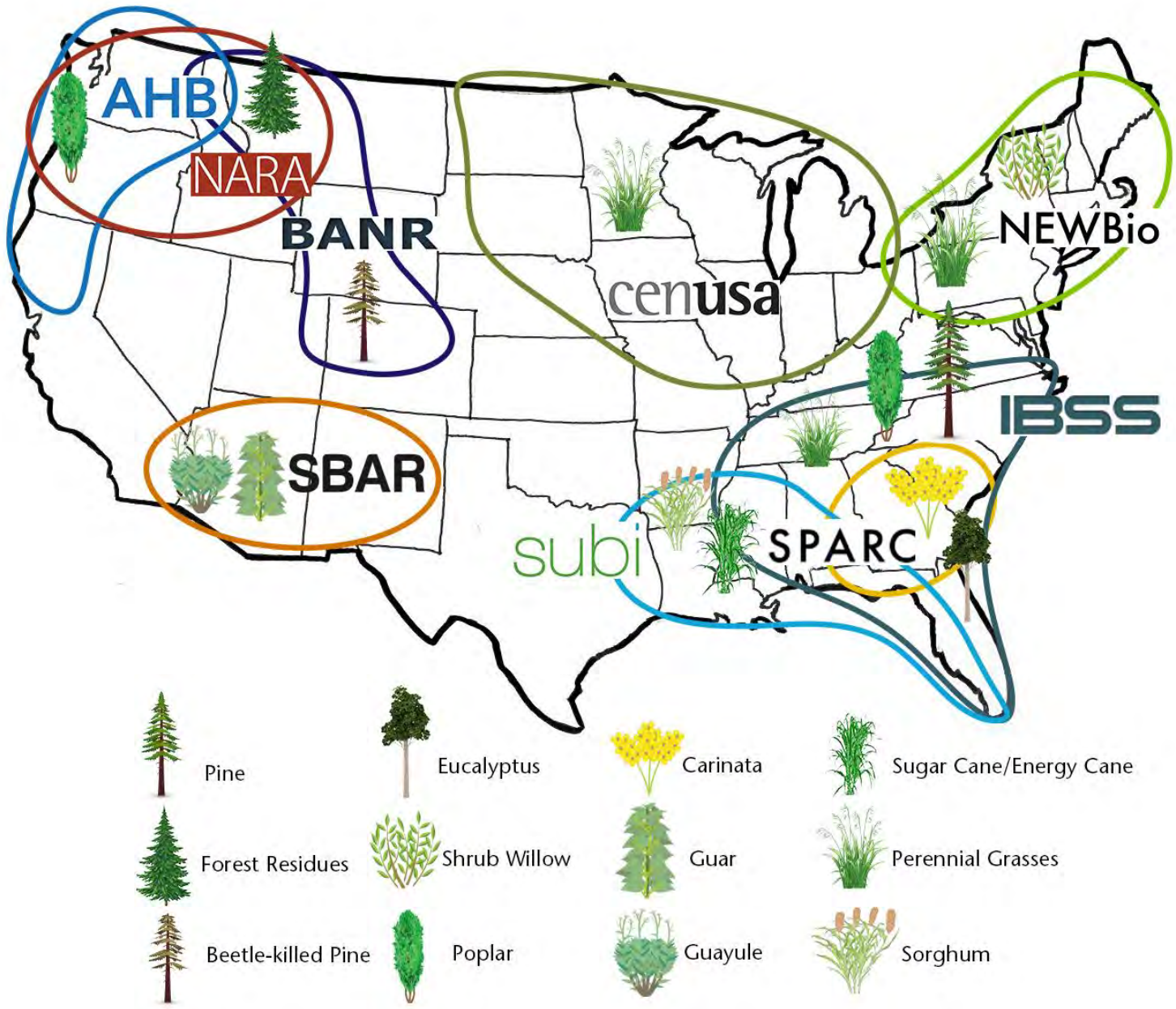
SBAR OVERVIEW 2021

Kimberly Ogden
Alix Rogstad



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SBAR

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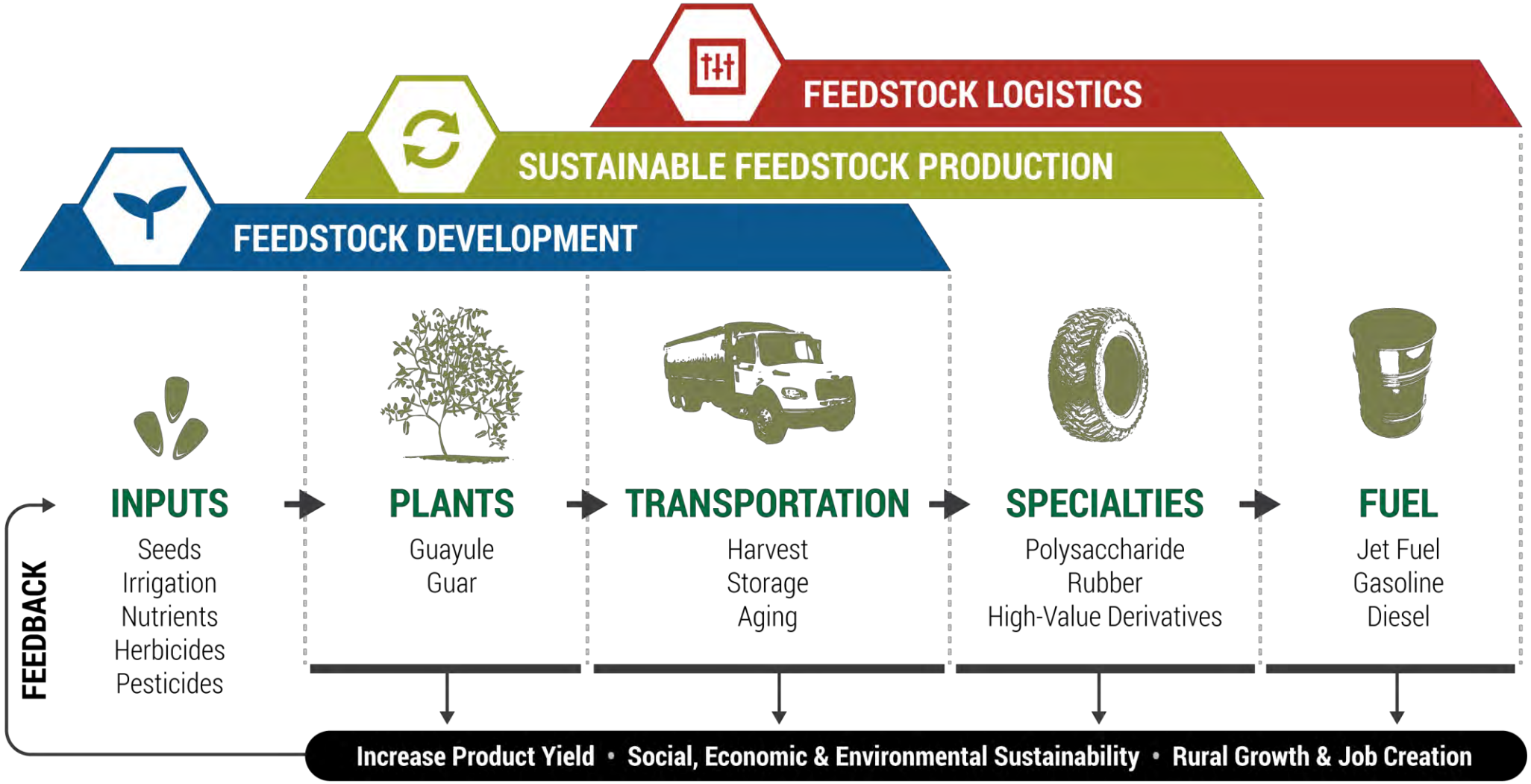
Sustainable Bioeconomy for Arid Regions (SBAR)



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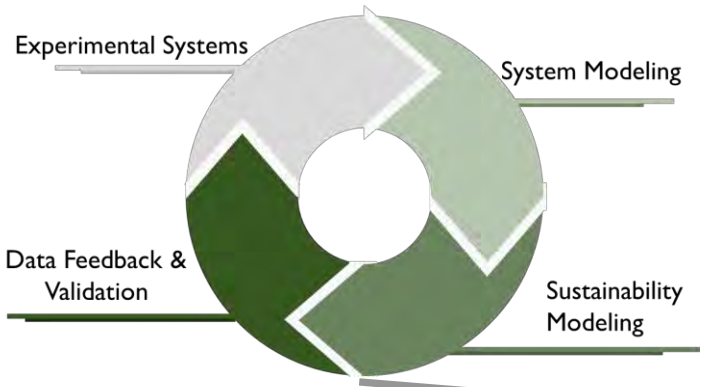
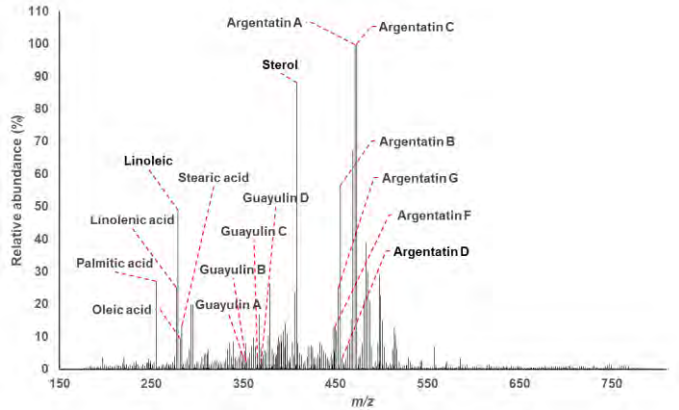
SBAR Today

System Performance Sustainability



Feedstock Development

Characterization Coproducts



Extension, Education and Outreach

Stage	Teachers
1-Educator Professional Learning	-Summer PD -Recruit from urban and rural -Build Foundational Knowledge
2-Classroom Partnerships	-Translate PD experiences to classroom – make content accessible, fun, interactive -Incorporate topics in curriculum -Knowledge of age group

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SBAR Personnel

Total Individuals Involved – 240

- Total Key Collaborators/Co-PIs - 26
- Total LEADS – 10
- Total Advisors since Inception (Members of Advisory Board) – 16 (Active now: 9)

- Total Post-docs – 12
- Total Graduate Students – 53
- Total Undergraduate Students – 91
- Total SBAR Fellows – 15
- Total SBAR Interns – 6

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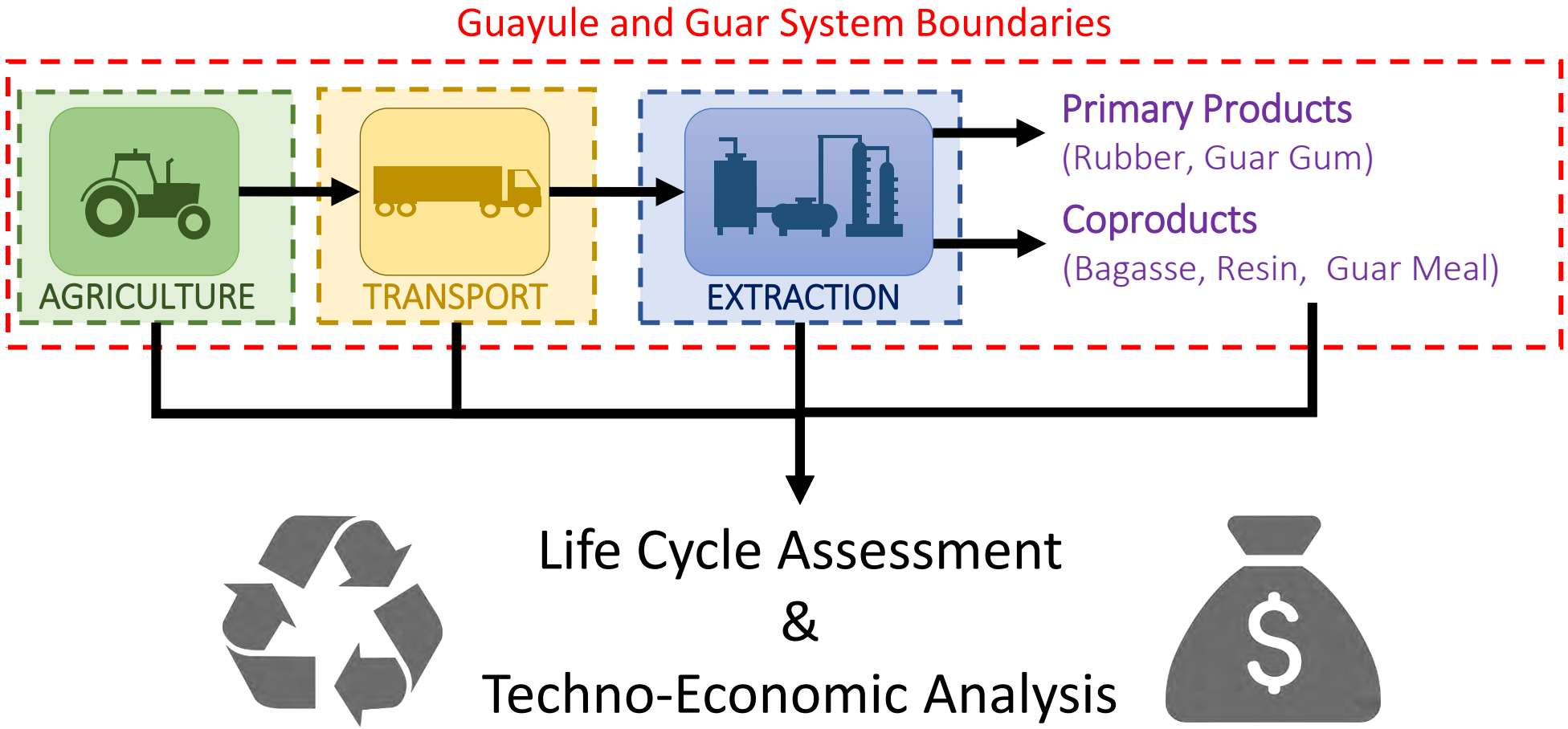
SYSTEM PERFORMANCE AND SUSTAINABILITY

Jason Quinn – Lead
Catherine Brewer, Neng Fan, Paul Gutierrez, Amy Landis,
Maryfrances Miller, Clark Seavert, Trent Teegerstrom

Integrated Models for Guar Gum and Guayule Rubber Production



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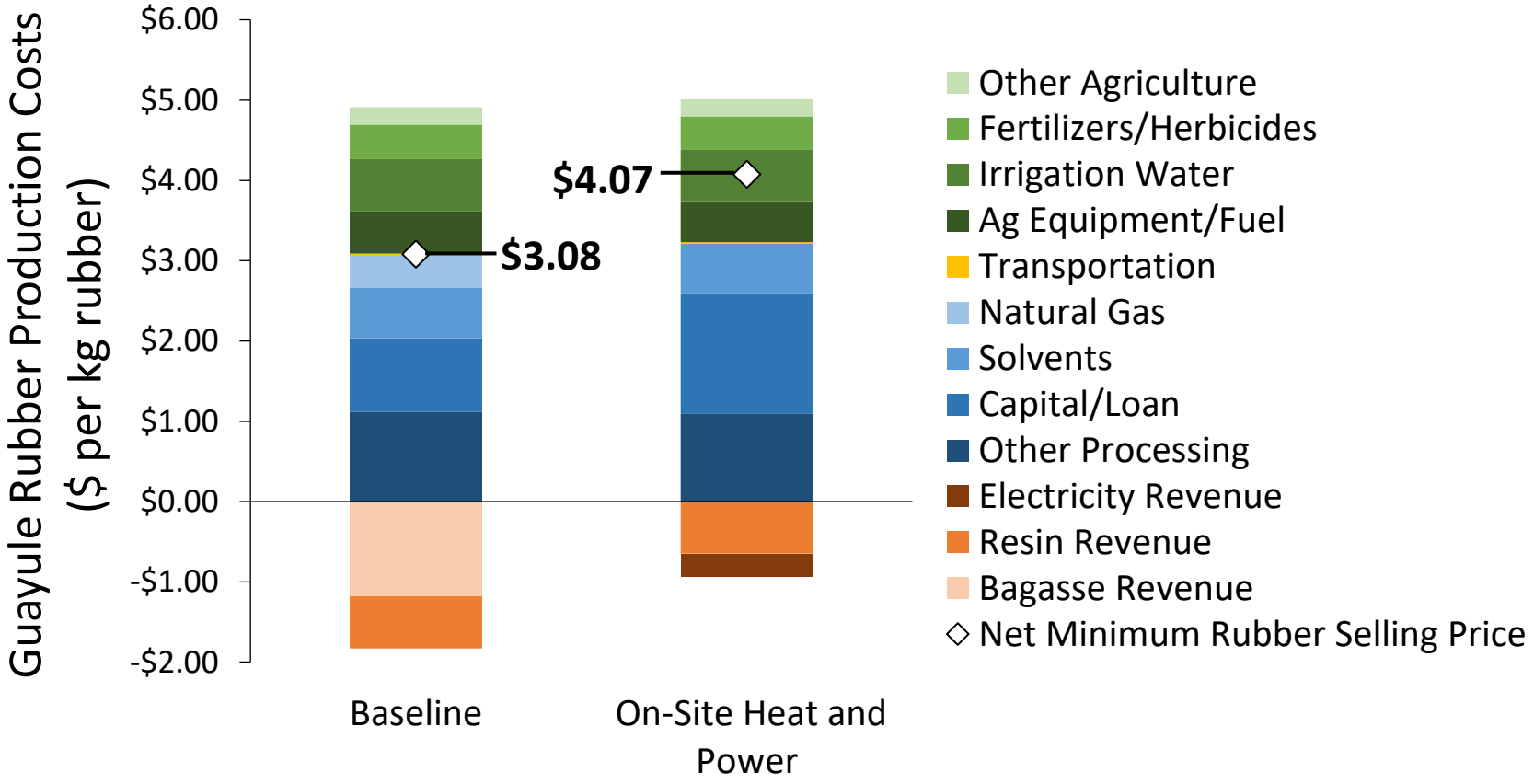
Baseline Guayule TEA & LCA Model



Assumes bagasse at $0.10/kg and resin at $1/kg

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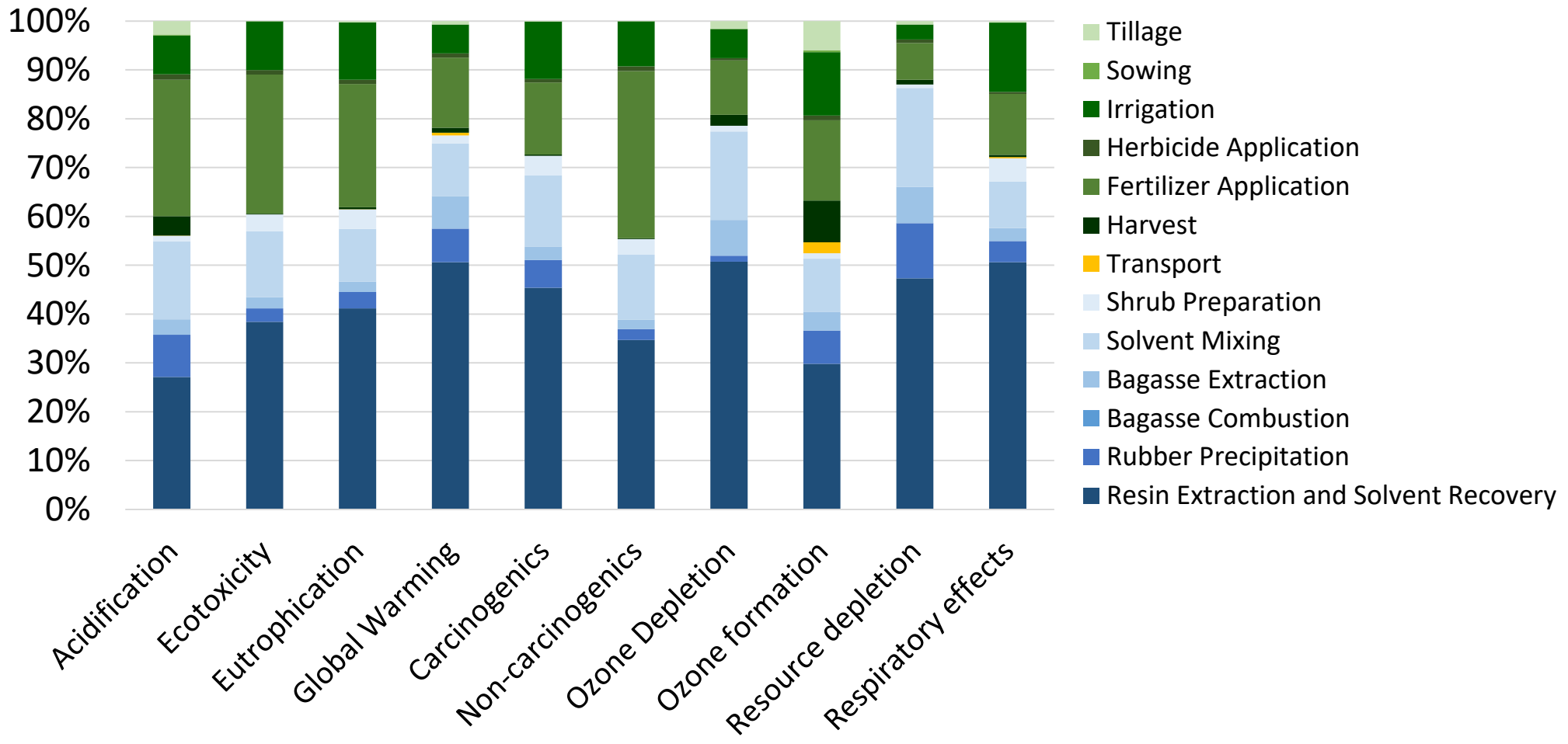

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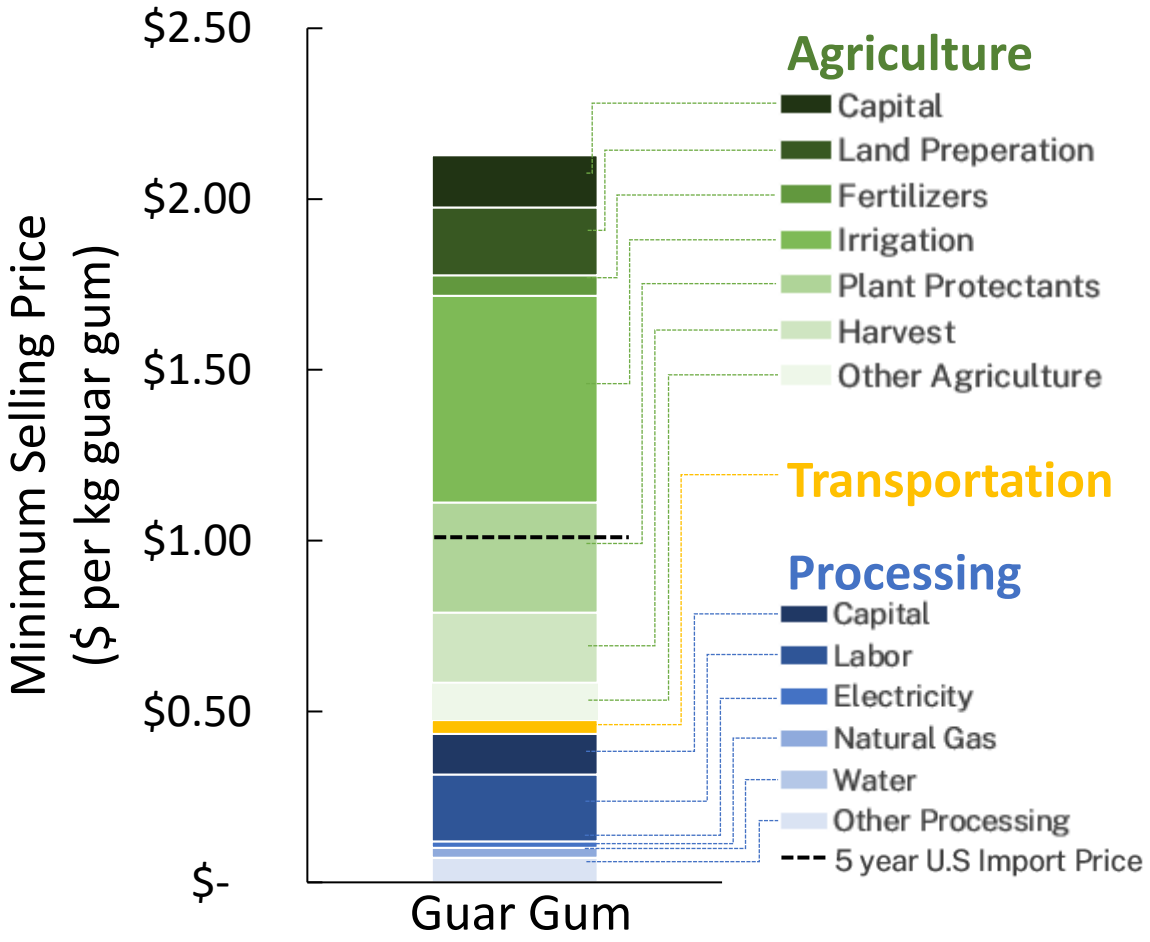
Baseline Guar TEA & LCA Model



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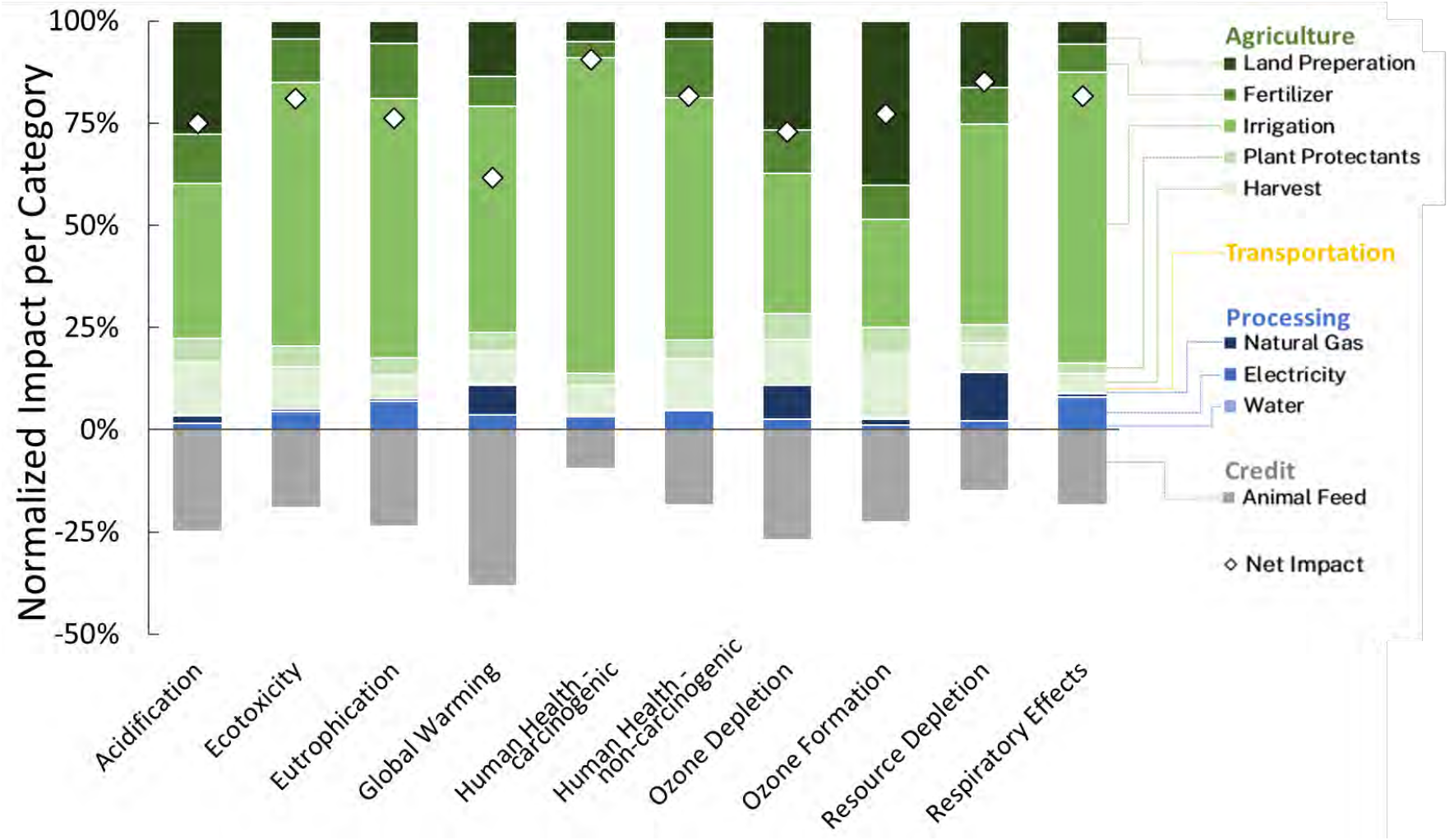
Baseline Guar TEA & LCA Model



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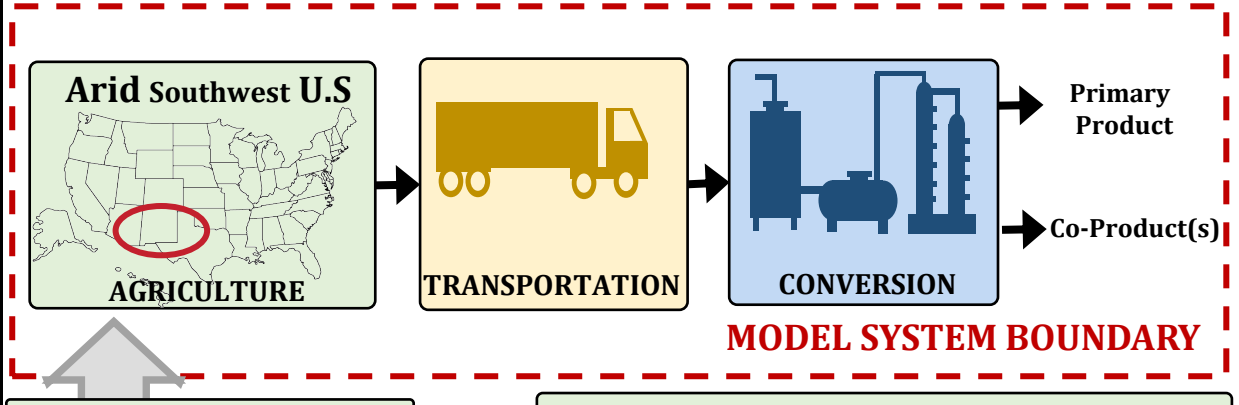
Guayule & Guar Field Data Integration and Uncertainty Analysis

Field Trial Data Collection & Integration

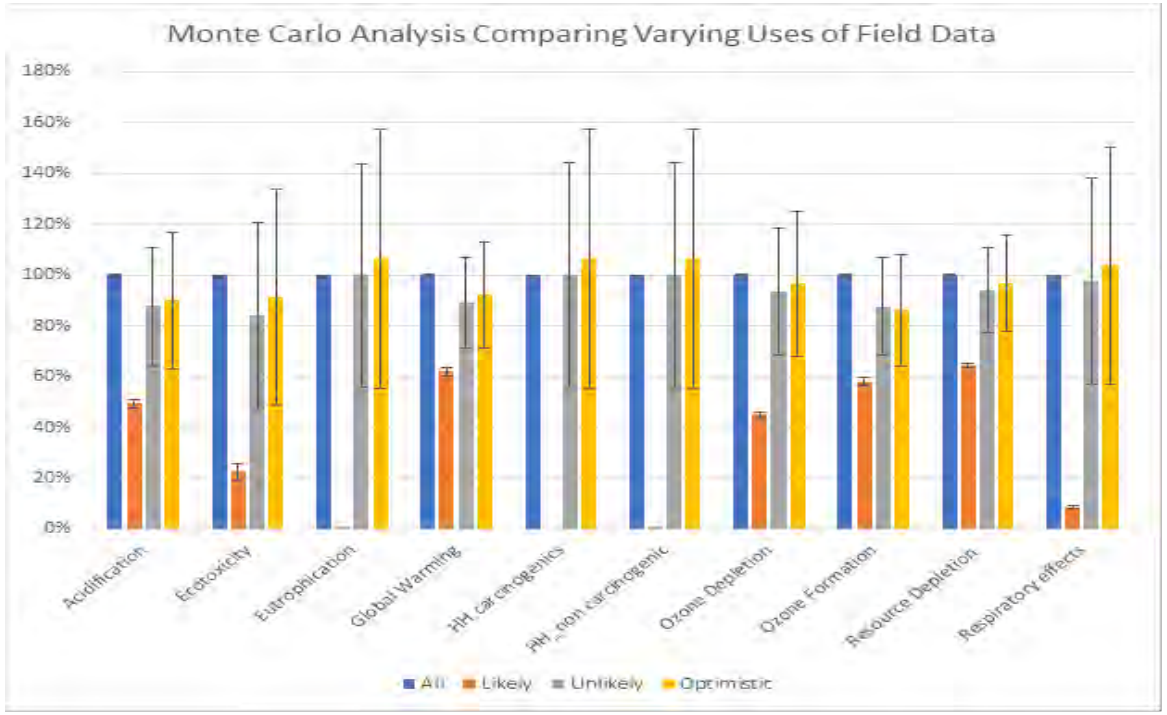


Integrating data from field trials into model

- Help you understand environmental and economic hotspots (& how to improve)
- Model is more representative of actual practice in US & Higher fidelity model

- Guayule - field data integrated through LCA & TEA
- Guar ~20% of data integrated through LCA & TEA
- Use model to run scenarios of interest
  - Irrigation
  - Soil or Nitrogen

Uncertainty & Variability Analysis of Guayule Field Data



- Irrigation is still the main impact
- Optimistic scenario - largest yield and impact
- Likely scenario as the new baseline

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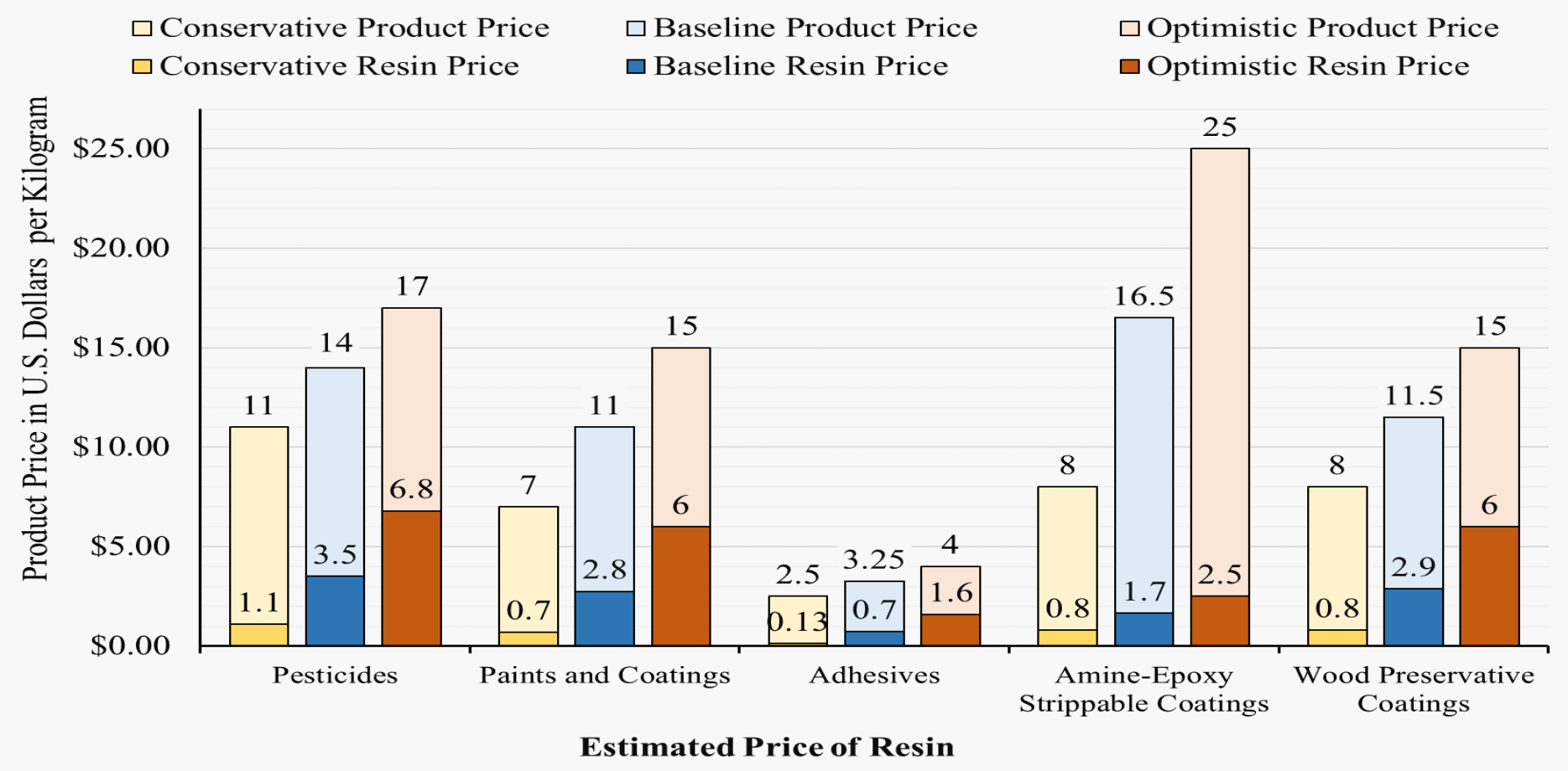
Preliminary Analysis for Coproducts

Estimated resin value from <$1 to >$6 per kg



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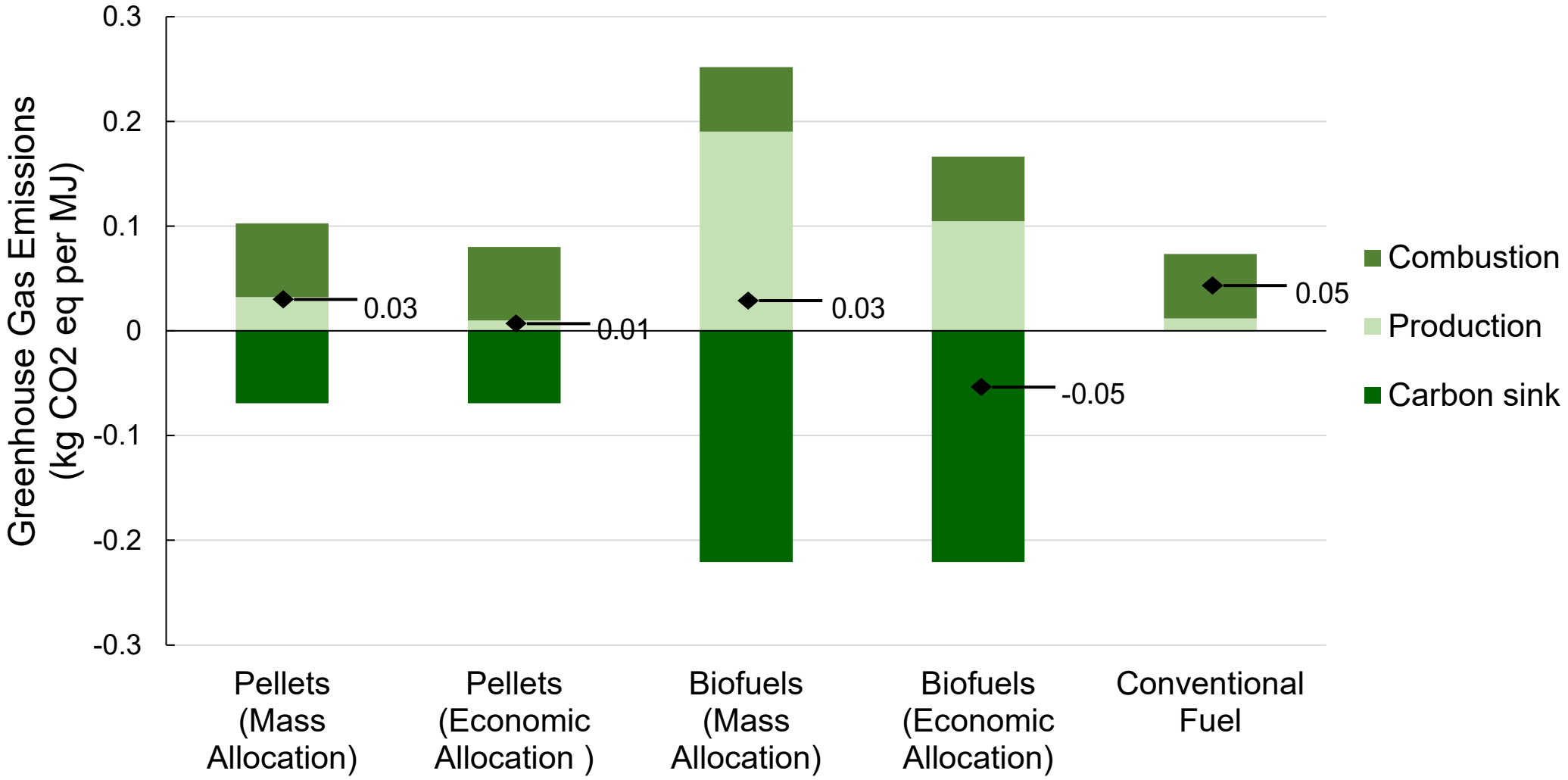
Potential for GHG Reduction



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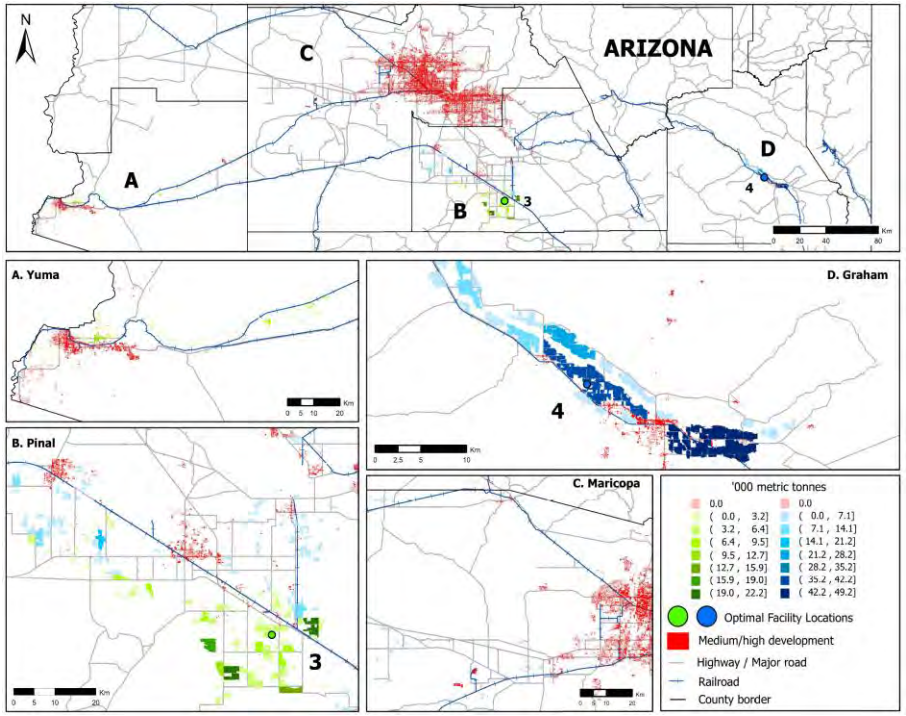
Optimization for Feedstock Logistics and Transportation

- Guayule and guar optimal production planning and machinery scheduling for semi-arid farms
- Optimal design of guayule and guar supply chains for the American Southwest with the consideration of economic, environmental and social impacts
- Transportation cost analysis for both feedstocks
- Integration of the input parameters for the optimization modules of guayule and guar supply chain – run scenarios of interest (water, transport, probability of adoption, production rates)



Yearly expected guayule productivity for two optimal processing facility locations

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Tool for Growers – Economics of Guayule and Guar

- Assess research data to determine if growing guar and guayule can be more profitable than current cropping systems, based on representative case study farms in Arizona and New Mexico.
- Measure the state economic impacts as guar and guayule are adopted into current cropping systems.

Economic Impact Indicators of 25,000 acres of guar in New Mexico

Impact	Number of Employment	Labor income (million)	Value-added (million)	Output (million)
Direct	**32**	$3.23	$4.09	**$6.12**
Indirect	**14**	$0.50	$0.79	**$1.51**
Induced	**19**	$0.78	$1.50	**$2.69**
Total	**65**	$4.51	$6.38	**$10.32**

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Tool for Growers – Economics of Guayule and Guar

- Calculates costs and returns to produce guar, guayule, and several annual and perennial crops in AZ and NM on a whole farm basis
- Establishes equitable leases for annual cash rent, crop share, and flexible cash rents
- Calculates breakeven prices and yields for all crops in a system
- Generates whole farm net returns, inputs, and resources used before and after adoption

Southern Arizona: Total Net Returns and Inputs, Before and After Adoption

Resources and Inputs	Before	After	Change	% (+/-)
Total Farm Net Returns ($)	$345,076	$325,421	-$19,656	-5.70%
Irrigation Water Applied, AF	7,125	6,875	-250	-3.51%
Crop Seeds ($)	$152,269	$125,168	-$27,101	-17.80%
Fertilizers ($)	$83,184	$83,283	$99	0.12%
Pesticides ($)	$42,893	$43,847	$954	2.22%
Power Units: Labor (hours)	7,361	6,636	-725	-9.85%
All Other Labor (hours)	5,040	4,790	-250	-4.96%
Custom Hire Operations ($)	$0	$3,750	$3,750	0.00%
Machinery Fuel, Maint. & Repairs ($)	$143,406	$122,043	-$21,362	-14.90%
Machinery Fixed Costs ($)	$117,408	$118,027	$619	0.53%

FEED STOCK DEVELOPMENT

Dennis Ray – Lead
Hussein Abdel-Haleem, Sangu Angadi, David Dierig, Kulbhushan Grover, Omar Holguin, Bill McCloskey, Colleen McMahan, Julie Neilson, Kim Ogden, Peter Waller

Guayule Regional Field Trials

- Direct Seeding trial of 45 diverse guayule germplasm lines
- Two soil types (clay at Eloy; sandy clay loam at Maricopa)
- Measure biomass production, rubber yield, resin yield
- Goal – define optimum plant characteristics to economically produce and process guayule – yield higher at Eloy
- 6 to 10 excellent lines
  - *High **rubber** and resin*
  - *Stable yields at both locations*
  - *Moderate biomass (decrease water, harvest, transportation costs)*

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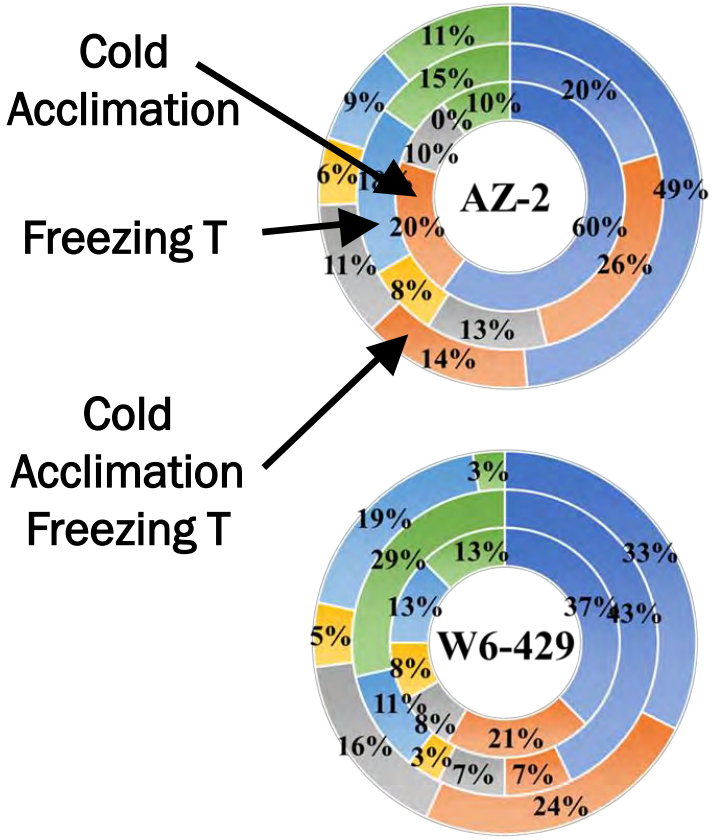
Guayule Winter Strains

Metabolite analysis on guayule winter 2020/2021 survivors.



- Carbohydrate metabolism
- Amino acids biosynthesis & metabolism
- Fatty acids & lipid metabolism
- Nucleotides
- Secondary metabolites
- Other

- 200 unique metabolic biomarkers polyploid and diploid
- Carbohydrate metabolism crucial

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Preemergence Guayule Weed Management

- 6 Herbicides - Prowl H_2O, Sonalan, Dual, Warrant, Spartan, and Prefar PREE
- Two soils.
- Tested PREE incorporation methods
- Range 0.5X to 2X normal field rate (X).
- Irrigation - furrow and sprinkler fields.
- Developed study data files for chemical company cooperators (BASF, Bayer, FMC, Gowan & Syngenta)
- Started work to obtain 24c SLN PREE herbicide labels for guayule.

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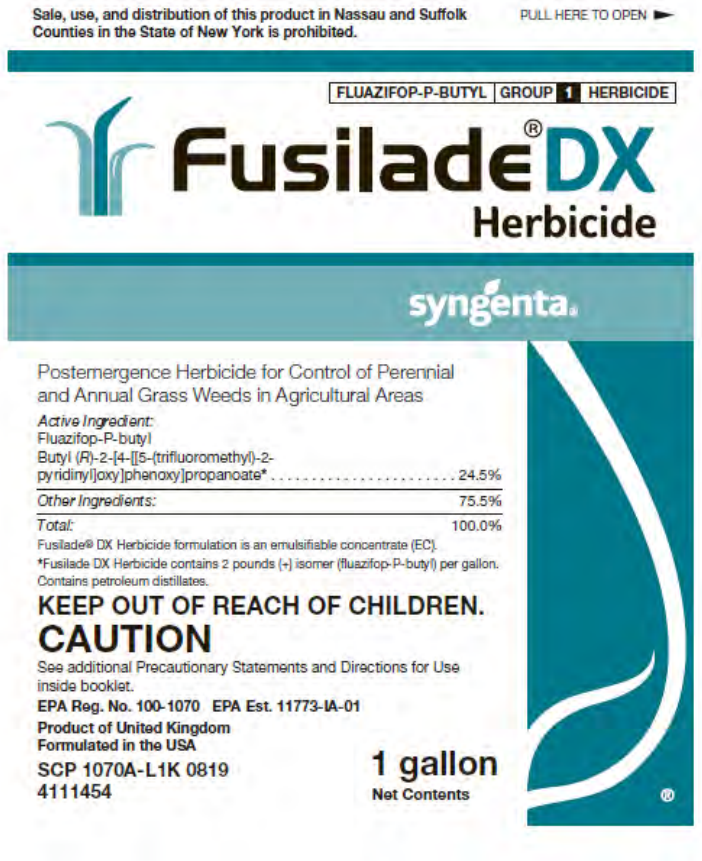
Postemergence Guayule Weed Management

- Screened postemergence (POST) herbicides
- Tolerance data:
  - *stand counts*
  - *visual injury ratings*
  - *canopy development from nadir photographs, and*
  - *guayule canopy height.*
- Grass herbicides, Fusilade, Poast, & Select were safe to use on guayule seedlings.
- Aim safe on 4-leaf and larger seedlings - some injury.
- Developed study data files for chemical company cooperators (BASF, FMC, Syngenta & Valent).
- Began studies on guayule tolerance to post-directed sprays at the base of the guayule canopy



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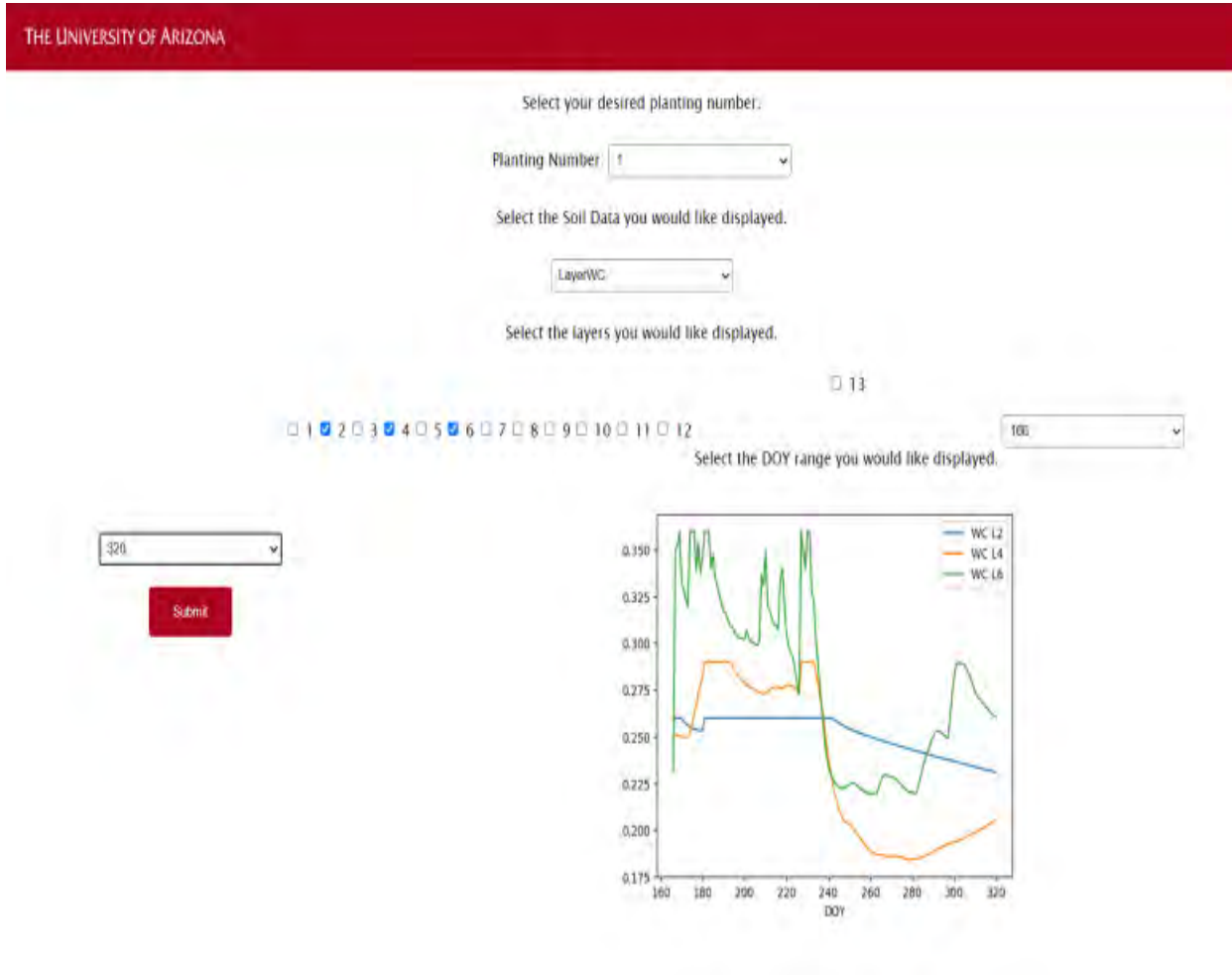
Irrigation – WINDS model and tool

- Validated with data
- The WINDS model was converted to python and MySQL.
- Online – Fall 2021
- Irrigation experiments quantified the relationship between water application rate, and guayule biomass growth, and resin and rubber productivity.



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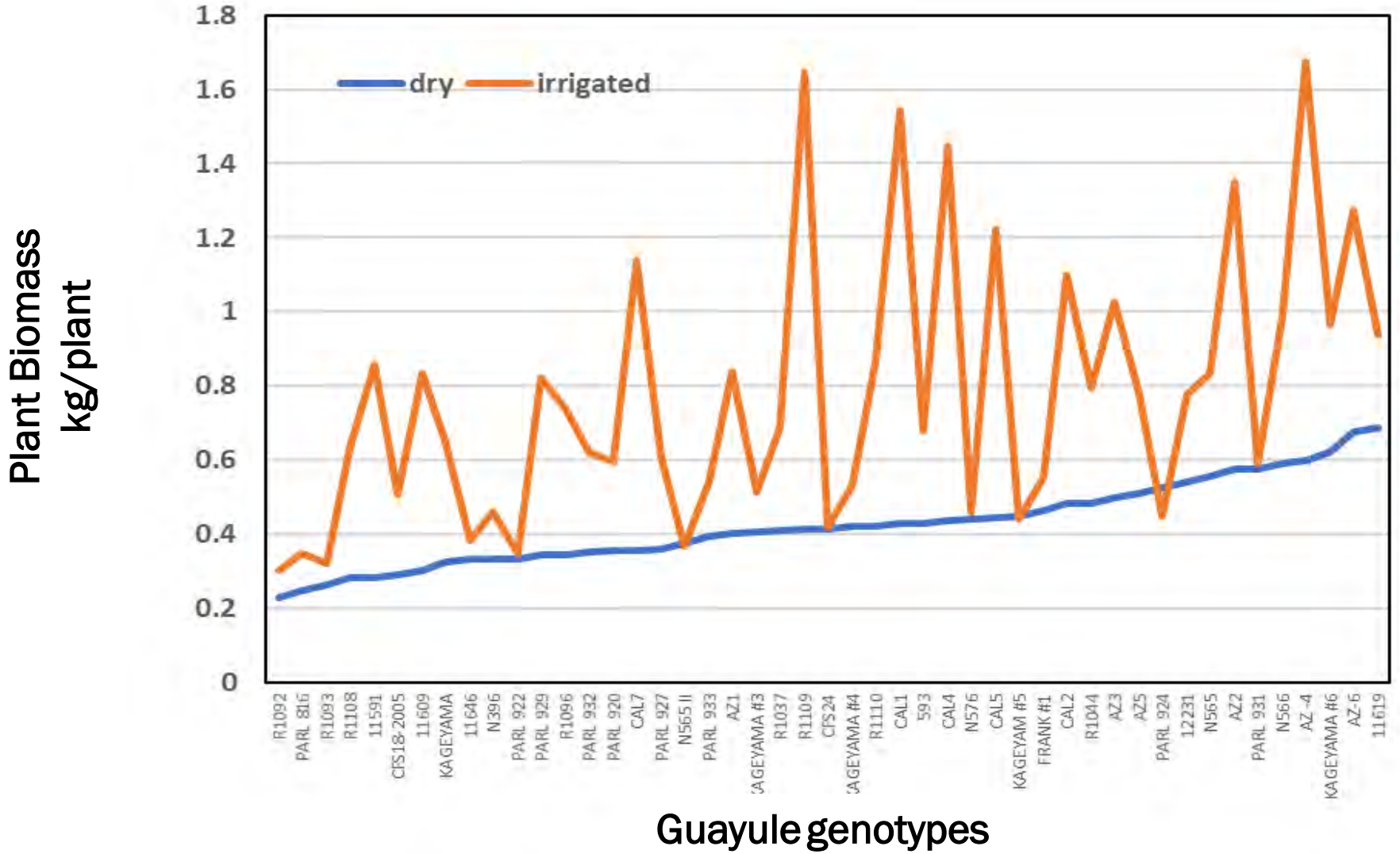
Response of Guayule Genotypes to Water Stress



Stress Irrigation Study

- Two Lines – AZ-6 and AZ-2
- Irrigation the same after planting for first month
- Irrigation Strategy
  - Full (75% evapotranspiration)
  - Half-Irrigation
  - Stress Before Harvest (Full 16 months – none last 8 months
  - Minimum Irrigation (9/20; 3/21; 5/21; 9/21)
  - Y2 minimum Irrigation (full then 3)
  - One Irrigation annually (9/20; 4/21)

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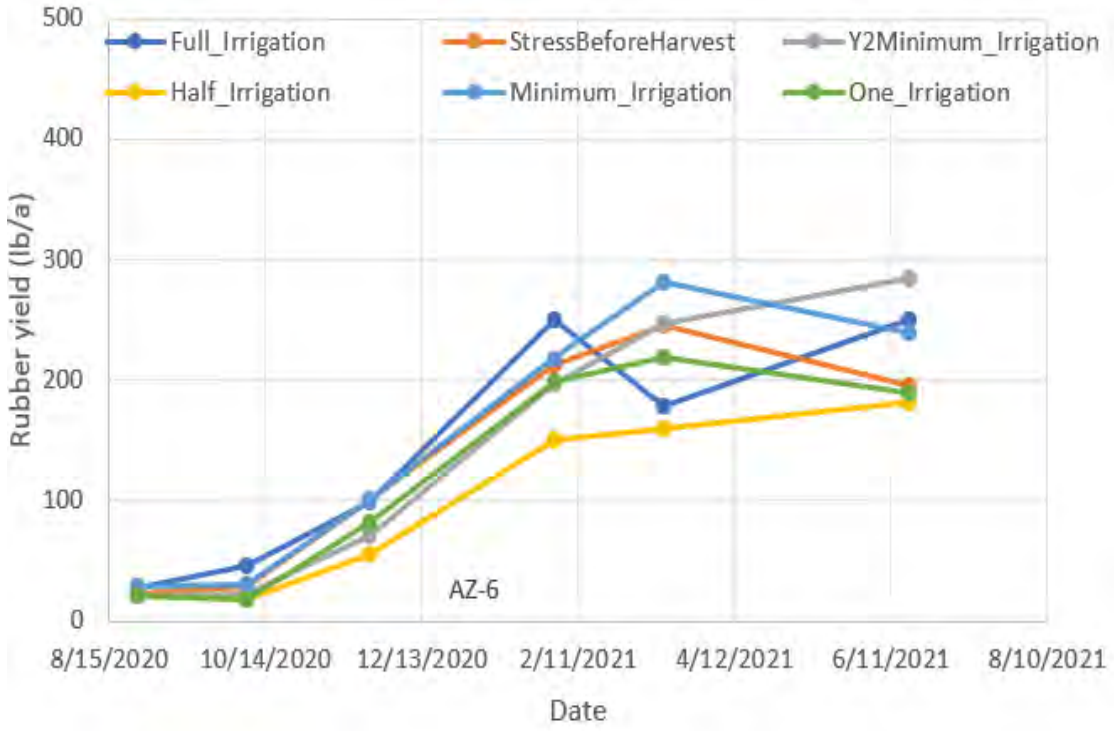
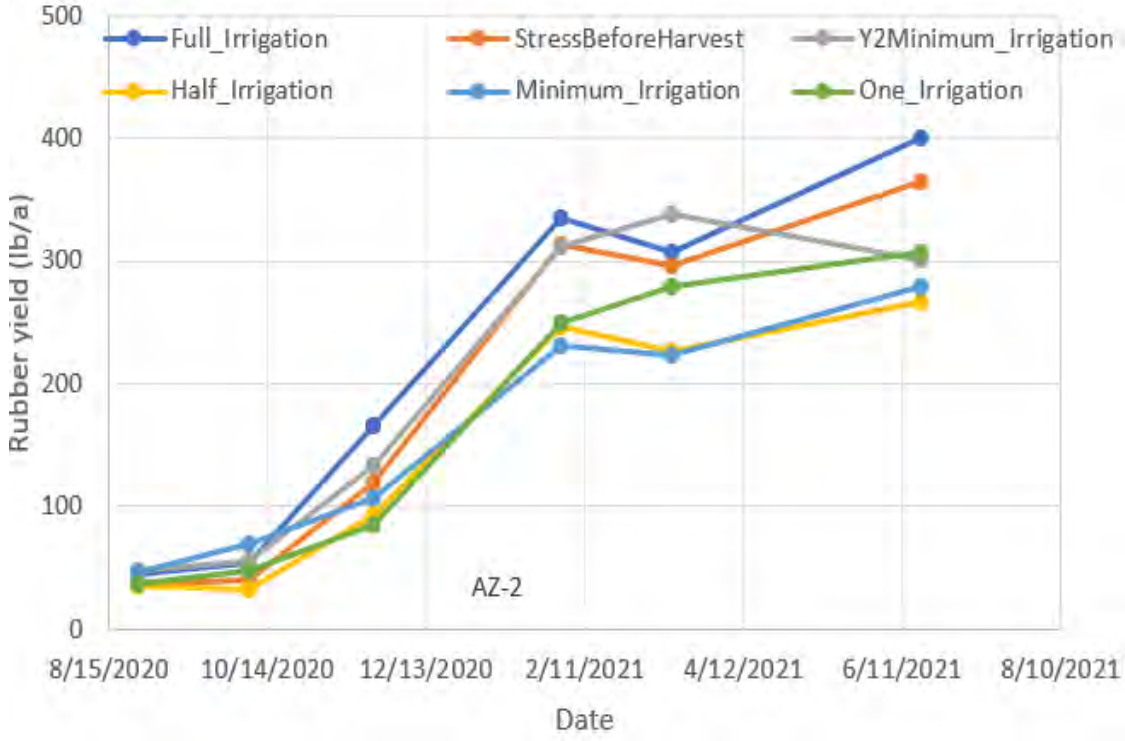
Rubber Yield - Stress Irrigation





- AZ-2 had higher rubber yield than AZ-6 due to higher biomass.
- In 14 months, the One irrigation and Minimum irrigation treatments (30-37 inches of water) respectable rubber yield compared to the Full irrigation treatment (80 inches of water)
- 30 inch of irrigation water per year would be too low for all major crops in Arizona.

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Soil Health and Guayule Productivity

Identification of guayule microbiome essential to a sustainable guayule agroecosystem

- Guayule percent rubber and resin correlate
  - Positively - soil DNA biomass
  - Negatively - soil organic matter (OM), shrub mass, and NDVI vegetation index
- Change in bacterial/archaeal functional potential during winter dormancy (rubber production phase)
  - decrease denitrification
  - Increase organic matter degradation by cellulolysis

Correlations between guayule rubber/resin content and select soil/plant parameters

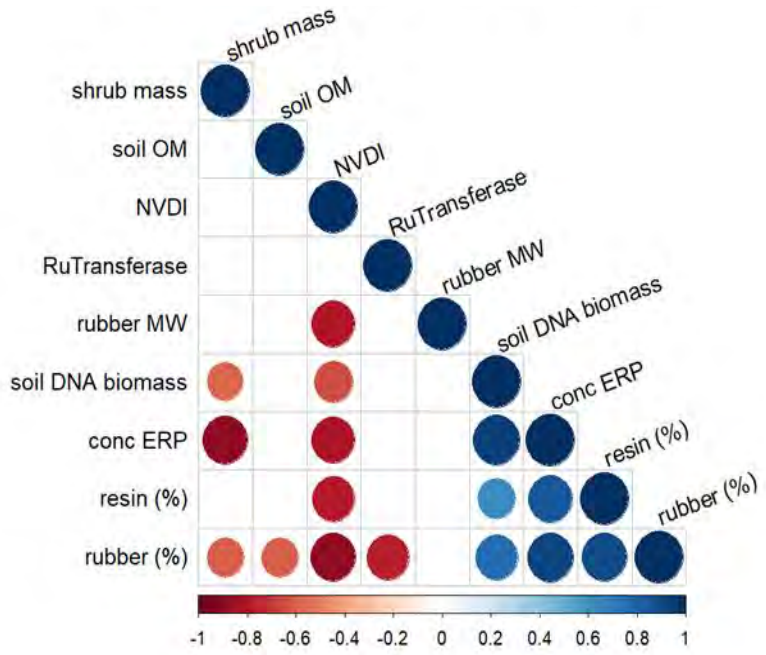

Fig. 1 Blue, positive; red, negative. ($p \leq 0.05$; circle size indicates level of significance; ERP=extractable rubber particles)

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Determining the Lower Nitrogen Threshold of Guayule

- Greenhouse study in semi-hydroponic system of 6 N treatments of 0, 50, 75, 100, 150 and 200 ppm N.
- Similar increased growth response to 50 ppm-150 ppm treatments.
- Limited growth at 0 ppm and reduced growth at 200 ppm

0 PPM | 50 PPM | 75 PPM | 100 PPM | 150 PPM | 200 PPM

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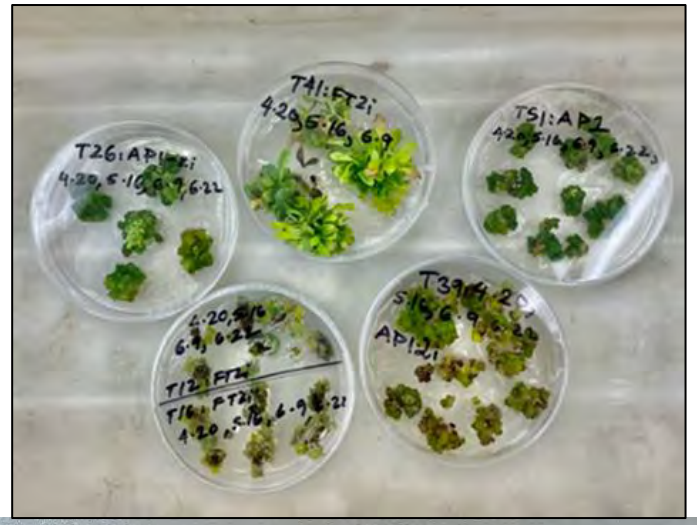
Improve guayule biomass quality – down regulate flowering

- Analyzed expression patterns for flowering-related genes (RNA transcripts) in high and low rubber-producing guayule
- Improved guayule transformation protocols (leaf segments, light, timing).
- Generation of healthy transformed plants/calli with downregulated (RNAi) transcription factors for : *SEPATALLA3, FLOWERING TERMINUS1*, and *LEAFY*.
- Plants with downregulated *SEPATALLA3 (flower development)* showed fewer flowers



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Guar Feedstock Evaluation

- Guar cultivar development

  Evaluation of breeding material of Dr. Ray at Clovis location showed significant seed yield variation

- Soil temperature and guar establishment

  Guar cultivars showed diversity in establishment under cooler temperatures; encouraging for breeding cold tolerant cultivars

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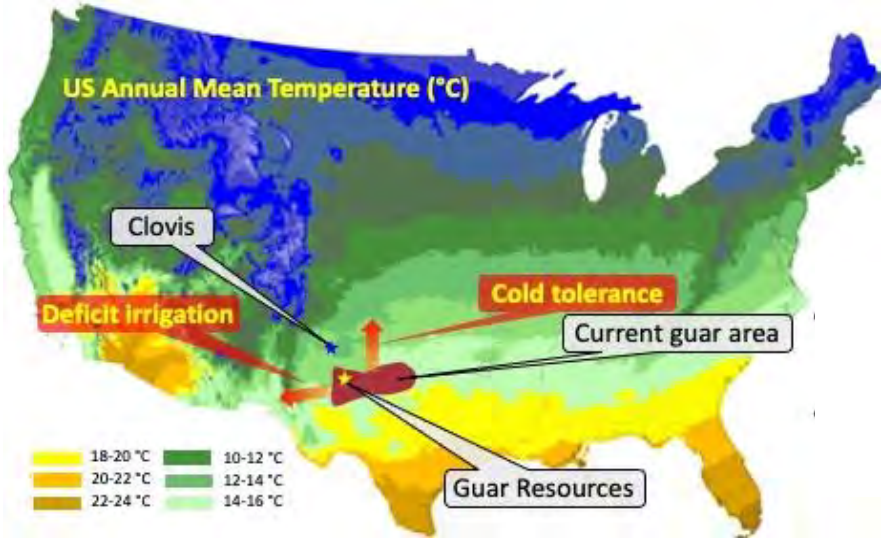
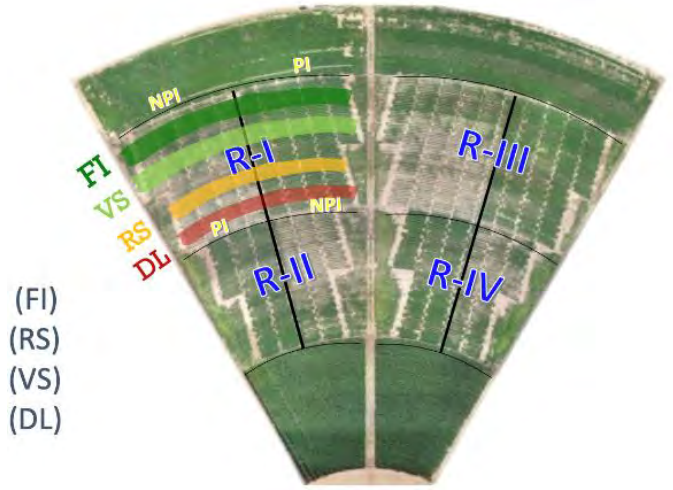
Increase Guar Acreage in Southwest

- Deficit irrigation management strategies for guar
- Preseason irrigation and skipping irrigation at less critical growth stages can help in reducing irrigation water
- Nutrient management trial





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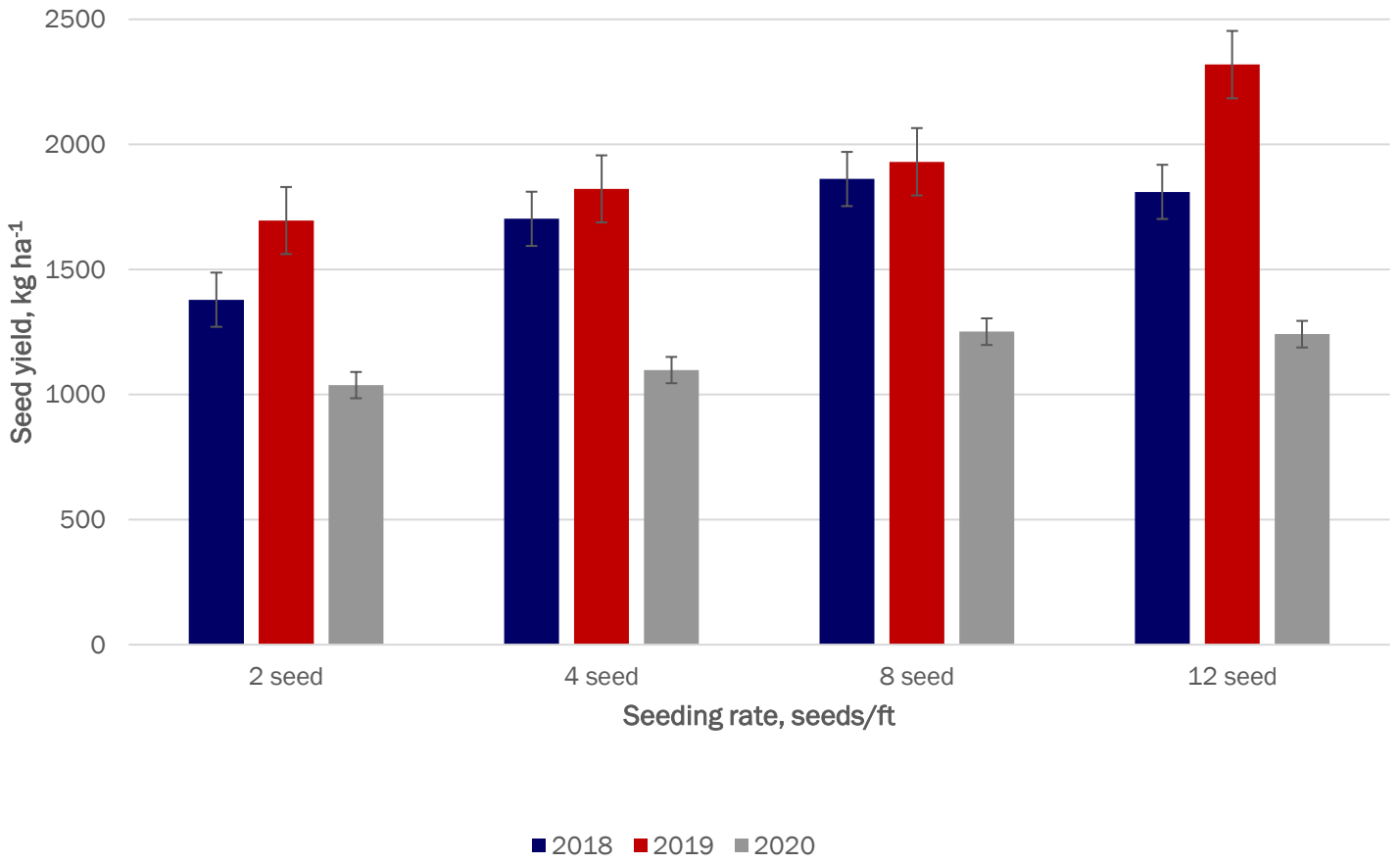
Seed Yield varying Seed Rate - Guar

- The seeding rates of eight and twelve seeds/ft has significantly higher yields
- Individual plants yielded more seeds under lower seed rates
- However, the higher seed rates compensated because there were more seeds per area



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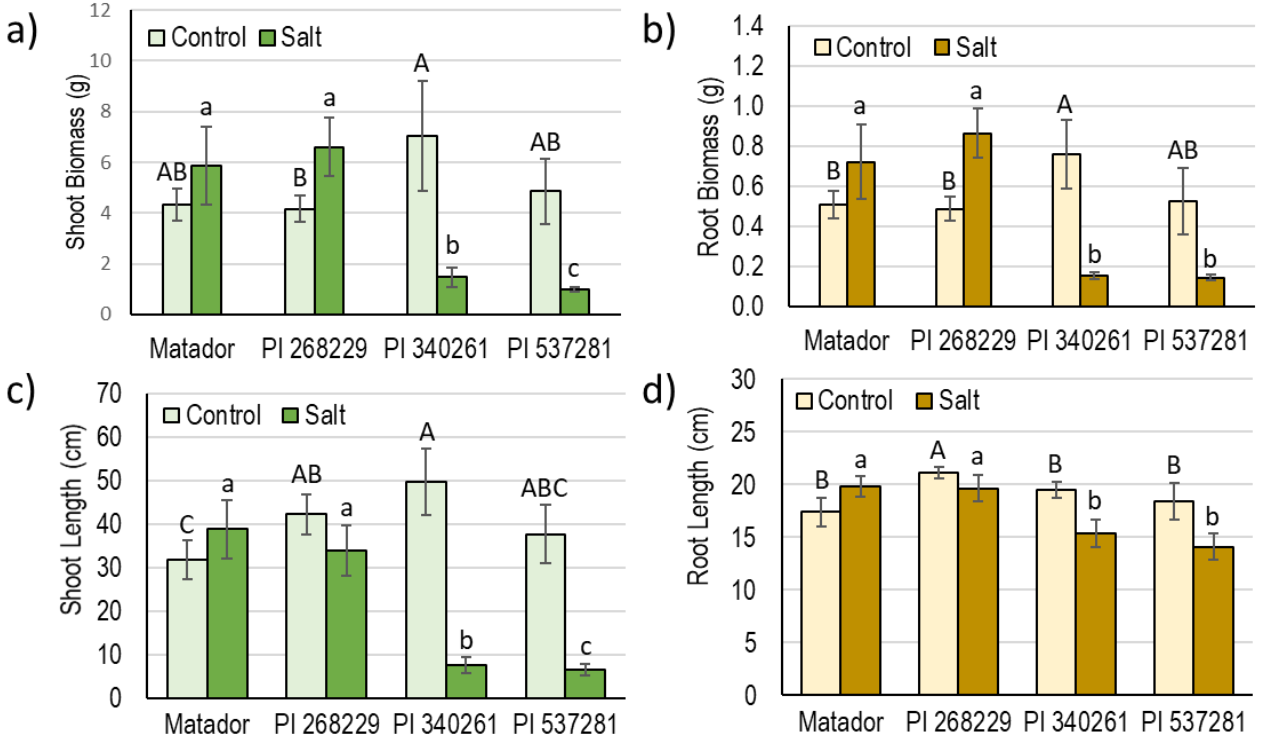
Salinity Tolerance Mechanisms in Guar genotypes

- Matador and PI 268229 were classified as salt-tolerant
- PI 340261 and PI 537281 were classified as salt-sensitive.
- Salt Tolerant strains performed significantly better in terms of shoot and root biomass and length.

Greenhouse evaluations under saline irrigation water (13.65 dS m^{-1})



[1] USDA Salinity Lab, Riverside, CA

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CHARACTERIZATION AND COPRODUCTS

Catherine Brewer – Lead
Leslie Gunatilaka, Omar Holguin, Istvan Molnar, Kim Ogden

Fuel

Rubber processing

Rubber

Guayule

Bagasse

Resin

Identify value-added processes and products for guayule bagasse

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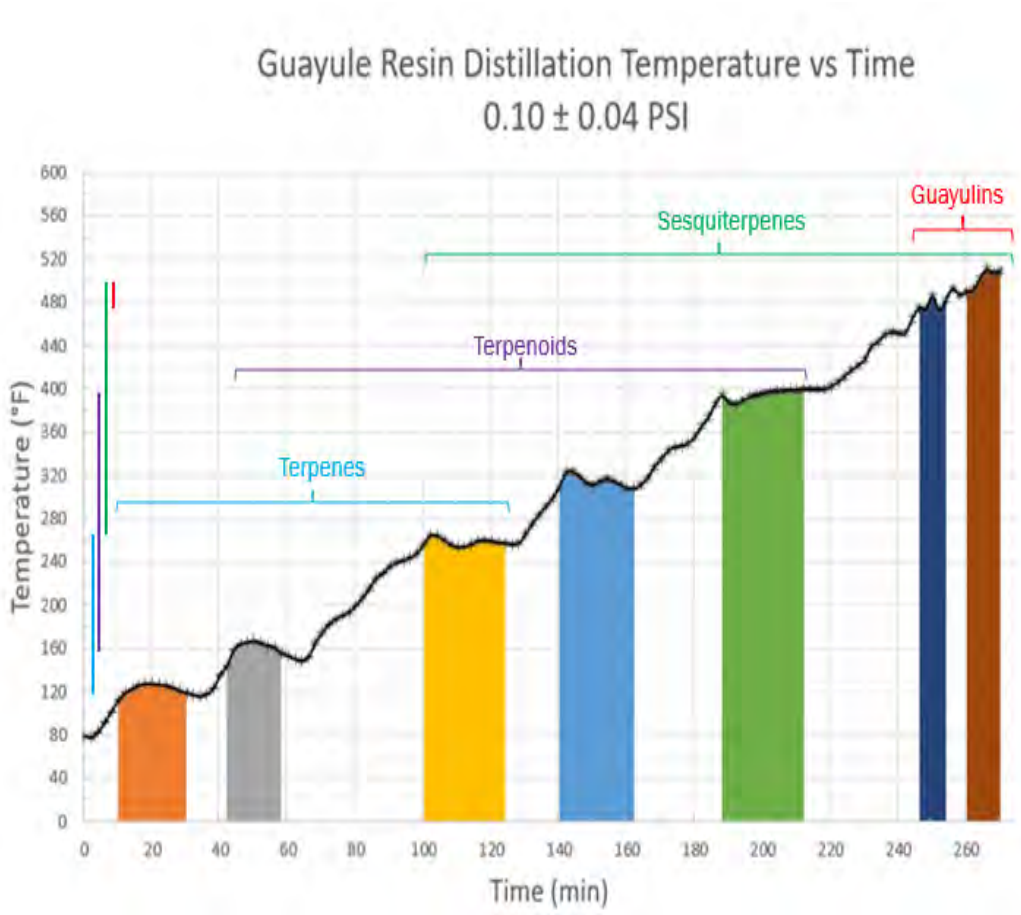
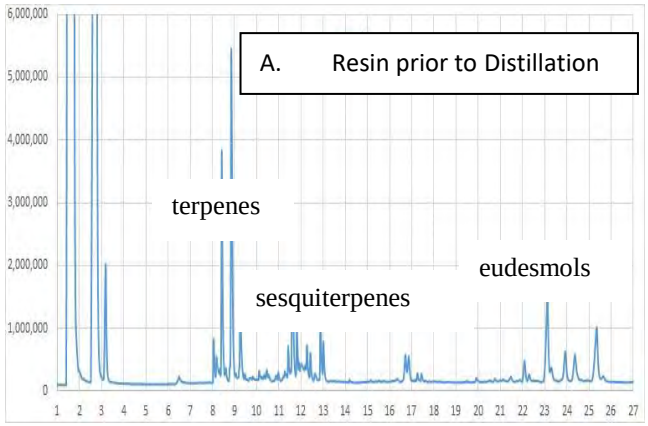
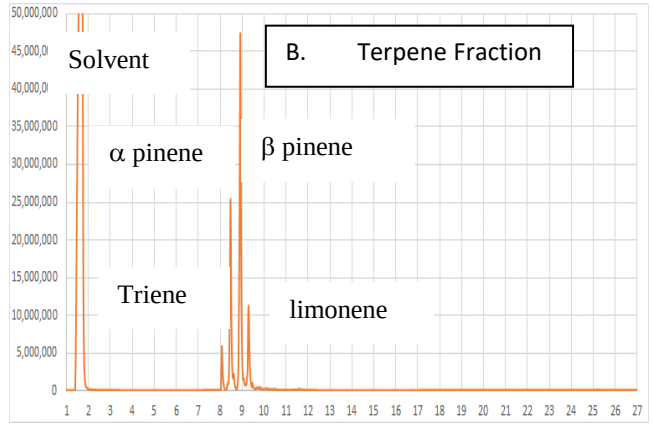
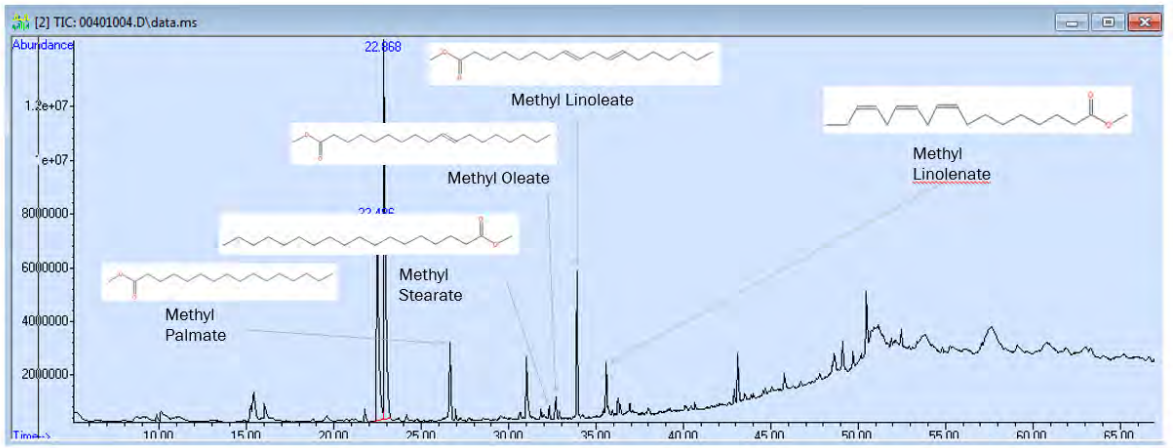
Co-Products (Distillation, Terpenes, FAMEs)









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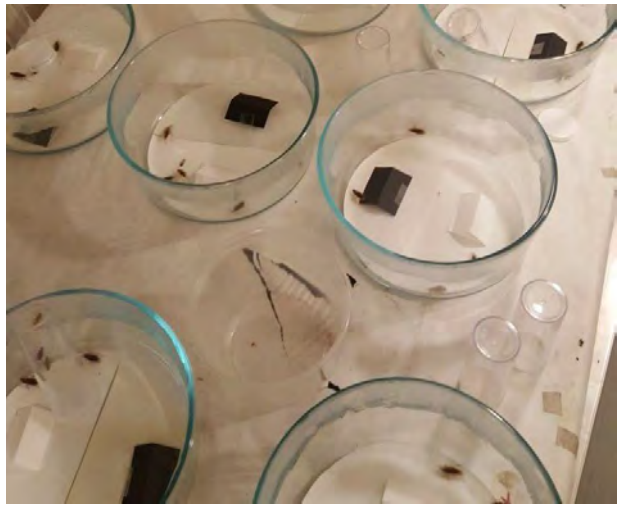
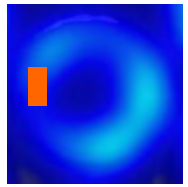
Co-Products (SCE & Insecticides)

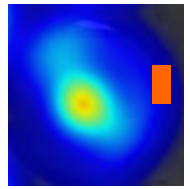
Resin

Identify value-added processes and products for guayule resin

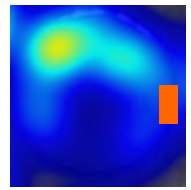




Lipid (fraction)



Resin (whole)



Terpene-rich (fraction)

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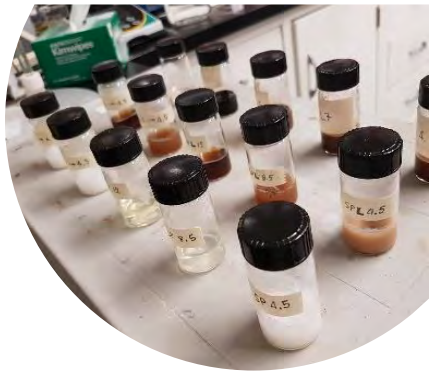
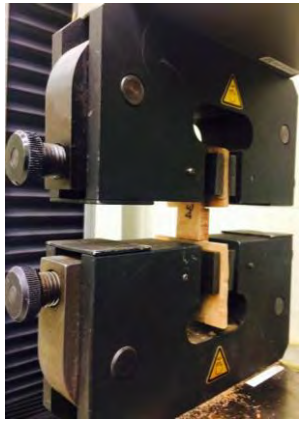
Co-Products (Adhesives)

Pure Resin

Acid/Base Modification

Plant protein/
commercial adhesives





Property

Test

Adhesion

Test

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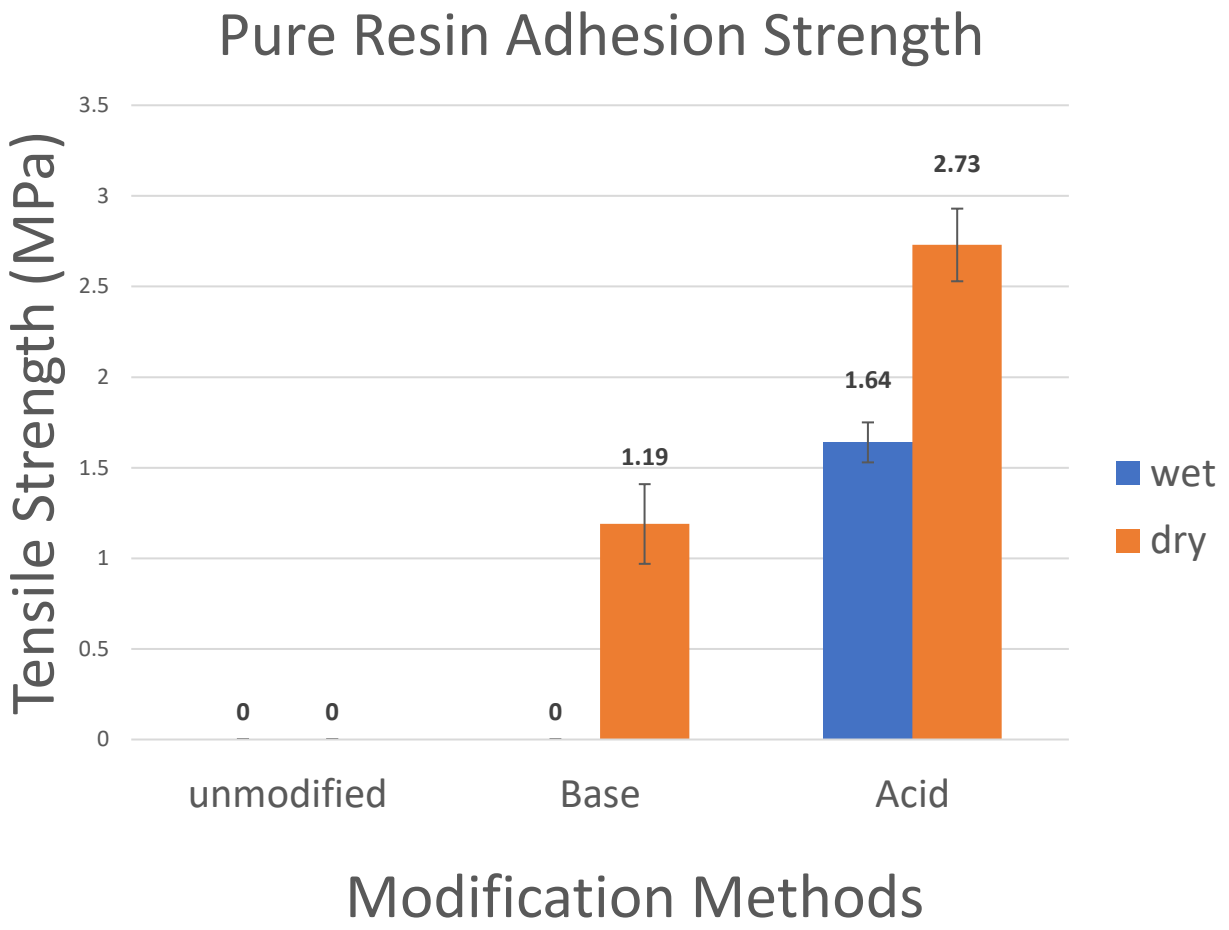
Pure Resin Adhesives

- Unmodified resin had weak (~0) adhesion strength.
- Base modification improved/provided only the dry adhesion property.
- Dry adhesion strength could be further improved by acid modification process.



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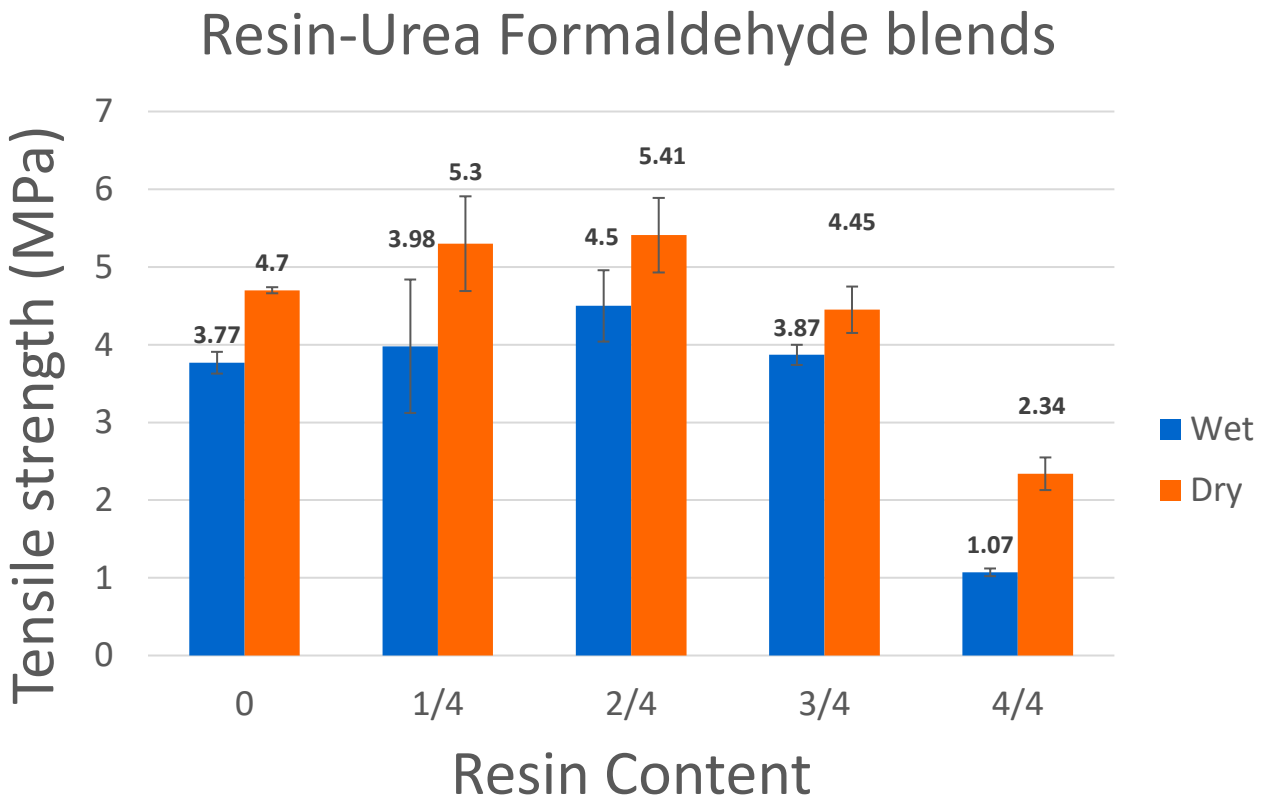
Resin-Urea Formaldehyde Adhesives

- The reference standard was the urea formaldehyde adhesive for wood industrial usages.
- No negative impacts were found on wet adhesion strength with an addition of resin up to ¾ of urea formaldehyde content.
- The maximum increase in both wet and dry adhesion strength was observed with the resin to UF ratio of 1:2.
- The improvements of wet and dry adhesion strength were 20% and 15%, respectively.



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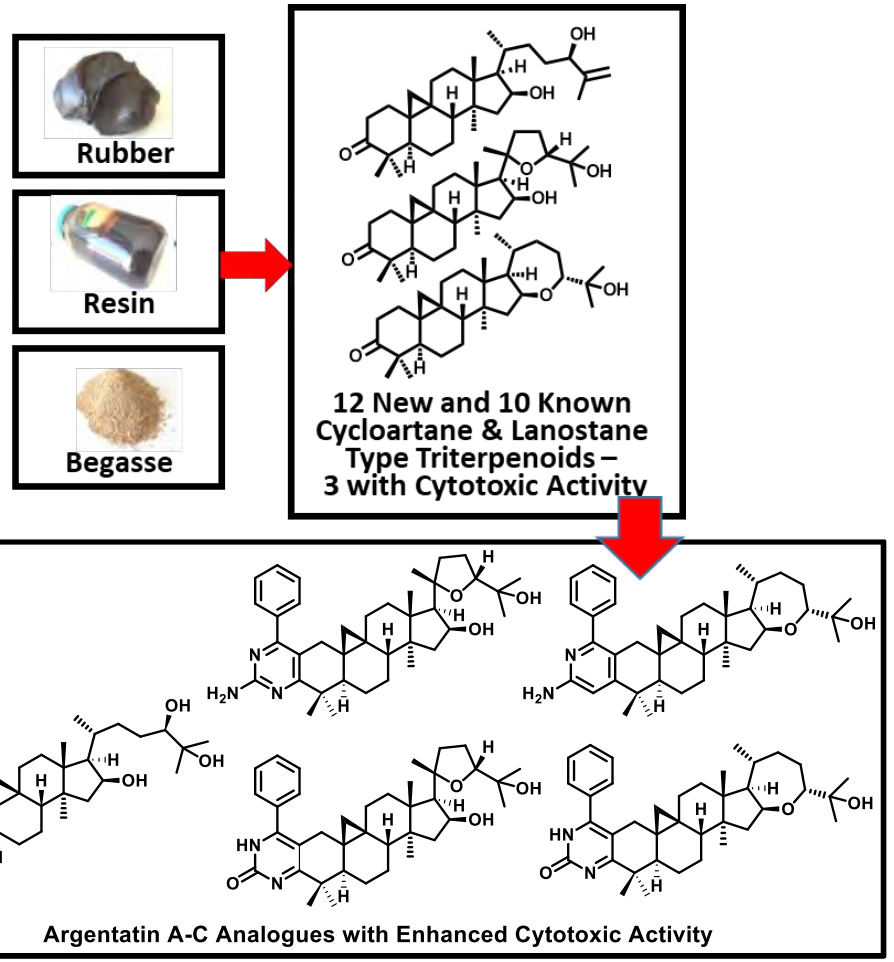
Isolation, Chemical and Biological Derivatization of Guayule Resin Constituents

- 26 metabolites, including 12 new and 10 known cycloartane & lanostane type triterpenoids compounds were isolated from guayule resin.
- Some of these compounds show in vitro toxicity to cancer cells.
- 15 argentatin and 8 guayulin analogues were prepared by semisynthesis.
- Some of these compounds display enhanced cytotoxicity (c.f. the natural products) and selectivity (cancer cells vs. normal cells).



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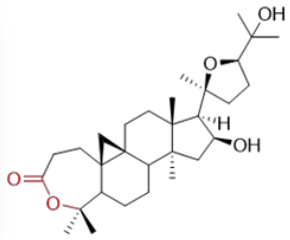
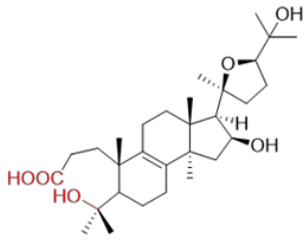
Biosynthesis of Guayule Resin Constituents

- Genome, transcriptome and phylogenetic analyses revealed candidate genes for the biosynthesis of the carbon skeletons of argentatins and guayulins.
- 3 fungal strains biotransformed 4 argentatin and 2 guayulin congeners
- Two *iso*-argentatin A, one argentatin A, and two argentatin C derivatives were isolated, and their structures were determined by NMR.
- Next steps is to determine if affective against cancer and/or infectious diseases.

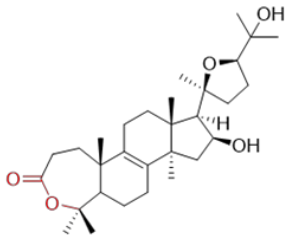
Chaetomium sp.



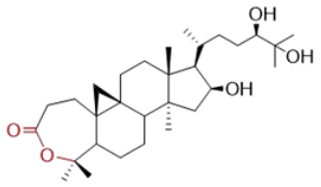
Argentatin A-P3



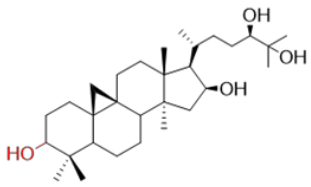
iso-Argentatin A-P2



iso-Argentatin A-P4



Argentatin C-P3



Argentatin C-P4

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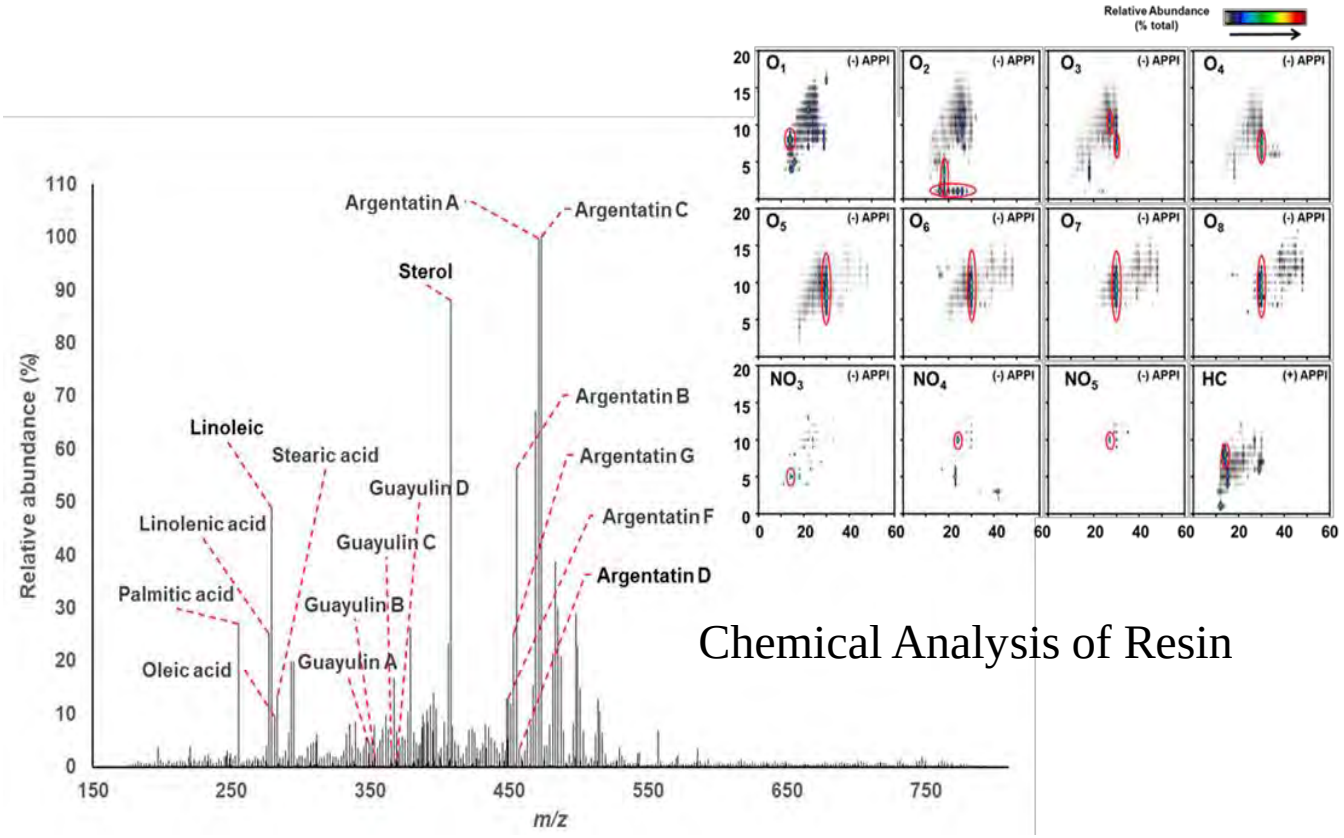
Characterization of Guar and Guayule

- Supported galactomannan content and size analysis for guar samples.
- Isolated and identified 5 Rhizobium species
- Detailed mass spectrometry analysis of guayule resin.

Guar Nodules

Determinate

Indeterminate



Chemical Analysis of Resin

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EXTENSION & OUTREACH

John Idowu and Blase Evancho – Leads
Sangu Angadi, Kulbhushan Grover, Paul Gutierrez, Maryfrances Miller, Nick Morris, Channah Rock, Laura Rodriguez, Clark Seavert, Trent Teegerstrom

SBAR – Guar Grower Extension

- Guar seeding density on-station demonstration trials:
  - *NMSU Leyendecker Plant Science Center, Las Cruces*
  - *Clovis Ag. Science Center, Clovis*
  - *Los Lunas Ag. Science Center, Los Lunas*
- N & P Guar multilocational demonstration trial hosted in Las Cruces, Clovis, Los Lunas & Tucumcari, NM (over 2 seasons).
- New Mexico Alternative Crop Conference was successfully hosted in 2020 - information shared on guar production, processing and economics.

Guar Demonstration Trial
Los Lunas, NM (August 2020)

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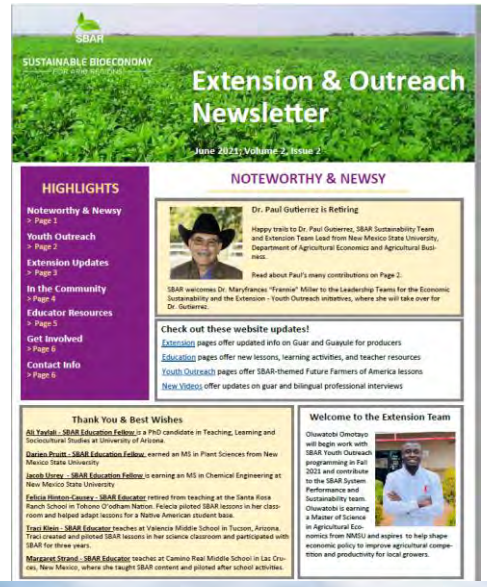
SBAR – Guayule Grower Extension

- Guayule demonstration field was established in Las Cruces with transplants.
- Guayule grower field days were held. Delivering updates on guayule agronomy and market advancements to approximately 200 individuals both virtually and in-person.
- USDA-NRCS plant guide published on national USDA Plants website
- Arizona needs assessment survey completed
- Foster agreements between Tribal Farms and Bridgestone
- Web updates, newsletters and fact sheets



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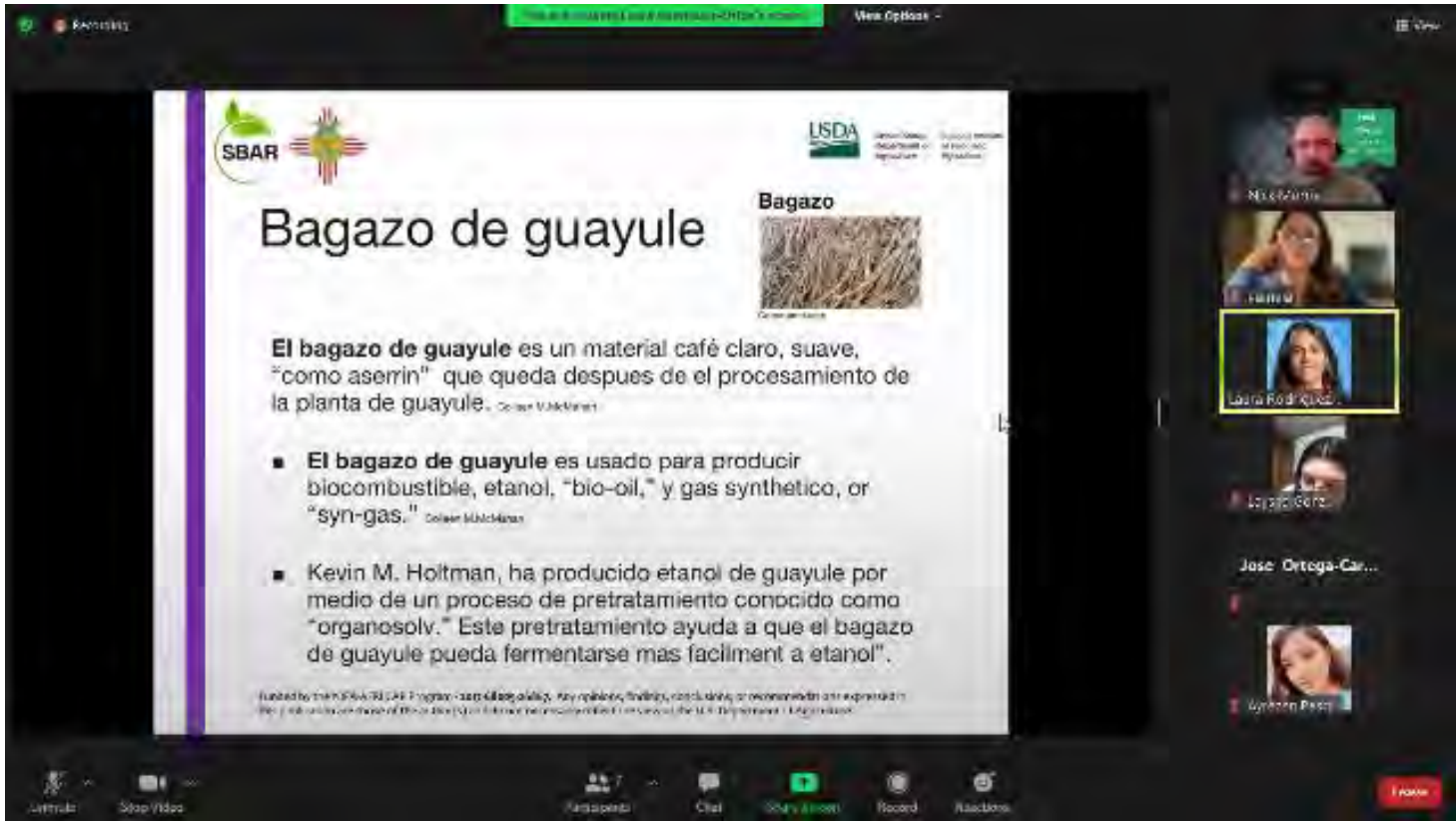
4-H Youth Development

- Resource Development
  - *UA/NMSU Partnership to develop and record bi-lingual introduction presentations*
  - *Infographics for use in outreach and education*
  - *Lesson adaptations in progress for Desert Ecology, Plant Adaptation, and Ag in Arid Regions.*
  - *Videos - Guar & Guayule introduction*



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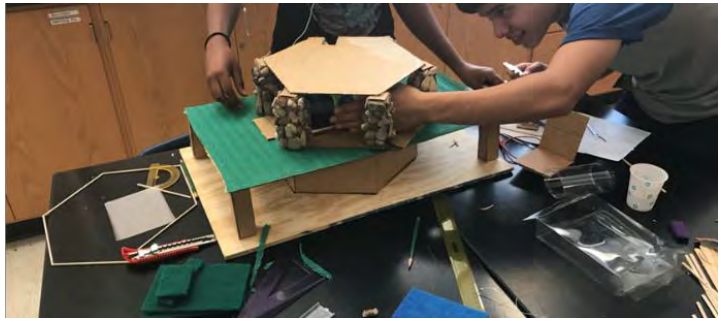
4-H Youth Development

- Volunteers
  - *Unable to host trainings in 2020. Recruiting for trainings in 2021-2022*
- Ambassadors
  - *Piloted the first set of county STEM Ambassador trainings. Teaching youth how to promote STEM literacy across their communities.*
  - *Developed ambassador activities and lessons (AR/VR and Sustainability) for delivery in the 2021-2022 4-H Year.*
- Train the Trainer workshops
- Agri-science 4H project – State Fairs
- Camps



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Project Puente – Internships

(High school and college)

- Emphasis on placing students with industry and academic mentors
- Development of skills in students that employers want/need
- Preparing the next generation of skilled workforce

- 2021/2022 New student recruitment, new student mentors, new ways to communicate!!
- Developed new materials for interns and mentors
- Partnership with 4H

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EDUCATION

Sara Chavarria and Catherine Brewer – Leads

Torran Anderson, Corey Knox, Maryfrances Miller, Nick Morris, Laura Rodriguez-Uribe,

Education – Fellows and Trainers

- Middle school teachers
- 15 Graduate Fellows
- *Guardians of the Biosphere* afterschool program
- Train-the-Trainer Workshop in summer 2019
- Agri-Science Kits
- Science Fairs
- Collaboration with Extension

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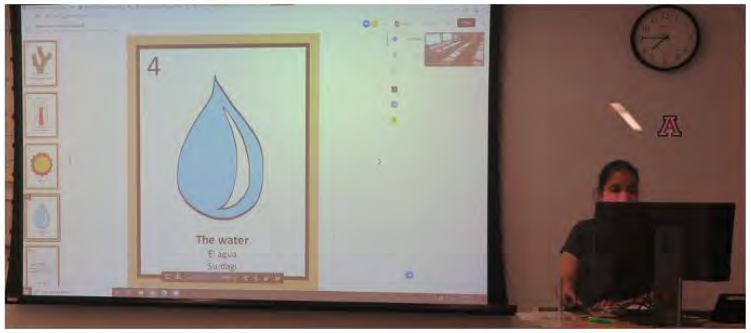
Education – Materials & Teachers

Development of **educational training and classroom materials** per partnerships

Support for teachers and outreach into the community

Lesson Extravaganza



Lesson refinement and sharing

In-person team building

Evaluation exercises

Daily meetings with the education team in New Mexico

d in

Dissemination

Translation of SBAR topics into arid land themes and **creation of educational resources**

Lessons and Activities

Theme 1 — Sustainability & Arid Lands
- Agriculture in Arid Regions
- What and Why of Deserts
- Water Footprint and Agriculture
- Environment and Sustainability

Theme 2 — Land Use and Culture
- Origins of crop breeding in North America
- SBAR Loteria
- Mesoamerican Games-Guayule

Theme 3 — Building Bioeconomy in Arid Regions
- What is a Bioeconomy?
- What are Bioproducts?

Theme 4 — Plant Science & Sustainable Crops
- Plant Adaptations for Arid Lands
- Guayule in a Bottle
- Soil: A lot More than Just Dirt

Theme 5 — Technology, Engineering, & Chemistry for the future
- Energy from Plants: Plants & Polymers
- Fermentation
- Pyrolysis & Fuel

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BY THE NUMBERS

Products

- Publications (Book Chapters and Peer Reviewed Manuscripts) – 28
- Publications in review – 8
- Capstone Projects, Theses, Dissertations – 3
- Conference Papers – 14
- Presentations (invited speaker and conferences) – 143
- Herbicide Labels for guayule– 2
- Patents for guayule resin– 2
- Fact Sheets – 6
- Project Highlights (quasi-press releases) – 33
- Tabling Events – 3,562 people contacts
- EEO Newsletters – 4

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Education and Outreach

- Biofuel Lessons in Classrooms (SBAR Teacher/Fellow Partnerships)
  - 2018 – 7
  - 2019 – 10
  - 2020 – 6
- Total Cumulative Youth participants – 1,715 students

Youth Participation Demographic Parameter	Previous Total (Cumulative)	This Report Total	Cumulative Project Total
Age Level			
11-13 years	1,242	0	*1,242*
14-16 years	433	40	*473*
Gender			
Males	834	24	*858*
Females	841	16	*857*
Race/Ethnicity			
Hispanic	893	3	*896*
Asian	33	0	*33*
Native American	159	24	*183*
African American	47	0	*47*
Anglo/White	538	5	*543*
Multiracial	6	8	*14*

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SBAR EEO Evaluation

- Project years 1&2 evaluation focused on using participant data to inform design modifications and iterative improvements in products (e.g. curriculum/lessons), activities (e.g. youth camps, teacher PD, and processes). Data was collected via surveys, individual and focus group interviews, observations, artifact review with youth participants, growers, teachers, graduate fellows, staff, and other stakeholders.
- Year 3 evaluation focused on thematic and pedagogical review of select curricular materials and other artifacts and establishing the research design for case study publications.
- Year 4 evaluation focused on in-depth qualitative research and data collection, primarily with participating teachers and graduate fellows, for planned publications.
- Over all 4 project years, conducted continuous process evaluation to document and assess progress towards overarching EEO outcomes and objectives.

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Web Site (https://sbar.arizona.edu/)

- Launched website – May 2018
- Total unique views (through Dec 2020) – 10,719
- Total unique views in 2020 – 5,473
- Views from USA – 49 states and Washington DC (all but Vermont)
- Worldwide views – 85 different countries

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Grant Proposals

- Molecular basis of natural rubber biosynthesis in *Parthenium argentatum* (Guayule) – Bridgestone Americas, USDA-ARS, and BTI – JGI Sequencing Proposal
- Cold Stress Impacts an Arid-Land Specialty Crop: Addressing Emerging Challenges to Sustainable Guayule Production – Bridgestone Americas, USDA-ARS, UArizona, NMSU, BTI - Standard Research and Extension Project
- Scaling Guayule Resin Separations to Enable Rubber and Biofuels Production – Bridgestone Americas, UArizona, CSU – DOE
- STEM Rise Arizona – Phase 2: A Partnership – Sustainable Bioeconomy for Arid Regions (SBAR) Center and Arizona 4-H STEM and Sustainability in Agriculture (SSAG) – Uarizona - Haury Foundation - awarded
- Curbing our Carbon Appetite Challenge: An Agricultural Innovation Experience for Arizona – Bayer - awarded

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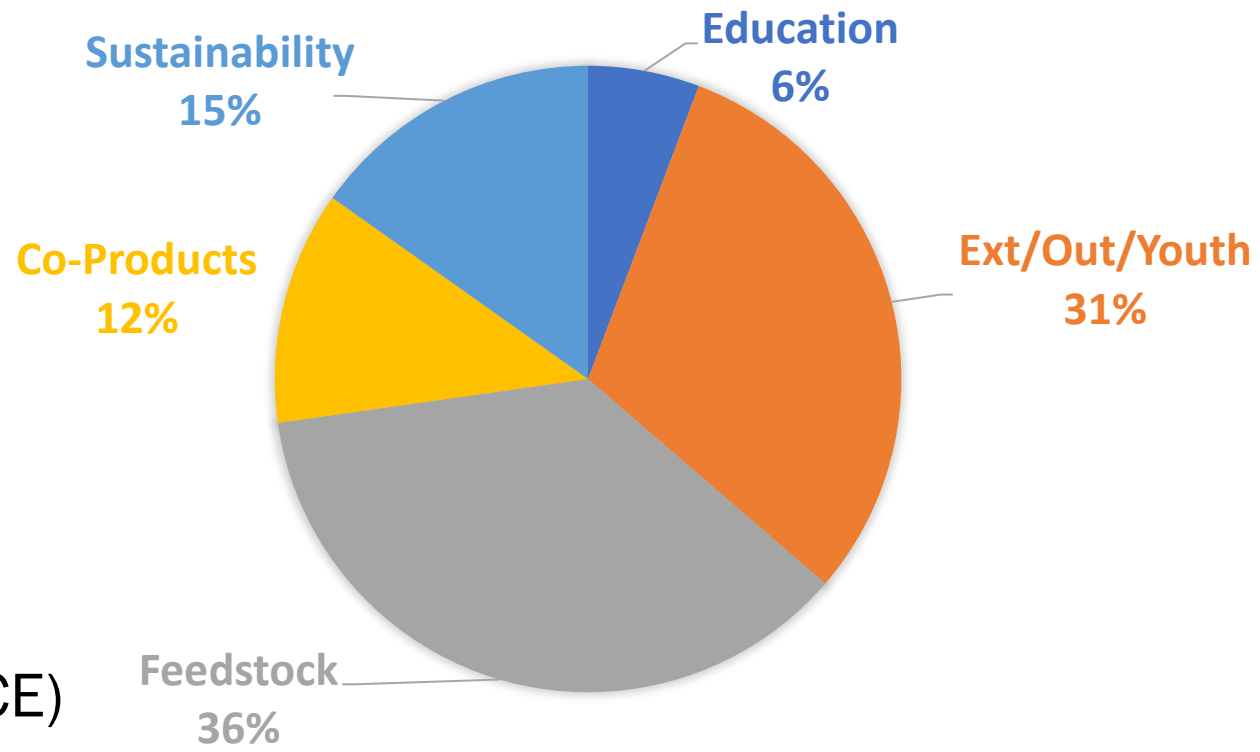
Budget

- Total Awarded
  $14.8 million
- Additional Supplemental Award (Haury)
  $53,000
- Total Allocated (through Year4)
  $10,490,885
- Planned Allocation (Year 5)
  $2,328,386
- Anticipated Amount available for Yr6 (NCE)
  $1,980,729



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Plan for Retreat

- Focus
  - *Working Sessions for Components*
  - *Industry and Grower Updates*
  - *Working Groups*
    - Prioritize Year 5
    - No-cost Extension Ideas
  - *Seeing each other*

- Logistics - Alix

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