. We are currently working on:
    - Literature review
    - Studying plant growth parameters
    - Model writing

2. BioCro model: The model mainly focuses on the effects of carbon dioxide level and temperature on the biomass and other products of guayule. We are currently working on:
    - Literature review
    - Studying plant growth parameters
    - Obtaining plant growth parameters (see Table 12)
    - Model writing

Plant Density Trials:

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

Biomass Drying Experiment:

Statistical analyses is completed (Table 13). According to results of Student's t-Test (Table 14) there were no differences between drying treatments for cyclohexane extractables ("rubber"), but there were for acetone extractables ("resin") for variety AZ2 (Table 14 – marked with *). This experiment may be repeated or expanded.

Table 13. *Means and standard deviations for acetone extractables ("resin") and cyclohexane extractables ("rubber") for two varieties harvested one week apart and either dried in the lab (6/12) or in the field (6/19). N=5 for each variety/date combination.*

	RESIN	RUBBER
11693 6/12	5.80 ± 1.88	5.24 ± 0.95
11693 6/19	8.64 ± 2.93	5.95 ± 0.91
AZ2 6/12	2.76 ± 1.01*	3.87 ± 0.68
AZ2 6/19	6.95 ± 0.82*	3.42 ± 0.34

Table 14. *p-values for results of Student t-test.*

	RESIN		RUBBER	
	11693 6/12	AZ2 6/12	11693 6/12	AZ2 6/12
11693 6/19	0.1115	-	0.2601	-
AZ2 6/19	-	0.0001	-	0.2380

Guayule Trials (Direct-Seeded and Transplant-Established):

Due to the failure of greenhouse environmental controls, all transplants died. Both experiments are due to be replanted in January.

Installation of TDR, Infrared Cameras, and Flowmeter System:
We are close to linking the sensors to the server. It has been a steep learning curve and the link is not finished.

Python MySQL WINDS Model Integration with Existing Tools:
Waller has made the WINDS model run with the MySQL database on the server. He is working on the website presentation of data with a python library called Flask. A faculty member in Biosystems Engineering. We are still working to link the sensors to the server.

Irrigation Experiments – Guayule and Guar:
In October-December 2018, 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 location with the help of Bridgestone crew.

Neutron probe data was collected once a week until mid-November 2018. 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. We stopped irrigating both sites in November 15, 2018, however, the soil moisture data collection will continue biweekly until mid-February 2019.

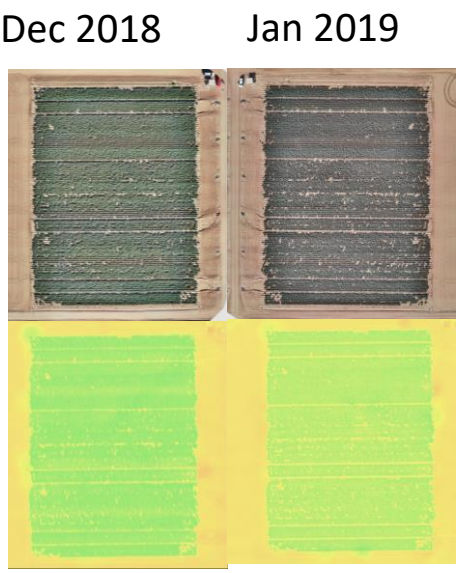

Photo 8. *Remote sensing data for irrigation experiments and models on guayule fields planted at Maricopa Agriculture Center, Arizona.*

Using the irrigation model and the soil moisture data collected in the first year, we were able to develop the K_{cb} curves for furrow and subsurface drip irrigated guayule. All the data collected in the first year will be analyzed and published in the annual international meeting of the American Society of Agricultural and Biological Engineers in July 2019.

Remote sensing data, multispectral and RGB, was collected every week from the Maricopa site. However, the collection of the RGB data was stopped for two weeks in December because the drone needed repair. Also, remote sensing (multispectral) data was collected 1-2 times from the guayule irrigation experiment in Eloy. Some of the remote sensing data was processed, image stitching, and the rest of the data will be processed soon.

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 Mar 19 1 Mar 19
2 Maier/ Neilson	DNA extraction of soil samples for microbiome analysis	Quantify available biomass for 108 samples for amplicon sequencing	1 Mar 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 for Soil Chemical Analysis is March 1, 2019

Soil chemical analysis of the baseline soil samples is near completion. Progress is reported as orange because the nitrate analysis remains to be completed. Statistics are reported in Table 15. Full data tables are available to anyone upon request. Statistical differences were observed between the MAC and Eloy fields for Organic matter, pH, SAR, potassium, zinc, manganese, iron, and copper. The differences in pH and SAR are not significant to plant growth or microbial community structure. The impact of nutrient variability on plant development and microbial communities will be analyzed by correlation analysis when plant and microbial data are available. Field heterogeneity for each field is reported as %CV for each soil property. Across-field variation varied from 2% to 47%. The greatest variation was observed in soil phosphorus content. The smallest variation was observed for soil pH. Associations between variability in soil chemistry and field plot locations will be analyzed and plotted for the 2019 Q1 report.

Table 15. *Baseline characterization of field soil physio-biogeochemistry.*

Soil Property	MAC Farm	Eloy Farm	Location Comparison (T-test)
Soil Texture	Sandy loam	Not complete	
Clay Content (%)		Not complete	
Average	15.9		
Stdev	1.5		
CV	9.3%		
Range	10.5-18.3		
Organic Matter (%)			
Average	0.58	1.06	Eloy greater
Stdev	0.19	0.22	than MAC
CV	32%	21%	p<0.0001*
Range	0.17-1.10	0.51-1.67	
pH			
Average	8.0	8.2	Eloy greater
Stdev	0.2	0.2	than MAC
CV	2%	2%	p<0.0001*
Range	7.7 – 8.3	7.8 – 8.5	
EC (ds/m)			
Average	1.11	1.06	
Stdev	0.36	0.34	NSD
CV	32%	32%	
Range	0.47 – 2.05	0.65 – 1.98	
SAR (Soil sodicity)			
Average	5.46	4.31	MAC greater
Stdev	0.60	0.62	Than Eloy
CV	11%	14%	p<0.0001*
Range	4.03-7.47	2.87-5.80	
Phosphorus (mg/kg)			
Average	7.58	8.54	
Stdev	2.87	4.00	NSD
CV	38%	47%	
Range	2.96 – 10.60	3.07 – 8.03	
Potassium (mg/Kg)			
Average	44.8	37.08	MAC greater
Stdev	13.3	5.32	Than Eloy
CV	30%	14%	p<0.001*
Range	25.0 – 76.3	28.5 – 49.8	
Zinc (mg/Kg)			
Average	0.75	0.64	MAC greater
Stdev	0.17	0.13	Than Eloy
CV	22%	20%	p<0.001*
Range	0.48-1.36	0.43-1.01	
Manganese (mg/Kg)			

Average	9.81	18.03	Eloy greater
Stdev	1.69	5.01	than MAC
CV	17%	28%	p<0.0001*
Range	7.29 – 13.1	9.71 – 29.0	
Iron (mg/Kg)			
Average	5.32	6.33	Eloy greater
Stdev	0.70	1.03	than MAC
CV	13%	16%	p<0.0001*
Range	4.07-7.23	4.03-7.88	
Copper (mg/Kg)			
Average	1.39	3.16	Eloy greater
Stdev	0.13	0.47	than MAC
CV	10%	15%	p<0.0001*
Range	1.12 - -1.65	2.28 – 3.72	
Biomass (ng DNA/g)	Not complete	70% complete	
Average		42.5	
Stdev		13.4	
CV		31%	
Range		20 - 79	

Concentrations are expressed per weight dry soil
*Significance determined by two-tailed test
NSD = no significant difference between Eloy and MAC fields

New target completion date Soil Physical Analysis March 1, 2019.

The soil texture analysis is complete for all MAC samples, but has not been done for the Eloy samples, thus the progress is reported as orange. The results are summarized in Table 1 and a full data table is available upon request. The undergrad doing this work did not return this semester, thus we need to train a new undergrad to complete the Eloy analyses. The variability in clay content for the MAC field was 9% with an average content of 15.9% and a range of 10.5-18.3%. This data will be used to determine the impact of clay content on guayule biomass and rubber production. The effect of clay content on microbial community composition will also be determined. Associations between field plot location and clay content will be presented in the 2019 Q1 report.

DNA Extraction for Microbiome Analysis:
New target completion date March 1, 2019.

DNA extractions have been completed for 70% of Eloy samples. DNA extractions have not been done on the MAC samples. Progress is reported as orange because we are behind schedule, however we will be able to meet our goal of completing this work prior to the Year 2 sampling to help inform sampling design. Results thus far indicate high variability of DNA biomass across field samples. Average biomass concentration was 42.5 ng DNA/g dry soil with a range of 20 – 79 ng DNA/g dry soil. These soil DNA concentrations are low and reflect values significantly

lower than Sonoran Desert soils. We expect these values to increase significantly with plant establishment. During 2019Q1, associations between soil biomass and field location will be evaluated.

Baseline Microbiome Profile and Spatial Variations:
This work will be initiated when all Year 1 DNA extractions are complete

Soil Sampling for Guayule Microbiome Winter Dormancy Studies:
The initial plant and soil sampling for the Winter Dormancy Experiment was conducted on November 13, 2018 to correspond to the projected timing for a spike in guayule rubber transferase activity. Soil rhizosphere samples were collected from six plants by pulling the plant from the soil and shaking rhizosphere soil from the root ball. Soil samples were flash frozen within 1 hour of sampling for RNA extraction and transported on ice for DNA extraction. Samples were archived at -80°C at the UA and will be extracted when all samples for this experiment have been collected. Two other sample times are scheduled for this experiment, a second dormancy sample will be collected in February and a third sample will be collected when the plant returns to active growth, These samples will provide a temporal analysis of microbial community dynamics and activity during the winter dormancy. Bioinformatics analysis will be performed to look for plant-microbe associations that correlate with rubber transferase activity and rubber content.

Photo 9. *Rhizosphere soil from guayule plant growth.*

Year 2 Guayule Plant and Soil Sampling:
Sampling coordination for year 2 will be planned during a Plant Feedstock Production conference call in February.

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 student availability, instrument operation, and standard methods not working well for our samples. The graduate students are continuing to communicate with other biomass conversion groups to troubleshoot analytical methods.

After finishing his PhD in December, Cheng's hire as a postdoc has been delayed by an error in his OPT card application paperwork. This will require postponing the official start date for him by a month or two. As a postdoc, I have asked him to concentrate on completion of the lignocellulosic conversion review paper, completion of the two manuscripts on the continuous flow HTL reactor, and coordination with the Quinn and Sustainability groups to identify the most promising industrial partners. While he will still support the bagasse characterization work, I have asked Audu and Dehghanizadeh to focus on the experimental work.

Equipment required repairs during reporting period delaying purification and galactomannan assay procedure. Repairs were managed and arranged, and the potential impact included a small delay of <1month in beginning of assay procedure.

Though we have made improvements on our bagasse evaluation we continue to implement modification to the NREL biomass characterization methods with the aid of Dr. Brewer's group on bagasse material. We are continually troubleshooting the process to improve the digestion efficiency.

Investigation of guayule bagasse for polysaccharide coproducts and investigation of low-molecular weight fraction of guayule rubber have been delayed by about 3 months due to challenges with decolorization of polysaccharide mixture and the complexity of the low-molecular weight rubber fraction.

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

Bagasse Characterization Support:
Cheng and Bayat continued work on the lignocellulose waste material-conversion method review paper; they expect to submit in Q1 of 2019. (Figure 6)

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 GC/MS various extraction steps from the Bridgestone plant. A chemical analysis report is currently being drafted.

Nipsit Analysis on Guayule leaf and pollen samples has begun and we anticipate completion by February 1st.

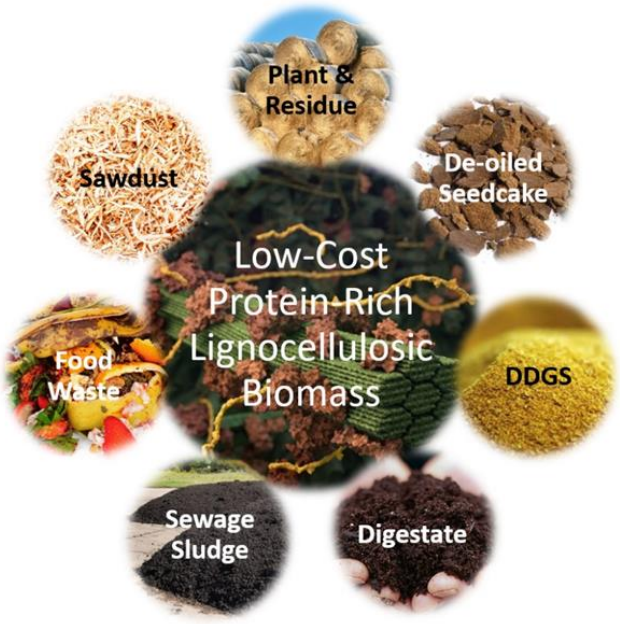

Figure 6. *Graphic illustration of low-cost, protein-rich lignocellulosic biomass derivatives.*

Guar Bagasse Biochemical Composition Analysis:
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 have begun aqueous size exclusion analysis of carbohydrates as well as galactomannans from guar seeds.

Analytical Evaluation of Thermochemical Conversion Products:
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.

In addition we reviewed the two sets of excel files with the results from the metabolomic analyses of leaves from Guayule plants subjected to cold stress treatment in growth chambers done by Stephanie Willette on 2018.

Other SBAR Collaborative Work:
Soil samples received from Dr. Julie Neilson are greater than 95% complete. We are lacking NO3 data and we anticipate the full completion of the soil samples prior to February 1st.

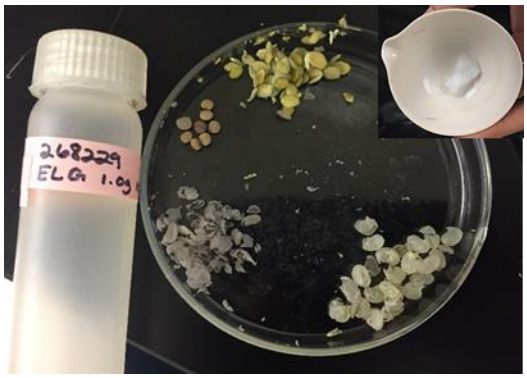

Photo 10. *Guayule leaves subjected to cold stress.*

Metabolomics and Biochemical Analysis.
We have also continued our work with Dr. Von Mark V. Cruz and Dr. David Dierig on characterization of guayule leaf material. We worked on the literature review on the acclimation of plants to cold temperatures. For this, I have gathered literature on

cold stress and cold acclimation on Guayule and other plants including Arabidopsis, Bermuda and zoysia grasses, Maize, Eucalyptus, Spring wheat, Siberian spruce, Beans, Stevia, Tithonia, Dendrobium, Tomato, Tabacum.

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 has been partially finalized. 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 7 shows the data collection process.

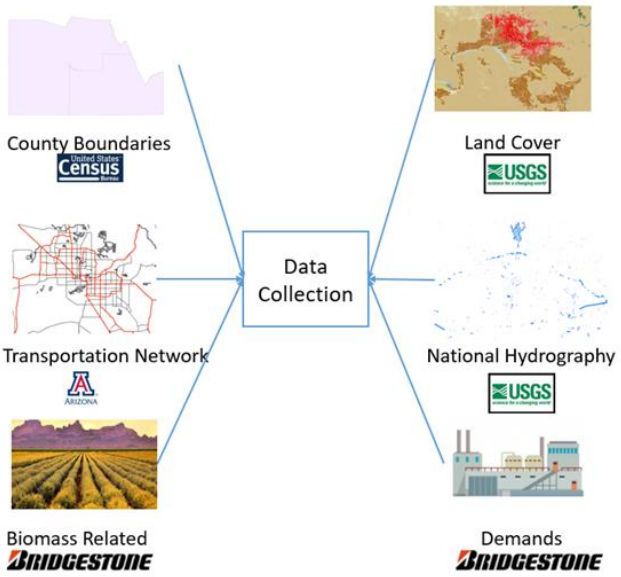

Figure 7. *Data collection process and its sources.*

The future work of this task is to update the data to reflect any changes and new trends in this area.

Economic Benefits and Environmental Influences:
The collected data has been integrated into the developed mathematical optimization model.

The mathematical model is formulated as a two-stage stochastic mixed integer program with consideration of planting plan uncertainty. Also, Benders Decomposition algorithm was developed and applied to the problem. Numerical experiments were tested to help find the optimal processing facility location and decide on its capacity. Testing code was written in C++ programming language with the commercial solver CPLEX to solve the problem.

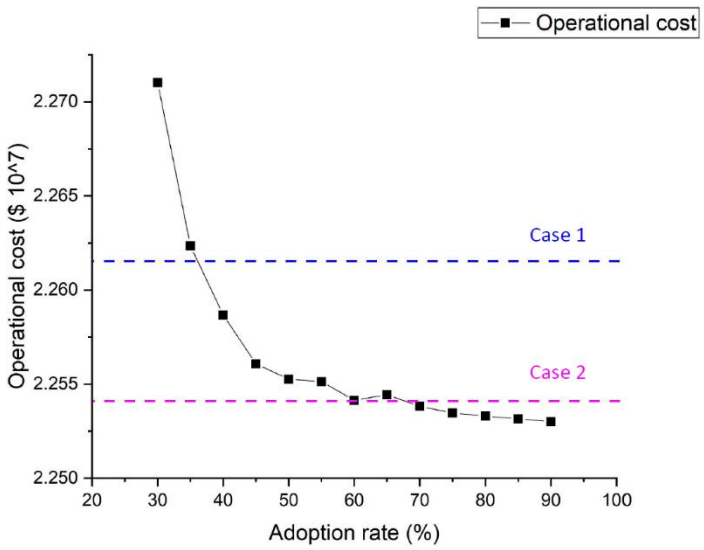

Figure 8. *Operational cost varies with adoption rate.*

Sensitivity analyses on demand amounts are completed to reveal the impacts of demand on decision making. For example, in our preliminary results, we have the following analysis, the operational cost decreases with the increase of adoption rate of biomass. The deterministic cases together with the stochastic cases (two stochastic cases: Case 1 and Case 2) are presented in Figure 8.

Hybrid Optimization Models for Operations:
We plan to work on dynamic harvesting scheduling problem starting next quarter. However, currently, the pilot fields in Arizona are still with small region and not big enough to support our test cases. Making hypothetical dataset or collecting data from published references maybe available options.

In the meanwhile, communication with industry partner to obtain useful information could be another challenge for us as well.

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:
Audu has begun the methods section drafts for the guayule and guar bagasse characterization sections, which we intend to include in a manuscript on guayule bagasse/resin characterization study with the Holguin and Jarvis groups, and a joint paper with Grover's group on guar variety trials. Biomass characterization measurements continued, especially towards getting reliable carbohydrate results for guayule bagasse.

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 began literature review manuscript on guayule resin extraction and characterization to guide his work on resin separation.

Comprehensive Literature Search for Commercially Important Metabolites of Guayule:
Literature search to identify major metabolites of guayule and determine the ability for conversion of the metabolites to value-added co-products is complete, and a manuscript to be submitted to the *Journal of Agriculture and Food Chemistry* describing the isolation and structure elucidation of new constituents is under development.

Chemical and Microbial Transformations:
Work continues, and is under review to meet intellectual property requirements.

Evaluate Major Metabolites of Guayule:
Work continues, and is under review to meet intellectual property requirements.

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 for the Team Meetings has been model integration, and the group continued to meet weekly. All notes and presentation materials are maintained in a community workspace available to all partners for future reference.

Issues/Risks:
Model integration represents a significant risk for the sustainability team. CSU has been diligently working to identify this as a risk with the team. In an effort to minimize this risk the team has been meeting on a weekly basis. The concept is for team members to come together and identify issues on a weekly basis such that the team can deliver on the timeline agreed upon at the workshop in August 2018. While the timeline did slip the model has been integrated.

Resources Limitations: CSU was originally budgeted at 1 graduate student, part-time hourly student, and 1 month of co-PI salary. Expanded scope has required an additional graduate student. The expanded scope is related to leading the sustainability thrust including integration. To date, CSU has dedicated 2 graduate students to the project based on an expanded scope of leading the model integration effort. The second student has been partially covered through combining co-PI salary and undergraduate hourly funds. The remaining funds for the second

graduate student are being covered by the co-PI though other means. If additional budget becomes available to fully support a second graduate student it would be most appreciated.

Gathering the current cost and price data continues to be difficult, but progress is being made. It is critical that the scenarios we develop are as accurate as possible, yet there are some variables that are not readily available and we will have to back into them.

Assisting with the interactions between tribal farms and Bridgestone have been progressing slower than expected due to the need for the farms to present to their Boards about the agreement details.

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	31 Mar 19
		Re-run model with new information	31 Mar 19
5 Landis	Clarify social sustainability metrics	Develop overview of sustainability tools and list of potential metrics	30 Jun 19
			30 Jun 19

		Generate publication/presentation for conference proceedings	
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 (Q4), 2018 is on schedule. The proactive bi-weekly meetings with project partners motivated the team to meet the identified task and set targets.

- **Farm Level Economics for Integrated Systems Model:** 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.

- **Potential Acreage for Crop Adoption in New Mexico:** Related to the farm level integration process, the team completed the task identifying potential acreage and crop mix for producers in New Mexico. The data was collected from USDA NASS CropScape for southern New Mexico counties to identify potential acreage for adoption of producing guar and guayule (Figure 10). Adoption will be identified using 10%, 15%, and 20% levels, which corresponds to various total potential acreage per New Mexico County (Figure 11). The information was shared with the systems model group to be used in the integrated model.

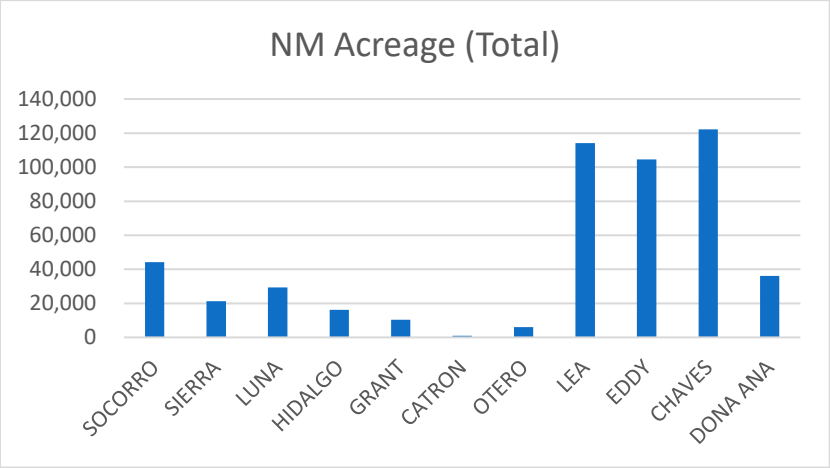

Figure 9. *Total potential acreage in New Mexico for guar and guayule production.*

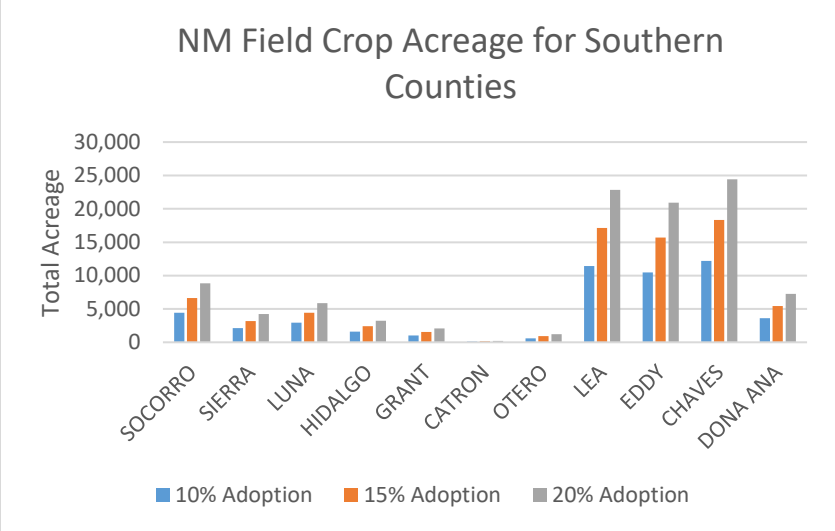

Figure 10. *Potential total acreage for guar and guayule in New Mexico counties at three adoption rates.*

- **Develop producer-level partial budget analysis for guar and guayule.** Enterprise budgets and narrative detailing the economic 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 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 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.

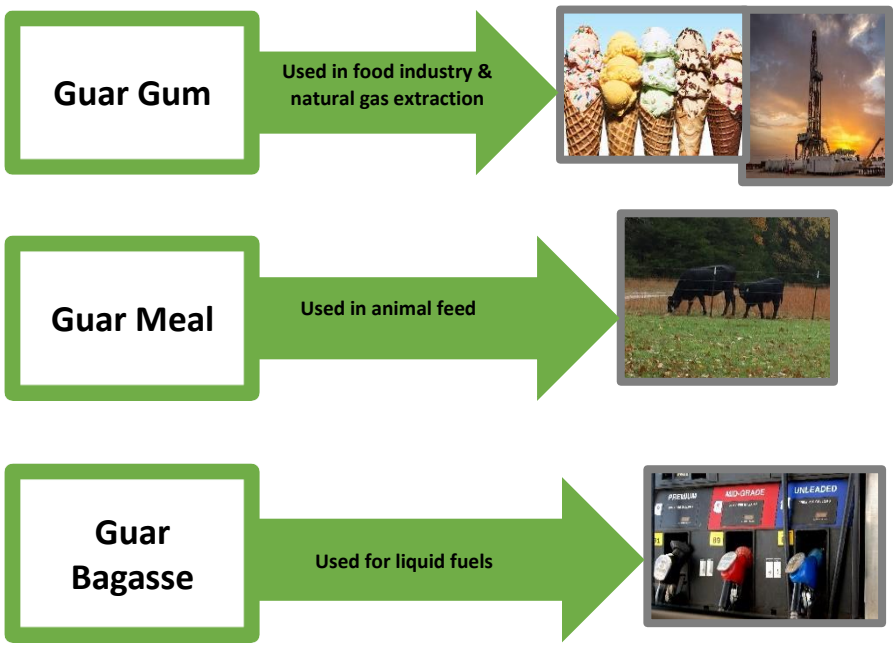

Figure 11. *Potential uses for guar included in LCA Model.*

Preliminary results were produced for guar agricultural 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.

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

Clarify Social Sustainability Metrics:
Initial social sustainability literature review was completed. An abstract on the review and its application to emerging technology (like guar) was accepted to the On Sustainability conference.

Techno-economic and Life Cycle Assessment Results:
On the environmental impact front, the integration has focused on working with CSM. CSU met with CSM multiple times to support integrating existing CSM models with the modeling framework and downstream process models which have been developed by CSU. CSU leads the effort for developing the backend of the results for environmental impact.

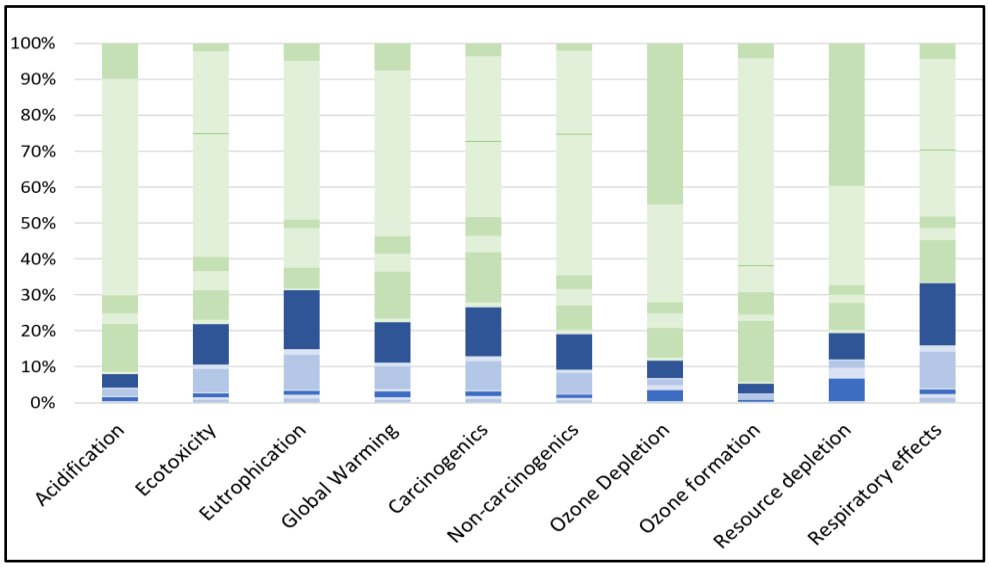

Figure 12. *Combined life cycle and techno-economic results including agriculture (green) and processing (blue) for guar.*

Enterprise Budget Development:
With the help of Teegerstrom, Gutierrez, and Robbs we completed the initial phase of the economics section for the integrated model. Integrated a machine cost generator as well as the ability to adjust certain inputs 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.

Three modifications will be completed in Q1 2019 for the model be fully operational, they include incorporating 1) the ability to insert zero acres to a crop, 2) a macro that establishes the current farm data as a basis for the user to modify crops, inputs, etc. to measure the change in net present value calculations, and 3) the ability to modify the percent of total replacement costs applied to all crop budgets within the machine cost calculator.

Further enhancements have been made 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 in the process of developing estimated guayule crop adoption estimates for Arizona growers, collected date and have estimates for Maricopa, Pima and Pinal counties (central Arizona) (Figures 14-15).

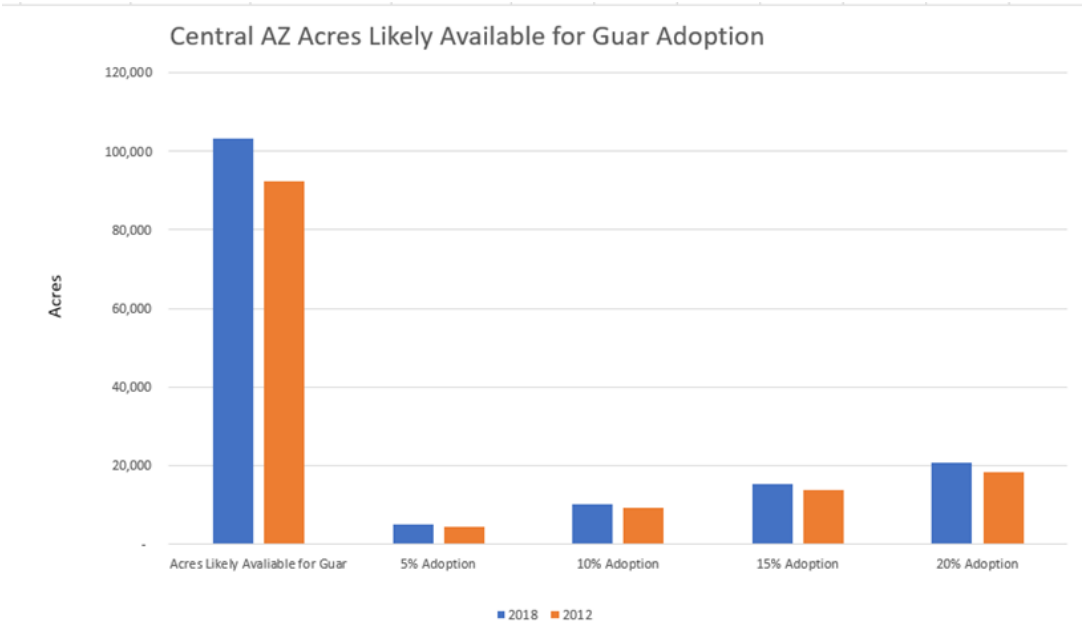

Figure 13. *Acres likely available for guar production in central Arizona.*

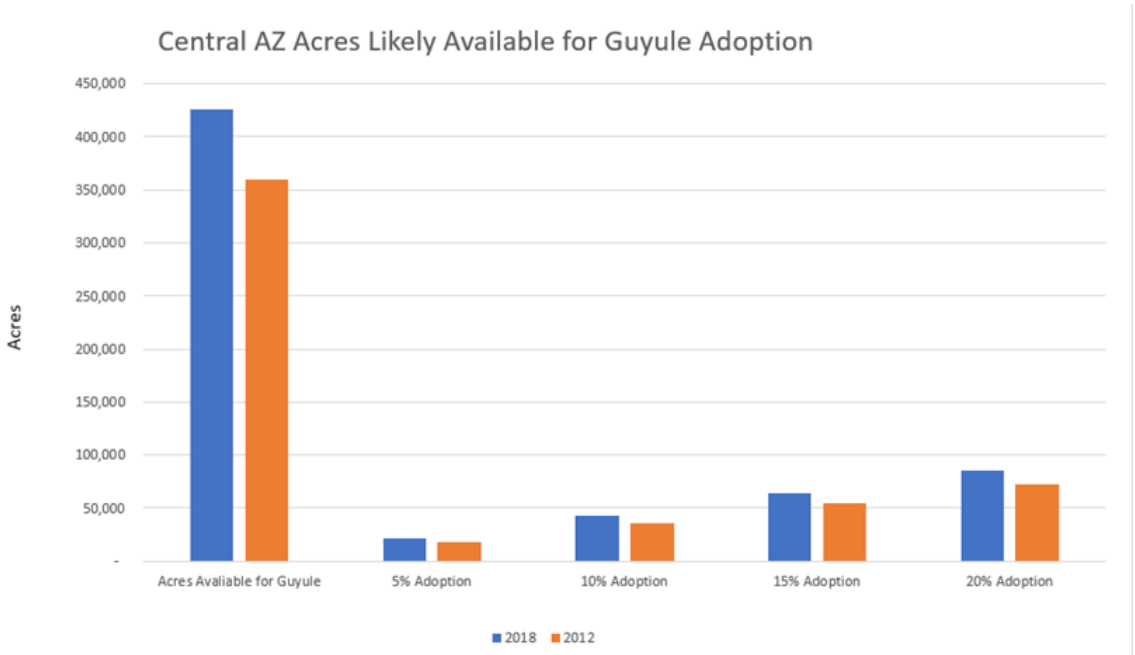

Figure 14*. Acres likely available for guayule production in central Arizona.*

Working Agreements between Tribal Farms and Bridgestone to Establish Experimental Plots: Assistance in securing experimental plots on two tribal farms is on-going. 1) This quarter, we connected Bridgestone and Gila River farms for experimental acreage agreement, held introduction meeting and started contract negotiations 2) We also connected Bridgestone and San Xavier Cooperative Farm for experimental acreage agreement. We have started the conversation and are in the process of setting up the first meeting to start contract negotiations.

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 led the integration effort with the development of a modeling framework to support the integration of the research across all research groups. At this point, the team has developed an integrated model (Figure 16) for guar. This effort has taken a significant amount of time but we are now in a position to start developing the front end and back end operations required for supporting the research and development of the project including outreach modules.

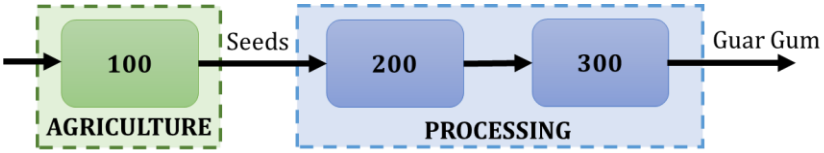

Figure 15. *Model integration for guar.*

The coordination has included group and individual meetings across the various partners. The current model includes the combined economic and environmental impact for both crops. The economic integration has focused on connecting with UofA, NMSU, OSU, and CSU. UofA, NMSU, and OSU are leading the economic modeling effort on the agricultural aspects of the process. CSU is leading the economic modeling on the downstream processing aspects of the

process. CSU has met multiple times with the upstream modeling team members in support of model integration. CSU has also led the development of the backend results for the economic modeling.

Engineering Process modeling:
Sub-process modeling work has focused on improved model fidelity but has been limited based on the primary thrust this quarter being model integration.

LCA results:
The foundational engineering process models have been integrated with life cycle methodology to evaluate the environmental impact of downstream processing. This quarter has continued to focus on expanding the LCA work to include TRACI impacts. This required the use of EcoINVENT software. The work was presented at the ACLCA conference held in Fort Collins, CO in October.

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.

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:
Dehghanizadeh's student visa was not granted until January 11, 2019, therefore, he was only able to participate as an SBAR Fellow as a volunteer through this reporting period. In Quarter 1, he will be on full-time status.

A Fellow recruitment challenge was identified and a plan was developed. We need to recruit SBAR Fellows who have direct research experience with SBAR and the faculty. Fellows with SBAR experience, like those recruited by Dr. Brewer in NM, can enhance lesson plan development with their in-depth knowledge of SBAR topics. To address this we will invite SBAR faculty to present during the seminar to help current Fellows make deeper connections to SBAR. We will also ask SBAR faculty to help recruit students they are working with as future Fellows to ensure that their expertise is brought into the lesson plan development process.

Initial meetings and networking has highlighted the challenges of recruiting teachers who are working with Native American youth. To address this Dr. Chavarria is doing outreach and using existing networks and connections to recruit. Since recruitment in this area can be slow moving we are exploring involving those who are working in education with Native Americans in settings outside of school to evaluate how to best connect with rural schools and tribal communities.

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 Implement Fall 2018 SBAR Fellow observation Implement Spring 2019 teacher observation	30 Nov 18 30 Nov 18 30 Apr 19
5 Fields	Design/Schedule evaluation tools, protocols and metrics for all Education activities	Fall tools developed/refined; evaluation data gathered	31 Dec 18

		Spring tools developed/refined; evaluation data gathered	31 May 19
		Summer tools developed/ refined; evaluation data gathered	31 Jul 19
		Data synthesized; evaluation report generated	31 Aug 19

New Mexico SBAR Fellows and Teacher Mentors (2018-2019):

Table 16. *The first cohort of SBAR Teachers and SBAR Fellows pairings (2018-2019 school year).*

Teachers	**Fellows**
Priscilla Fischback (Apollos MS*, AZ)	Holly Barton (Landscape Architecture, UA)
Jaime Camero (Walter Douglas ES*, AZ)	Ashton Leo (Plant Sciences, UA)
Wilma Amaro (Pueblo HS*, AZ)	Matt Katterman (Ag/Biosystems E*, UA)
Mellisa Walburn (Quail Run ES, AZ)	Arisbeth Ibarra (Environmental E, UA)
Tracie Mikesell (Mesilla Valley Leadership Academy, NM)	Meshack Audu (Chem E, NMSU)
Cathy Bradley (Sierra MS, NM)	Brian Treftz (Chem E, NMSU)
*E = Engineering; ES = Elementary School; HS = High School; MS = Middle School	

In October, Mostafa Dehghanizadeh, a new PhD student in chemical engineering who will be doing research on guayule resin separation, stepped to replace Brian Treftz as the SBAR Fellow working with Ms. Bradley.

The fellows and teachers conducted the rest of the semester of 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 December, they met with the EEO group over dinner as part of the retreat.

Recruit and Train SBAR Fellows (2019-2020):
Planning efforts were initiated for next year's SBAR Fellow cohort recruitment.

A new teacher was recruited to replace the teacher who had a medical emergency. Chemistry teacher, Wilma Amara was recruited from Pueblo H.S. Meeting were held with Chavarria and Amaro to go over the program and provide her with background information and documents. A site visit was completed to Amaro's classroom with fellow partner Matthew Katterman and staff Knox and Anderson. Amaro has been working well with her SBAR Fellow and the addition of a H.S. chemistry teacher has brought in a fresh perspective and shown the potential for higher level lesson plans at the high school level.

SBAR Fellow Seminar (Fall 2018 and Spring 2019):

Photo 11. *SBAR Fellow seminar hosted at the University of Arizona.*

The first seminar was completed and went 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 5:00-6:00 pm and the sessions alternated between staff presentations on relevant topics such as Chavarria's presentation on the 5 E Model, hands-on working on lesson plans and presentations/discussions by fellows based on their needs. Weekly seminar planning meetings took place on Thursdays at 4:00-5:00 pm to discuss presentations, arranging of speakers, assignments, and lesson design support. Some highlights from the seminar include: SBAR Fellows presented lesson plans and the revised lesson plans were posted on Schoology for teachers/Fellows to use and give feedback on, a meeting was held on Dec 8, 2018 with teachers/Fellows to debrief the semester with Chavarria, Knox, Anderson, Duncan and Sikora, a fieldtrip was taken to Bridgestone on Dec 14th with Knox and Fellows/teachers.

Both NMSU SBAR Fellows attended and participated (virtually) in the Fellows' course at UA, and with the SBAR group meetings at NMSU.

Classroom Observations:

Site visits were completed by Knox and Anderson to observe all AZ SBAR Fellows in the teachers' classrooms. The visits included debriefing lesson plans with Fellows/teachers, discussing website resource needs, and observation write-ups. The classroom visits provided valuable information on teacher/Fellow needs and allowed Knox and Anderson to observe how the teacher/Fellow pairs are working together in the classroom setting.

Design and Implement Evaluation Tools:

During the fourth quarter of 2018, a number of tasks were completed related to the evaluation of the EEO components of the SBAR project. I participated 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. During this planning process, I can begin to envision some of the specific evaluation tools and tasks that will be needed to evidence impact of the program components.

I developed and deployed follow up surveys for both teachers and fellows who participated in the summer Education PD experience. The two separate surveys were co-designed with the Education lead and team members in order to capture feedback from teachers and fellows about 1) how confident they are feeling in completing SBAR related tasks and 2) their experience during the summer 2018 PD experience, including what worked and what might be modified for the summer 2019 PD experience. Questions on the surveys related to confidence asked teachers/fellows to rate themselves on a 5-pointscale from 'strongly agree' to 'strongly disagree' on questions such as: "I feel confident in my ability to communicate SBAR related

science to middle and/or high school students", or "I feel confident in my ability to develop a lesson plan for middle and/or high school students that incorporates SBAR-related science/research with the help of my teacher/fellow partner".

An additional set of questions was included in the surveys to garner feedback as to the 2-week professional development experience in order to incorporate changes in the 2019 summer PD experience. Questions included items about the timeframe, the approach of observing during the 4-H camp, the resources made available to participants, and additional strategies that might be employed in the next iteration of the PD. Fellows were also asked if they would be interested in a 2-year fellowship to mirror the participation of the teachers.

Early challenges in implementing the surveys were my fault and related to errors with using the Qualtrics distribution system. In early October, I first attempted to send the link to each survey to the appropriate email distribution lists (i.e. teachers and graduate fellows separately.) After seeing that nobody had completed the survey by the due date, I did some trouble shooting and realized that I had incorrectly 'published' the surveys and that they had not been sent directly to the distribution lists. For the fellows, we decided that simply emailing the survey to the NMSU fellow (one of the two fellows had dropped out of the program) and having the Education team deploy the survey with the UA fellows during the weekly seminar would be the best approach. This strategy resulted in survey data from 4 of the 6 fellows who had participated in the summer PD. For the teachers, we decided to try the Qualtrics distribution again. The survey was successfully deployed in November, but none of the teachers had completed it by late November. A reminder was sent out prior to the EEO all hands meeting in December so that we could have the data to incorporate the feedback into planning, however, still none of the teachers had completed it as of the date of the planning meeting. Three of the six teachers have now completed the survey. One teacher had to leave the project due to a medical emergency, so I do not have survey data from 2 of the participating teachers. Even without full participation from teachers or fellows, the completed surveys do provide a snapshop into their early experiences with SBAR.

Fellows (4 of 6 fellows responding, one left the project) tended to show a high degree of confidence, with all fellows rating themselves as agreeing or strongly agreeing with all confidence questions. All fellows indicated a high level of confidence that they understand their role and responsibilities as an SBAR fellow. For teachers, their degree of confidence was only slightly lower. Teachers (3 of 6 responding, one left the project due to medical emergency) more often indicated that that they agreed or were neutral with the statements of confidence in completing the various tasks related to incorporating SBAR related content into their lesson plans. They seemed to indicate a higher level of confidence when working together with their graduate fellow partner. Because the teachers will now be participating for two full years, I will work with the education lead and team members to host a focus group interview with teachers as a mid-year check in. This will allow us to better understand their experience during the first semester with their 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.

Other tasks during Q4 included attending the 2-day planning meeting in Las Cruces, NM (December 5-7) to debrief on evaluation findings from year 1, receive input from the teams for year 2 needs and create preliminary evaluation plans for year 2. At the meeting, I hosted one of the sessions to report out on findings from the year one evaluation including impact data related to the summer camp activities in order to inform 2019 camp activities for both AZ and NM and areas for programmatic improvement and design iterations. I was also able to hear from the larger group about their planned activities for the coming year and hear any concerns about the project. I met individually with each EEO team to discuss the evaluation processes and their needs for the upcoming year.

Photo 12. *Discussing and synthesizing SBAR Project evaluation results submitted by SBAR Fellows and Teachers.*

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:
Planning efforts were initiated for the train-the-trainer events to be hosted in New Mexico during July 2019.

4-H Team Connection:
We were able to connect with the 4H Team during the EEO meetings at NMSU with the full Education team: Chavarria, Knox, Anderson, Duncan, Sikora and Brewer. The trip completed from Dec 5-7 included discussion of SOW and planning for summer professional development workshops at NMSU, and overall approach to the seminar/professional development.

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:
Curriculum design continued for the planned Sustainable Bioeconomy and Bioenergy (SBB) track (study concentration area) for the existing Professional Science Master's in Applied Biosciences (PSM-ABS) Graduate Interdisciplinary Program (GIDP) for MS students. Lists of existing classes offered at the UA were scrutinized for inclusion into the list of elective classes for the Science Module (15 credit hours total). Suitability of the previously compiled list of elective classes for the Professional Preparation Module (12 credit hours) is being investigated. Harmonization of the new track with the existing 5 other tracks of the PSM-ABS GIDP is important to maintain program consistency.

EXTENSION & OUTREACH

Project Coordination: Dr. O. John Idowu (New Mexico State University) continues to serve as the lead for the Extension & Outreach working team; and he continues to serve as the lead for when the Education and Extension & Outreach teams come together for monthly discussions.

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:
No issues or risks were identified this reporting period.

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 Visit guar farmers' fields to identify future research needs	31 Aug 19 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 Train graduate students in guar agronomic management	31 Aug 19 31 Aug 19
3 Angadi	Guar deficit irrigation study	Gather/analyze data; develop peer-reviewed paper on guar deficit irrigation management Analyze/present results at regional and national meetings	31 Aug 19 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	31 Aug 19 31 Aug 19

		Gather data/synthesize results (toward generating an Extension bulletin) Generate first year trial summary (published on SBAR website)	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 Generate peer-reviewed manuscript using AZ survey results	31 Mar 19 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:

During 2019 field season special guar field day will be arranged. In addition, field tour will be arranged for interested farmers from the region. We will also visit some of the guar farms nearby and interact with experience farmers. Understanding research needs of guar farmers in the region will be ascertained. We have visited Guar Resources and interacted with agronomists about guar production in the region. Hope to continue our interaction for mutual benefit. During the first week of December in SBAR-EEO meeting at Las Cruces, NM, I accepted to conduct a guar demonstration trial on farmers' field near Clovis, NM. I will be contacting Guar Resources to secure some seeds for the demonstration.

Photo 13. *Field tour hosted at the Agricultural Science Center in 2018, Clovis New Mexico.*

After presenting an invited talk in Indian Society of Agronomy meeting, I traveled to Jodhpur, Rajastan. The region is the major producer and exporter of guar gum in the world. Interacted with a farmer and researcher. Also visited a processing plant and interacted with owner and general manager of the plant. Discussed about factor limiting guar production in the area. Not able to increase guar yield, is one of the major issues limiting guar industry in the region.

Guar Phosphorus Rhizobium Study:

The trial on plant growth promoting microbes/rhizobium mix (Micronoc) from Sono Ag (Brownfield Texas) and P fertilization has been harvested. Samples are being processed. Data will be analyzed and interpreted. Data will be shared with Dr. John Idowu to use it with data from other two locations.

Guar Deficit Irrigation Study:

Data collection for deficit irrigation study implemented at the Agricultural Science Center in Clovis, New Mexico is on-going (Photo 13). Results of deficit irrigation trial from 2018 will be used in the field days and regional workshop presentations. Alternative crop that uses less water is of great importance in sustaining Ogallala Aquifer. Soil water extraction and its role in yield formation will also be assessed.

Photo 14. *Field deficit irrigation sampling in Clovis, New Mexico.*

Produce Guayule Newsletter Articles:
Two newsletter articles are under development and will be produced for the Central Arizona Extension weekly newsletter by August 2019.

Design and Implement Evaluation Tools:
I had the opportunity to meet the new extension lead for AZ (Blase Evancho) and to meet with the entire UA/NMSU extension team to go over the current evaluation questions for extension and see if they were still a fit with their efforts. We made some revisions to the evaluation questions, based on their activities, and discussed ways to document and evaluate their efforts. For the extension group, I am drafting a tool that is intended to better capture information about their outreach efforts and reach. The draft tool will be sent to the extension team next week for their comments and any desired revisions will be made. The goal is to be able to 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.)

Since the December meeting, I have also met individually with Jerry Lopez to discuss the 4-H/outreach efforts in Tucson for summer 2019. Once he is further along with his plan, we can begin to decide the types of evaluation tools that will be best suited to the activities. Another issue that was discussed at length as a group involved the SBAR website and concerns that it may not be responsive to some of the EEO stakeholder's needs. As a follow up, I met with Alix to discuss some possible solutions. During the next quarter, one of my tasks is to work with each group on ways that they can customize some of the content and web formatting to better meet their needs. Other tasks for the coming quarter include further refining the evaluation plan for summer 2019 and design additional tools as necessary to be implemented during 4-H camps and Train the Trainers workshops and teacher/fellow PD activities.

Showcase Guar as Potential Crop in New Mexico:
A workshop focused on guar was hosted at the National Immigrant Farming Initiative, where we provided information and answered queries of growers/clientele about guar cultivation and related topics. We also continue to conduct on-station demonstration fields for guar in New Mexico. During this reporting period, SBAR representatives served on the advisory committee of the Western Sustainable Agricultural Research and Education (WSARE) and helped plan for the New Mexico Sustainable Agricultural Conference, held on December 12th that included poster presentations on guar.

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.

Travel to Conferences:
A SBAR informational table was displayed during the New Mexico Sustainable Agriculture Conference held in Las Cruces, New Mexico on December 12th. About 100 people had the opportunity to view SBAR materials and some took the handouts and publications presented on the table.

Photo 15. *SBAR informational table at the New Mexico Sustainable Agriculture Conference, Las Cruces, New Mexico.*

Distribute Needs Assessment to farmers in New Mexico:
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.

Working directly with county extension faculty to conduct the needs assessments is taking more time than anticipated. However, the PI feels their participation in the process is important to have their buy-in and support for future producer workshops and educational efforts.

Establish Guayule and Guar Trials in New Mexico:
The on-station guar trial at NMSU Los Lunas Agriculture Science Center (ASC) was harvested. The harvest materials are currently being processed and the results are being analyzed. Some growers in Valencia County, New Mexico who live close to Los Lunas ASC paid visits to the guar trial to observe the growth characteristics. One of the growers indicated interest in customizing his pinto bean harvester for guar harvest in the future if he decides to grow the crop.

***Photo 16**. Root structure of a guar plant.*

Pruitt (graduate student) started working on mycorrhizal colonization of guar roots as affected by different organic amendments and biorational products. She is currently designing experiments necessary for this study.

A guayule cold tolerance study was initiated at Leyendecker Plant Science Center in collaboration with scientists from Bridgestone. The trial was established on October 5, 2018. The trial is still in progress.

Design and Implement Extension & Outreach Evaluation:
Evaluation of the Extension and Outreach activities is still currently under development, and is slightly behind schedule.

Stakeholder Needs Assessment in Arizona:
Over the last reporting period, the research-driven Extension team has focused on the completion of the Arizona needs assessment survey to better understand grower stakeholders and aid in UA Cooperative Extension's ability to develop useful tools and resources to meet their needs. As mentioned in the previous report, the Extension team in New Mexico and initiated their needs assessment survey on Guar during Q3. During Q1 of 2019, the Arizona Extension team plans to work to support the New Mexico Extension team on evaluation of data and creation of outreach materials mirroring the Arizona outreach materials as well as comparison of collected stakeholder data.

Efforts over the next reporting period will include additional recruitment of needs assessment responses from grower partners and stakeholders in New Mexico. The anticipated date of completion of the grower needs assessment survey for Arizona is December 2018 with a target completion data in New Mexico of June 2019.

Cost-Production Budgets for Current Cropping Systems:
This is not the current focus as we are working on an integrated model with the System Performance and Sustainability team. However, we will be developing estimated crop adoption estimates for guayule in Arizona; estimates are available for Maricopa, Pima and Pinal counties (central Arizona).

Dissemination of Guayule and Guar Economic Information through Extension Meetings:
Economic information related to guayule and guar production is still being formalized and will be shared with the extension outreach group as it becomes available.

Input Tool for Potential Adoption Rates in Arizona and New Mexico:
Continue to refine the Arizona and New Mexico whole farm scenarios. These scenarios are near finalization for the baseline whole farm analysis and will be prepared for a presentation to complement 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:
Two meetings have been hosted with Native American farming communities in Arizona to discuss their interest and knowledge of guayule production. Initial contact has been made with two Native American farming communities to discuss the potential of guayule production on their land. Both are interested and discussions have commenced about the requirements for guayule production. Teegerstrom (University of Arizona) and Dierig (Bridgestone) were also involved in these conversations and

Photo 17. *Community meeting hosted in Arizona.*

are working toward installing acreage with one community as early as 2019. Meetings with Native American communities will continue throughout the year.

Initial presentation has been created that highlights the history of guayule, current research that is ongoing and the market outlook for guayule production. This presentation will be given at grower meetings in January in targeted areas for guayule production in the future.

Needs Assessment survey data continues to be collected in Arizona, and as relationships are strengthened with the Native American communities, we will request their input via the survey tool.

Grower Workshops in New Mexico:
Information on guar has been presented at multiple Field Meetings held at the NMSU Fabian Garcia Plant Science Center, Las Cruces, New Mexico.

Photo 18. *Sharing information about guar at a Field Meeting, Fabian Garcia Plant Science Center, Las Cruces, New Mexico.*

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:
The 4-H Team held 6 planning meetings total; 5 teleconferences and 1 in-person meeting with members from UA and NMSU. We began 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. G. Lopez and Duncan attended UA-Research Team meetings and Rodriguez-Uribe is collaborating with NMSU researchers to gain a better understanding of project research areas and how to best incorporate the research and their undergraduate and graduate students into the summer camp. Rodriguez-Uribe and Brewer have both developed separate activities for the 3 day train the trainer camp that is scheduled to take place in New Mexico in July 2019.

4-H Biofuel Activities to Youth:
G. Lopez and UA undergraduate students, J. Lopez (AmeriCorp member) and S. Perez who are part of Lopez's outreach and research team, met once with the chemistry club at Pueblo High School to introduce the Biofuel activities but could not schedule a follow up due to high school events. We plan to continue to collaborate with High School Chemistry Teacher at Pueblo High School. Gutierrez is working with the NM state 4-H office to host some biofuel activities.

Expand 4-H Biofuel Camp:
G. Lopez, J. Lopez, and Perez 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. Due to high school scheduling events we were not able to meet with them again. G. Lopez has reached out to the 4-H Extension Program to advertise the program with 4-H Agents. Gutierrez is working with the NM 4-H state office to recruit agents and volunteers for the train the trainer workshop in July 2019.

Refine Evaluation Instrument for the BYOE Program:
G. Lopez, Cabrera, and 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:
The extension team has developed and revised the resources for SBAR Arizona-based faculty. We plan to provide these resource documents to the potential faculty mentors before the self-identified deadline of 02/28/2019.

Project Puente Internship Recruitment:
During this reporting period the Arizona Extension team worked alongside Central Arizona College to begin 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:
We have not started this process yet. Once SBAR faculty have been identified, our team will work with them to confirm their understanding of the roles and responsibilities of participation in *Project Puente* to meet project deliverables.

PRODUCTS GENERATED.
September 2017 – December 2018

PUBLICATIONS, CONFERENCE PAPERS AND PRESENTATIONS

Publications

None this reporting period.

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.; and 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.;** and 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. **Brewer, C.E. 2018**. *Pairing biomass residues with conversion technologies*. Advanced Bioeconomy Leadership Conference, Washington, D.C. 28 February.
5. **Brewer, C.E. 2018**. *Polymerization and guar gum bubbles*. Outreach event activity. New Mexico 4-H State Conference. 11 July.
6. **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.
7. **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.
8. **Brown, K.S., Neilson, J.W. 2018.** *Microbial contributions*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. April.
9. **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.
10. **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.
11. **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.

12. **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.
13. **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.
14. **El-Shikha, D. 2018.** *Update – Guayule irrigation experiments at Maricopa Agricultural Center*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 12 September.
15. **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]
16. **Evancho, B. 2018.** *Guayule Fuels the Future*. IES – Energy Talks Seminar, Sky Bar, Tucson, Arizona. 9 October.
17. **Fan, N. 2018.** *Review on Optimization Methods for Biomass Supply Chain*. SBAR UA Research Team Seminar. University of Arizona, Tucson, Arizona. 28 November.
18. **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.
19. **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.
20. **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.
21. **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.
22. **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.
23. **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]
24. **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.
25. **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.
26. **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.

27. **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.
28. **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.
29. **Grover, K. 2018.** *Sustainable agriculture and guar production in New Mexico*. New Mexico State 4-H Conference, Las Cruces, New Mexico. 10 July.
30. **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.
31. **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.
32. **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.
33. **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.
34. **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.
35. **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.
36. **Hoare, D.M. 2018.** *Irrigation Sensors and the WINDS Model.* SBAR UA Research Team Seminar Series, Tucson, Arizona. 26 September.
37. **Idowu, O.J. 2018.** *Introduction to the SBAR Project*. Las Cruces, New Mexico. 6 Feb.
38. **Idowu, O.J. 2018.** *Sustainable Bio-economy for Arid Regions: Update*. Extension Field Day, Clovis, New Mexico. 9 August.
39. **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.
40. **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.
41. **Lopez, E.; Fox, S.; Brewer, C.E. 2018.** *GK-12 Lesson Documentation Spreadsheet*. American Institute of Chemical Engineers Annual Meeting, Pittsburg, Pennsylvania. 29 October.
42. **Maqsood, H. 2018.** *Guar Crop Coefficient Development for New Mexico Environments*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 7 November.
43. **McCloskey, W. 2018.** *Weed Trial Results for Guayule*. SBAR UA Research Team Seminar. University of Arizona. Tucson, Arizona. 14 November.

44. **McMahan, C. 2018.** *Flowering Reduction in Guayule*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 19 September.
45. **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.
46. **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.
47. **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]
48. **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]
49. 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]
50. **Niu, D., 2018.** *Partial cloning of APETALA1 (AP1) gene from guayule*. cDNA Lab Seminar, USDA-ARS Western Regional Research Laboratory. 28 March.
51. **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]
52. **Ogden, K. 2017.** *Sustainable Bioeconomy for Arid Regions*. Biomass Research and Development Technical Advisory Board Meeting. 15 November. [invited speaker]
53. **Ogden, K. 2018.** *Sustainable Bio-economy for Arid Regions*. Southwest Indian Agricultural Association. Laughlin, Nevada. 16-18 January.
54. **Ogden, K. 2018.** *Potential of the Bioproducts and Biofuels Economy*. AIChE Annual Meeting, Pittsburg, Pennsylvania. October [invited speaker]
55. **Ogden, K., White, R., Brewer, C.E. 2018.** *Public Private Partnerships*. ABLC Conference. Washington, D.C. 27-28 February.
56. **Rock, C., Brassill, N. 2018.** *Importance of Cooperative Extension in University Research*. University of Arizona, Tucson, Arizona. 14 March.
57. **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]
58. **Singh, J**.*; **Angadi, S.V.; Begna, S. 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]
59. **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]
60. **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.

61. **Sun, O. 2018.** *GIS-Based Two-stage Stochastic Facility Location Considering Planting Plan Uncertainty*. INFORMS Annual Meeting, Phoenix, Arizona. 5 November.
62. **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.
63. **Sun, O.; Fan, N. 2018.** *Harvest scheduling*. SBAR Logistics Team Group Meeting. (webinar) New Mexico State University. Las Cruces, New Mexico. 5 February.
64. **Sun, O.; Fan, N. 2018.** *Optimization of feedstock logistics*. SBAR UA Research Seminar. University of Arizona. Tucson, Arizona. 14 February.
65. **Sun, O.; Fan, N. 2018.** *Optimally locating biorefineries*. SBAR Sustainability Working Group Seminar. (webinar) Colorado State University. Lakewood, Colorado. 8 March.
66. **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, CO, October.
67. **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, CO, November.
68. **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.
69. **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.
70. **Waller, P.** 2018. *WINDS Model: A status report and connection to SBAR research*. SBAR UA Research Team Seminar Series, Tucson, Arizona. 10 October.
71. **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	629	195	***824***
Females	342	21	***363***
Race/Ethnicity			
Hispanic	165	8	***173***
Asian	84	22	***106***
Native American	174	0	***174***
African American	38	3	***41***
Anglo/White	510	183	***693***

Audience Cumulative Total *(when captured)****: 1,187 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. **Grover, K. 2018**. Guar – A potential alternative crop in New Mexico. Two page informational handout. January.
6. **Kiela, C. 2018.** Guayule. SBAR Project two-page fact sheet. March.
7. **Kiela, C. 2018.** Guar. SBAR Project two-page fact sheet. April.
8. **Kiela, C. 2018.** History of Guayule. SBAR Project two-page fact sheet. April.
9. **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.

→*Total Reach via Tabling Events and Workshops (when captured):* ***1,557 participants***

PARTICIPANTS AND COLLABORATING ORGANIZATIONS. September 2017 – December 2018

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*
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
Mira Theilmann	Undergrad Student	Feedstock Development & Production
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		
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: ***42***
Total Postdoctoral Researchers: ***6***
Total Graduate Students: ***33***
Total Undergraduate Students: ***51***

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 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	USDA – Agricultural Research Service, Western Regional Research Center - Chemistry (Bioproducts) - Plant Genetics
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
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:	