Water Quality and Soil Health Under Fallow Season Cover Crops in Mid-South Row Crop Production

PI(s) – Lisa M. Fultz & Brenda Tubaña

Co-PI(s) –
Kenneth Gravois
Donnie Miller
Albert Orgeron
Naveen Adusumilli
James Hendrix
Donna Gentry
Josh Copes
Sebe Brown
Paul P. Price

Graduate Students –
Jose Mite
Daniel Forestieri
Kritsanee Iamjud

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Background/Rationale

Cover crop usage, while not new, has garnered increasing interest as prices for fuel and inputs like fertilizer increase. Their use in cash crops like corn, cotton, and soybean have been established as has their potential to reduce runoff and sediment loss, improve nutrient cycling, and overall benefits to soil health. However, much of the existing work has focused on cooler, northern climates, while the mid-south's warmer winters, inclusion of crops like sugarcane, and farmer preference has resulted in many questions and reluctance to adopt cover crops in Louisiana production systems. Additionally, producers have encountered setbacks that have increased their reluctance to adopt conservation practices, like cover crops in their systems. For example, shorter winter fallow periods, in particular rotations from cotton or soybean into corn, has limited the growth potential for cover crops and thus the measurable benefits they provide. Producers are also concerned about the potential for increased soil moisture, coupled with warmer soil temperatures, may result in prime conditions for propagating pests and disease for cash crops. These hurdles, when combined with the added costs associated with cover crops has resulted in Louisiana ranking 35th in cover crop acreage across the United States.

Much of the cover crop information for Louisiana was gathered over 15 years ago, reducing its applicability to current crop varieties and production practices. Additionally, little work in the United States has examined the potential use of cover crops in sugarcane production systems. Sugarcane production, novel compared to commonly grown row crops, has a high potential for increased soil loss, particularly during fallow years (Figure 1). For this reason, Louisiana researchers have worked to gather existing information that can be used to aid producers in designing their own cover crop practice while also identifying where additional work is needed.

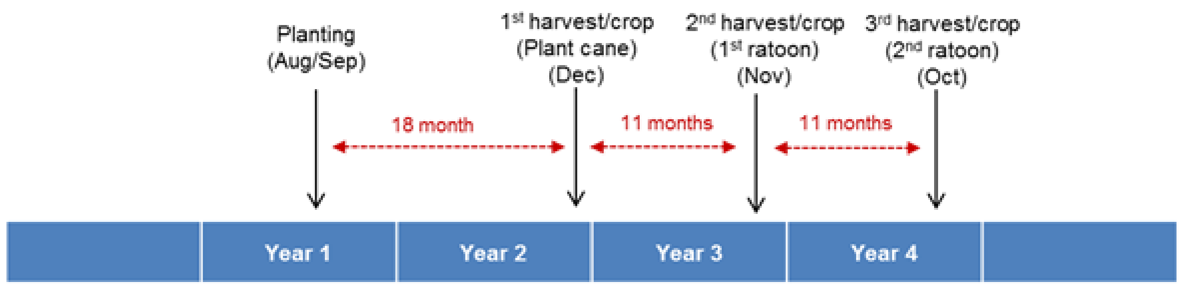

Figure 1. Sugarcane growth cycle typical in Louisiana

The goal for this project was to introduce and promote the use of cover crops in mid-south, and specifically Louisiana, row crop production systems. This was accomplished via a variety of methods including on-farm demonstrations, demonstration/trials located on Louisiana State University AgCenter research stations, hosting workshops and field days, and production of written material. Our aim was to increase the adoption of soil health management practices by demonstrating the effectiveness and efficiency of cover cops to reduce sediment loss and N and P contaminants at the farm and watershed scale. Specific objectives to achieve this goal included:

- The demonstration of the effectiveness and efficiency of winter fallow cover crops to improve productivity, profitability, sustainability, soil health, and water quality in

Louisiana row crops through on-farm demonstration programs and detailed research activities.

- To identify innovative conservation systems (i.e. cover crops) with the greatest impact on soil health, e.g. increased residue input and soil organic matter/carbon, improved soil moisture and nutrient cycling, weed control, and enhanced microbial activity to improve and protect water quality in the Mississippi River Basin.
- Quantifying potential cash crop and cover crops regarding nutrient competition, develop optimum pest/disease strategies, and compare on farm economics of cover crop systems.
- Provide training to local advisors (public and private) and educate several levels (producers, agricultural suppliers, agribusiness lenders) of Louisiana agriculture through demonstrations and outreach programs.

Methods

The initial stage of the project focused on identifying landowner/producers that were interested in cover crops but had little or no experience with incorporating them into the production systems. In-person visits were scheduled for each farm to assess:

1) Producers interest in participating in the project
2) Current and past management practices and cropping history
3) Landowner's goals for use of cover crops
4) Their willingness to participate for up to 3 years of cover crop planting and allow for field tours

Fields were selected, whenever possible, to allow ease of access for collaborators and field visits with particular interest in fields which producers had identified a specific need that may be addressed by cover crops. For example, fields with history of loss due to erosion, increased weed pressure, or recently precision leveled fields provided unique opportunities to assess the seconary benefits of cover crops for increasing soil health and weed suppression.

Of the sites visited, 16 farms predominantly across northeast and southern Louisiana, with one in central Louisiana, were established, with 2 dropping out after the first year, and two farms opting to host up to two additional demonstrations or treatments. (Figure 2). These farms were distributed across the Ouachita, Mississippi, and Terrebonne watersheds. Despite continued efforts and visits we were not able to establish demonstrations in western Louisiana.

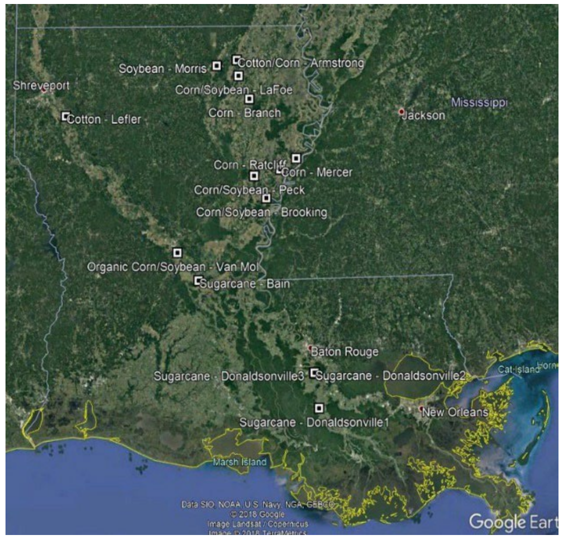

Figure 2. Location and primary crops grown in demonstration fields. Fields were primarily located in the Ouachita, Mississippi, and Terrebonne watersheds.

After fields had been identified, landowner/producer interviews were used to make cover crop recommendations focusing on cover crops mixes to address needs for projected cash crop, specific goals identified by landowners, and abiotic factors including soil texture. Mixes typically consisted of 2-3 species including a grass (black oats, cereal rye, or triticale), a legume (Austrian winter pea, red clover, crimson clover, or hairy vetch), and tillage radish (Figure 3). In fields projected to be planted into cotton or corn, mixes were typically 70:30 legumes:grasses based on NRCS current recommended monoculture broadcast seeding rates. For fields projected to go into soybean the ratio was 30:70 legumes:grasses. When radishes were included, they were seeded at a rate of 2 lbs ac^{-1}. Cover crops were broadcast seeded into strips up to 10 acres in the farmers' field, with strips of no cover crop included as controls (Figures 4, 5, & 6). Strips were separated into 3 equally sized areas (pseudoreplicates) for all subsequent biomass, soil, and yield sampling. Prior to termination (4-6 weeks pre-cash crop seeding), cover crop biomass and soil samples were collected. Biomass was collected by removing all cover crop within 2 – 1m transects per pseudorep, placing the biomass in brown paper bags which were dried and weighed (Figure 5). A minimum of 16 soil cores samples were collected at depths of 0-15 and 15-30 cm and combined for two samples (by depth) per pseudorep. Soil samples were analyzed for nutrient content, organic matter, pH, EC, soil respiration, enzyme activity (C & N cycling enzymes), total fatty acid methyl esters (proxy for total microbial biomass), and microbial community composition. Where possible crop yields were collected via either hand collection or yield monitors.

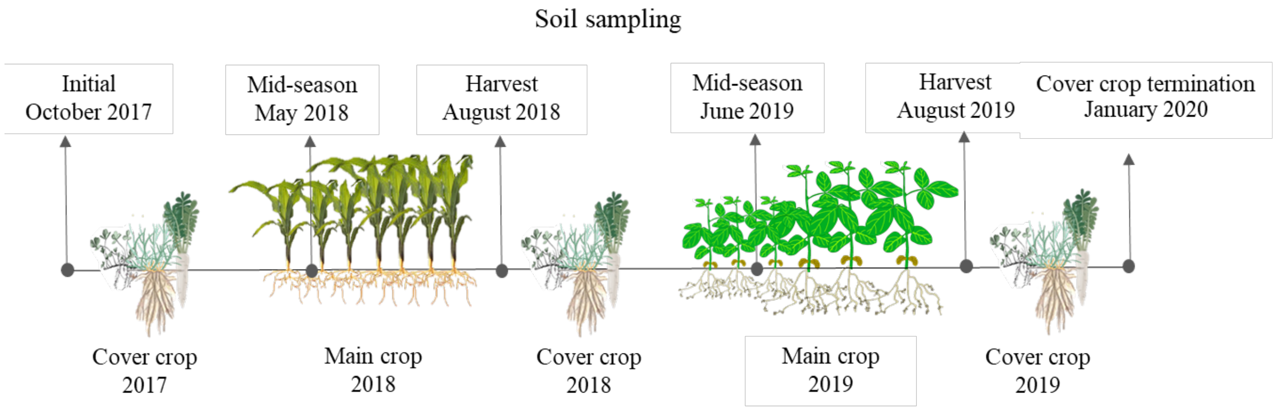

Figure 3. Soil and plant biomass sampling, and harvesting activities in 2017, 2018, and 2019.


Figure 4. Cover crops planted in strips for Macon Lafoe in northeast Louisiana. Image taken in December 2017, 2 months prior to termination, of areas seeded with berseem clover, Austrian winter pea, and cereal rye (left) or berseem clover, hairy vetch, and cereal rye (right).


Figure 5. Cover crops planted at Van Mol Farms, an organic row crop production system. Biomass (left) and soil (right) samples were collected in February 2018. A mixture of cereal rye, crimson clover, and hairy vetch yielded 2,910 kg ha^{-1} of biomass at one month prior to termination.

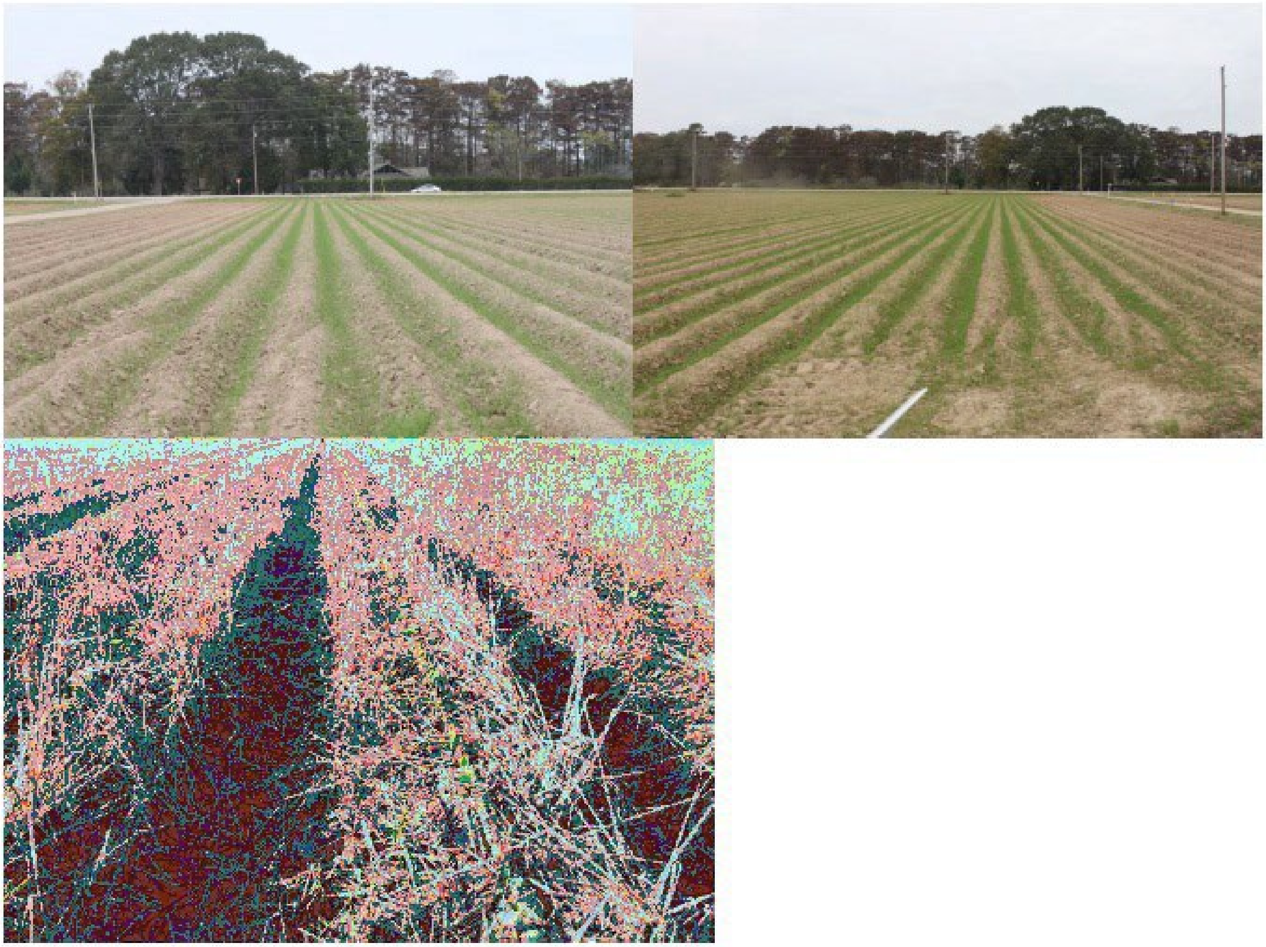

Figure 6. Cover crops planted in October 2017for Nick Morris in northeast Louisiana. Images were taken in November 2017. Left field was seeded with berseem clover (7 lbs ac^{-1}), hairy vetch (8 lbs ac^{-1}), and cereal rye (21 lbs ac^{-1}), while field on the right was seeded with berseem clover (3 lbs ac^{-1}), hairy vetch (4 lbs ac^{-1}), and cereal rye (49 lbs ac^{-1}). Bottom left image shows soybean planted into cover crop residue.

Demonstrations located on research stations were designed specifically to address questions put forward by landowners/producers or address issues that were identified throughout the project. This included investigating impacts of pre- and post-emergent herbicides, termination timing, cover crop biomass degradation and nutrient turnover, and impacts of crop productivity. Station demonstrations were primarily located on the Macon Ridge, Northeast, and Sugar Research Stations, within the vicinity of on-farm demonstrations and were utilized for multiple field tours. All station demonstrations were designed with 3-4 field replicates and replicated over time and/or space when possible. A variety of cover crops were included in station trials. Details relevant to each experimental design are provided in the following results section.

Results

There were many positive outcomes from this project, however there were two overarching conclusions related to improving the success of cover crop adoption that were not related to the numerical data collected. First, although many producers were interested in cover crops and their potential benefits, without pre-determined goals, any setback was often associated with ‘complete failure’ in the eyes of some landowners/producers. By establishing overall goals early in the experiment, it was possible to make recommendations with a higher potential for perceived success by allowing farmers to focus on those expected outcomes. Landowners and producers were also more open to secondary improvements to soil properties related to soil health when they felt they had achieved their initial goal. Secondly, the lack of consistent results further highlighted the importance and need for largescale, on-farm research and the development of individualized conservation plans. Site-to-site variability in on-farm demonstrations coupled with the relatively short-term (<3 years) of cover crop establishment may have delayed the development of some soil health properties like increased soil organic matter and plant available nutrients. It is important to include, that although improvements were not always measured between cover crop and no cover crop treatments, many of the producers who took part in the project have expressed their intent to continue planting cover crops.

Results are separated based on individual projects with figures and tables provided.

<u>Soil health in on-farm demonstrations – K. Iamjud dissertation Chapter 4 (under L.M. Fultz)</u>

- Seeded cover crops included berseem clover, hairy vetch, Austrian winter pea, black oats, cereal rye, triticale, and tillage radish.
- Impacts of cover crops were highly variable across locations. While improvements were measured in SOM, enzyme activities, and protein-N at some locations, one location demonstrated no change in soil health properties in the 3 years under cover crops (Table 1). This may be linked to biomass production (Table 2) at each of the sights as well as differences in inherent abiotic soil properties.
- Although differences in cover crop vs. no cover crop were not always evident, increased soil health properties (enzyme activity, protein-N, POX-C) were measured over time for some locations.
- No differences in soil microbial community were measured between cover crop and no cover crop treatments or over the time of the experiment.

Table 1. ANOVA of soil biological parameters according to cover crop and no cover crop treatment at sites 1, 2, and 3. Standard errors are in parentheses.

	SOM†			Respiration			POXC			Protein-N			β-glucosidase			NAGase		
	----mg kg^{-1}----			----mg CO_2 kg^{-1}----			----mg kg^{-1}---------			----mg g^{-1}----			----mg p-nitrophenol kg^{-1}h^{-1}----					
	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3	Site 1	Site 2	Site 3
Cover crops	21.8 (1.1) a‡	21.6 (0.6)	14.3 (0.3)	91.88 (5.5)	112.0 (4.7)	69.2 (4.3)	555.0 (11.0)	562.8 (11.0)	474.2 (8.8)	4.24 (0.2)	5.0 (0.2) a	3.1 (0.1)	49.4 (2.9)	42.5 (2.8) a	20.9 (1.6)	14.6 (0.9) b	15.8 (1.6)	9.3 (0.6)
No cover crop	18.7 (0.8) b	21.0 (0.8)	14.2 (0.5)	96.88 (7.8)	108.8 (5.5)	65.9 (5.4)	551.9 (20.0)	541.9 (14.2)	468.1 (16.7)	4.22 (0.3)	4.3 (0.2) b	3.0 (0.2)	44.5 (3.8)	36.9 (3.0) b	21.0 (2.5)	17.0 (1.4) a	15.4 (2.0)	10.0 (1.5)
P-value	0.02	0.34	0.68	0.38	0.54	0.20	0.85	0.20	0.24	0.92	<0.001	0.20	0.20	0.03	0.81	0.02	0.53	0.63

†Soil organic matter (SOM), active C (POXC), and β-glucosaminidase (NAGase)
‡Lower case letters within the column denote significant difference at $P \leq 0.05$

The effect of cover crops on nutrient turnover in soil under soybean/corn or cotton rotation – J. Mite dissertation Chapter 2 (under B. Tubaña)

- Cover crops typically produced higher biomass then winter weeds which were allowed to grow uncontrolled in farmer standard areas (Table 2).
    - Higher cover crop biomass was related to increased nutrient scavenging and subsequent increases in soil available nutrients following cover crop degradation.
    - This was most pronounced in soil nutrients like phosphorus, potassium, calcium, and magnesium but was specific to each location, with the magnitude related to already existing soil concentrations and abiotic factors.
    - This increase did not, however, result in increased yields or net returns.
- Cover crops planted in September produced 764 (39%) and 1632 (153%) kg ha^{-1} more biomass than those planted in October and November, respectively.
    - This also resulted in increased nutrient scavenging.
- Economic analysis of the three model systems indicated that in the first 3 years, with NRCS incentives, net returns were still lower than no cover crop systems without NRCS incentives. However, cover crops coupled with NRCS incentives did result in increased net returns (Table 3).

Evaluating the impact of cover cropping on productivity of soybean/corn rotation in Louisiana – J. Mite dissertation Chapter 3 (under B. Tubaña)

- Across sites and years there was no significant difference in grain yield and nutrient removal rate detected between cover crop and no cover crop treatments (Table 4).
    - This lack of yield response was not unexpected, due to the slow change observed in the soil nutrient pool and the limited time of the study.
- There was no significant relationship between cover crop biomass and soybean and cotton yields. However increased cover crop biomass was correlated with increased corn yields in Harper Armstrong's fields.
    - In general, increases in cover crop biomass corresponded with decreases in soil available nutrients, specifically P, K, and S.
- Earlier cover crop planting dates resulted in increased biomass production, but this also corresponded to decreased soil nutrient availability.

Table 2. Biomass yield and macronutrient recovered under cover crop and no cover crop treatments at three locations in north Louisiana in 2018 and 2019.

Location	Year	Treatment	Biomass	N	Ca	K	Mg	P	S
			kg ha^{-1}						
Armstrong	2018	Cover crop 1[2]	831*	16.21*	2.63	10.31	0.82	1.69	0.91
		Cover crop 2	529	10.51	3.25	12.85	1.00	1.86	0.99
		No cover crop[1]	356	5.86	3.36	10.08	0.69	1.13	0.62
	2019	Cover crop 1	337	6.27	2.28	12.33	0.87	1.32	0.57
		Cover crop 2	569	10.74	5.47	19.64	2.15	2.13	1.16
		No cover crop	487	8.02	2.98	15.25	1.12	1.62	0.65
Macon LaFoe	2018	Cover crop 1	885*	26.36*	4.35	16.73*	1.10	3.38*	1.15*
		Cover crop 2	1012*	22.42*	6.43*	21.82*	1.52*	4.26*	1.87*
		No cover crop	138	3.49	1.33	4.57	0.35	0.63	0.23
	2019	Cover crop 1	16	0.18*	0.10*	0.74*	0.04*	0.08*	0.05*
		Cover crop 2	141	4.14*	1.26*	4.53*	0.30*	0.62*	0.35*
		No cover crop	0	0.00	0.00	0.00	0.00	0.00	0.00
Trey Peck	2018	Cover crop	895*	25.90*	5.49	30.91*	1.46*	5.67*	2.12*
		No cover crop	225	5.71	4.69	5.99	0.53	1.14	0.47
	2019	Cover crop	1565*	37.53*	18.85*	84.05*	3.56*	6.89*	4.83*
		No cover crop	458	11.27	5.96	20.89	1.43	1.96	1.01

[1] No cover crops consisted of the native weeds.
[2] Armstrong and Macon LaFoe sites had two Cover crop treatments (1 and 2) and one no cover crop.
* Values are significantly different from no cover crops for each site-year at P<0.05.

Table 3. Cover crop impact on net return for on-farm crop rotations.

	Net Return ($Ha $^{-1}$)					
	Cover Crops with NRCS Incentives		**Cover Crops without NRCS Incentives**		**No Cover Crop/ No NRCS Incentive**	
Site	**Corn/Soybean**					
Trey Peck	$1,994		**$1,712**		**$2,370**	
Macon Lafoe	$1,903		**$1,622**		**$2,723**	
	Soybean/ Cotton	Corn/ Cotton	**Soybean/ Cotton**	**Corn/ Cotton**	**Soybean/ Cotton**	Corn/ Cotton
Harper Armstrong	$3,008	$3,034	**$2,726**	**$2,753**	**$2,293**	$3,374

Table 4. Grain yield and macronutrient removed of main crop under cover crops and no cover crop treatments at three sites in northeast Louisiana in 2018 and 2019.

Year	**Site**	**Crop**	**Treatment**	**Yield**	**N**	**Ca**	**K**	**Mg**	**P**	**S**
				kg ha^{-1}						
2018	Armstrong	Corn	Cover crop 1[2]	11596	130	1.38	46	9.23	32.6	11.77
			No cover crop[1]	10474	119	0.97	42	8.32	29.8	9.95
		Soybean	Cover crop 2	4409	31	15.10	108	11.06	25.3	13.71
			No cover crop 2	4416	34	20.63	90	12.95	24.5	13.45
	Macon LaFoe	Corn	Cover crop 1	15079	173	0.98	62	11.92	44.1	15.55
			Cover crop 2	14640	159	1.31	60	11.99	43.6	15.79
			No cover crop	15124	168	0.76	53	11.89	43.2	15.35
	Trey Peck	Soybean	Cover crop	5731	331	20.23	117	13.80	30.9	17.09
			No cover crop	6335	329	23.50	117	15.35	36.3	19.54
2019	Armstrong	Cotton	Cover crop 1	2437	-	-	-	-	-	-
			Cover crop 2	2317	-	-	-	-	-	-
			No cover crop	2092	-	-	-	-	-	-
	Macon LaFoe	Soybean	Cover crop 1	4534	235	21.02	82	11.4	20.5	12.32
			Cover crop 2	4567	233	20.22	79	11.1	19.8	11.92
			No cover crop	4217	222	20.06	75	10.3	19.4	11.78
	Trey Peck	Corn	Cover crop	14367	209	0.09	97	25.3	86.0	18.29
			No cover crop	15924	222	1.41	104	27.5	91.5	19.73

[1] No cover crops included native weeds.
[2] Armstrong and Macon LaFoe sites had two sites with cover crops and one no cover crop.
* Values are significantly different from no cover crops within site-year (P<0.05).

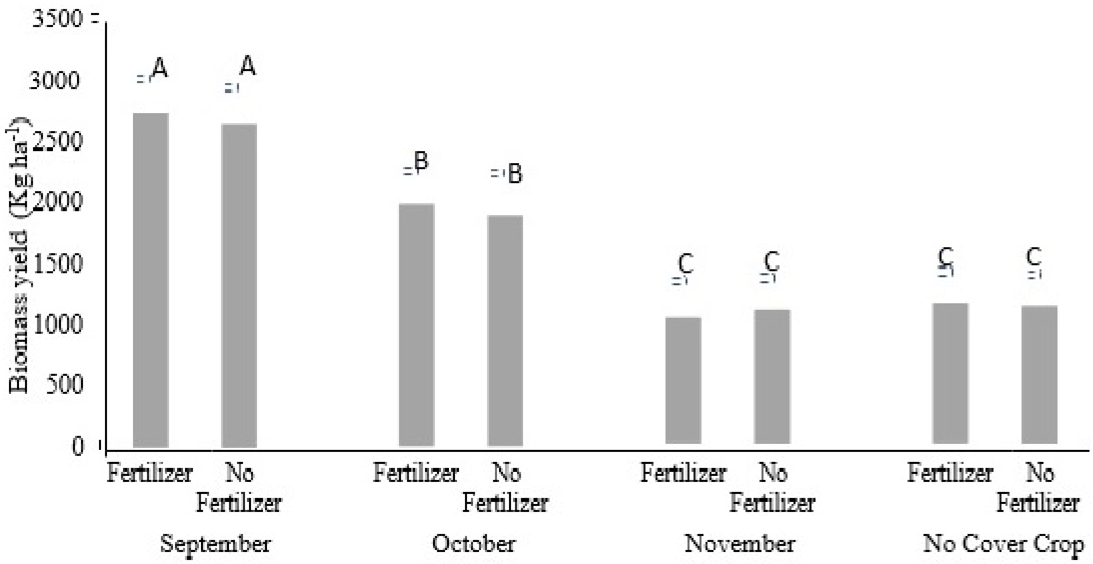

Figure 7. Cover crop biomass yield at different planting dates with and without starter fertilizer.

<u>Evaluating the effect of planting date and fertilization on biomass production of cover crops and nutrient turnover – J. Mite dissertation Chapter 4 (under B. Tubaña)</u>

- Cover crops (crimson clover, hairy vetch, and tillage radish) were established at the Ben Hur Research Station in September, October, and November of 2017 and 2018. This trial was overlaid with fertilizer treatments of P and K (17 kg ha^{-1}) or no fertilizer.
- Fertilizer application had no measurable impact on cover crop biomass production, however earlier planting dates resulted in increased cover crop biomass (Figure 7).

Soybean yields were greatest following cover crops planted in October and lowest following cover crops planted in November (Figure 8).

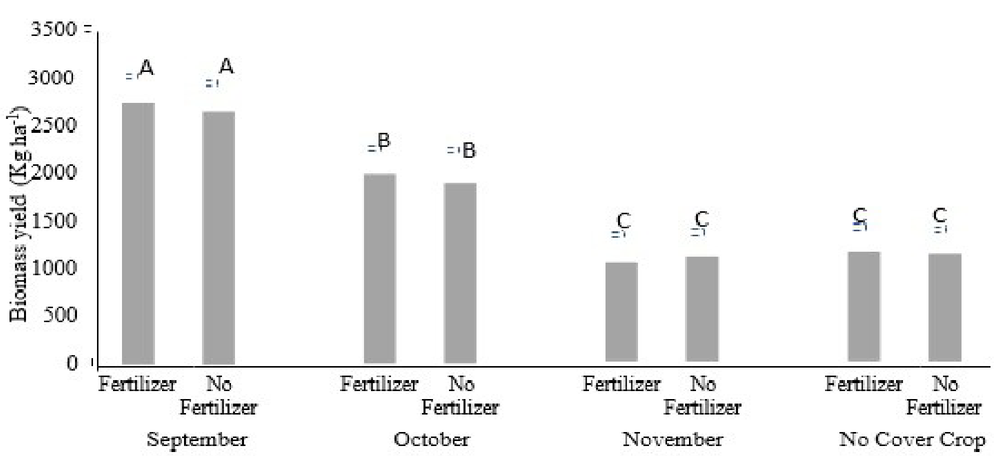

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Figure 8. Soybean grain yield in plots with cover crops planted at different dates, with and without starter fertilizer.

Cover Crop injury from pre-emergent herbicides - K. Gravois and A. Orgeron

- Cover crops tested included Persian clover, Florida broadleaf mustard, cherry belle radish, hairy vetch, Austrian winter pea, soybean (Figure 9). Preemergent herbicides included Prowl, Command, Velossa, and TriCor.
- Cover crops were somewhat susceptible to preemergent herbicides, with only one exception being Austrian winter pea, which was only susceptible to TriCor (Figure 10).
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Figure 9. Cover crop plots in sugarcane fields in St. Mary's parish. Fields were seeded with Persian clover, Florida broadleaf mustard, cherry belle radish, hairy vetch, Austrian winter pea, and soybeans in August 2017.

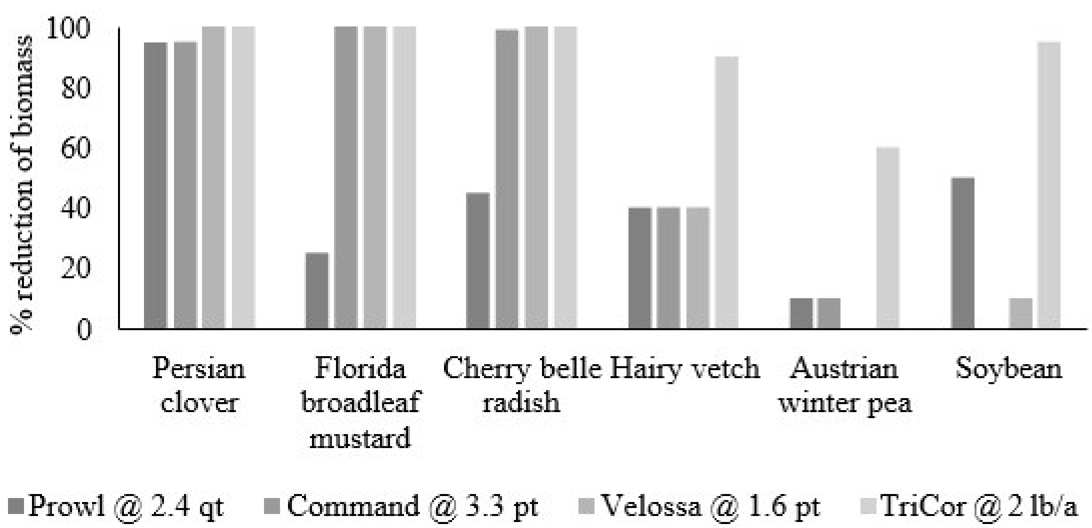

Figure 10. Cover crop susceptibility to preemergent herbicides.

Cover crop injury from fall applied herbicides Zidua/chloracetamide – J. Copes

- Cover crops damage was dependent on weather with dryer conditions reducing injury. Cover crops experiences greater injury under 4 oz ac^{-1} regardless of weather conditions.
  - Tillage radish was most sensitive to injury.
  - Broadleaf/henbit control was minimal, but control of bluegrass was excellent.
- These results provided recommendations for planting cover crops early into a clean seedbed.
  - Herbicides should be applied after cover crops are well established (1-3 weeks post emergence)

Cover crop effects on crop production – J. Copes

- Cover crops (more specifically grasses – cereal rye and black oats) significantly reduced winter weeds (Figure 11)
    - Hairy vetch also reduced winter weeds, but to a lesser extent.
- Covers crops have potential to reduce plant stand, however no reduction in crop yield was measured
- Cotton and soybean were more sensitive to cover crops than corn.
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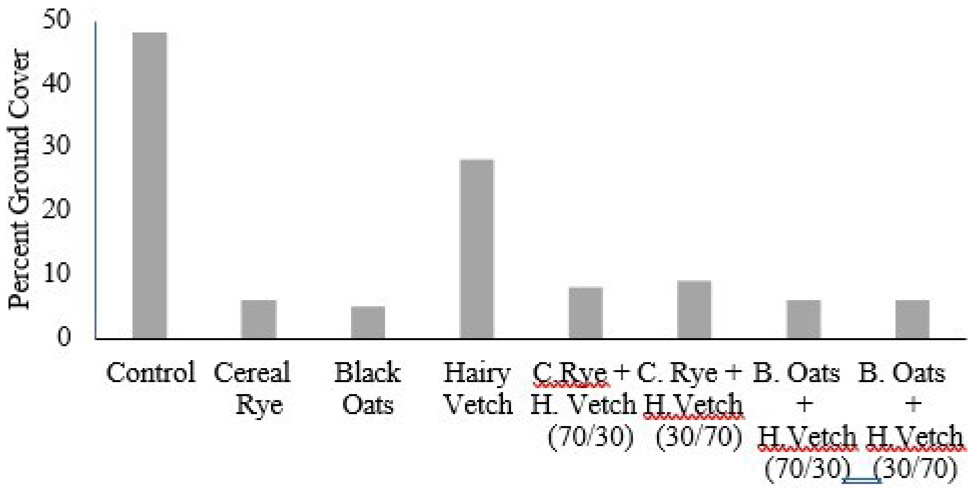
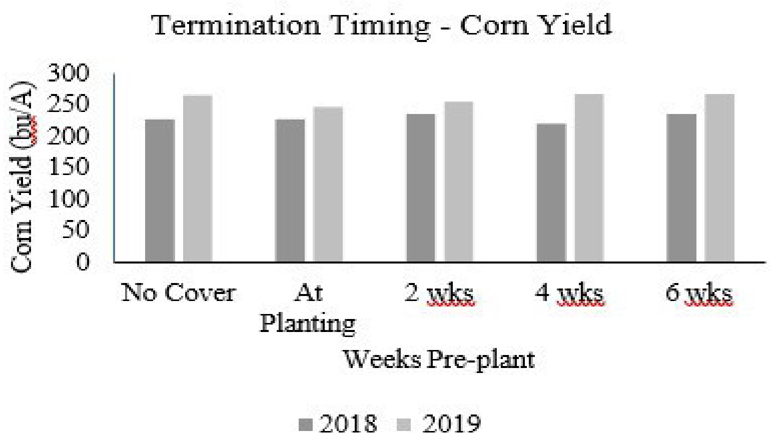
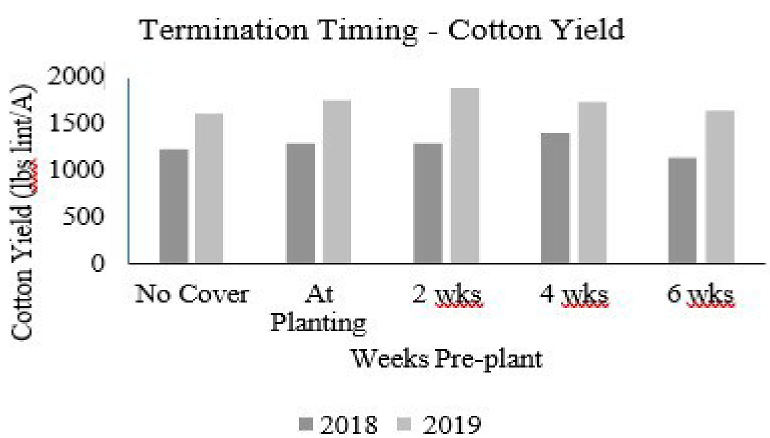


Figure 11. Percent ground cover provided by weeds (control) and cover crops.

Cover crop termination timing effects on crop yield – J. Copes

- Termination timing did not affect corn grain yield, but tended to yield higher when terminated 4 week pre-planting (Figure 12).
- Termination timing did not impact cotton yields.
    - Cover crops resulted in yield advantage ranging from 59 – 135 lbs lint ac-1
    - Depending on year, no-till + cover crops yields up to 154 lbs lint ac^{-1} over conventional till without cover crops
- Termination timing did not impact soybean yields, but tended to yield higher when terminated 4 weeks pre-planting.





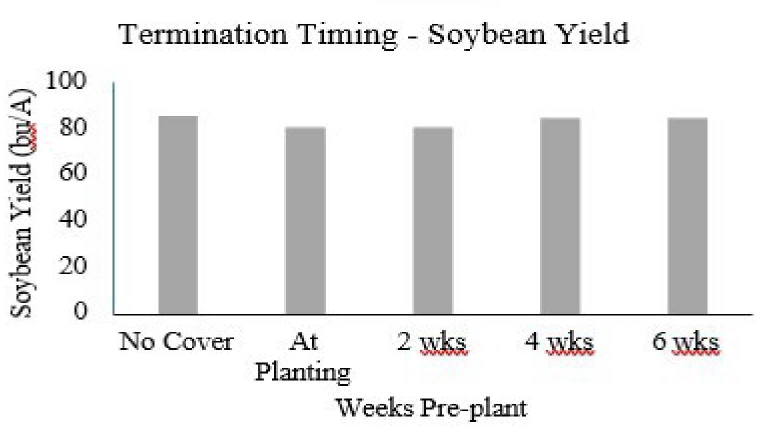


Figure 12. Impacts of termination timing on corn (a), cotton (b), and soybean (c) yields. Termination timing had no significant impact on crop yields.

Cover crops and N management - K. Iamjud dissertation Chapter 2 (under L.M. Fultz)

- Legumes (crimson clover, berseem clover, hairy vetch, winter pea) were seeded to supplement chemical N fertilizer applications (Table 5)
- Cover crops significantly reduced nitrate-N concentrations over winter, taking up residual N from corn production.
- Economic optimum N rates for corn production averaged 35 kg N ha^{-1} lower when following legumes compared to grasses and brassicas and 44 kg N ha^{-1} compared to fallow treatments (Table (Table 6),
- Legumes resulted in higher soil available P but lower soil K compared to grasses and brassicas (Table 7).
- Distinct microbial communities were present in the spring following cover crops. This was evident by higher proportions of Gram positive bacteria and saprophytic fungi following legumes and increased proportions of Gram negative bacteria and AMF under grasses and brassicas.

Table 5. Interaction of N rate, cover crop type, and sampling year on corn grain yield. Standard error in parentheses.

	N fertilizer rate (kg N ha^{-1})			
	0	90	179	269
	Corn grain yield (Mg ha^{-1})			
Cover crop type				
Legume	3.9 (0.26) A†b‡	8.3 (0.35) Aa	9.3 (0.37) Aa	9.1 (0.42) Aa
Grass & Brassica	2.4 (0.33) Bc	6.9 (0.24) Bb	8.8 (0.38) Aa	9.0 (0.43) Aa
Fallow	2.0 (0.28) c	6.5 (0.46) b	8.4 (0.75) a	8.4 (0.69) a
Sampling year				
2017	3.3 (0.38) A†c‡	8.8 (0.31) Ab	10.6 (0.25) Aa	10.6 (0.34) Aa
2018	3.0 (0.26) Ac	6.4 (0.18) Bb	7.5 (0.21) Bab	7.6 (0.28) Ba

	Cover crop type		
Sampling year	Legume	Grass & Brassica	Fallow
	Corn grain yield (Mg ha^{-1})		
2017	9.0 (0.39) Aa	7.7 (0.53) Ab	7.4 (0.9)
2018	6.4 (0.26) Ba	5.9 (0.33) Bb	5.2 (0.6)

†Same uppercase letters are not significant (α = 0.05) between cover crop treatments or sampling year.
‡Same lower letters are not significant (α = 0.05) across N rates with cover crop treatments. Fallow values are provided for quantitative comparison only and were used in statistical analysis within N rates.

Table 6. Corn yield response parameters† at economic optimum nitrogen (N) fertilizer rate (EONR) for each cover crop treatment as predicted by the quadratic-plateau regression model

Cover crops	a	b	c	N rate at the plateau	EONR	Yield at plateau
		Mg ha^{-1}		kg N ha^{-1}	kg N ha^{-1}	Mg ha^{-1}
Legume	3.92	0.06987	-0.00023	151	149	9.23
Grass &brassica	2.39	0.06356	-0.000169	207	184	8.31
Fallow	1.95	0.06569	-0.000167	197	193	8.43

Table 7. The effect of cover crop treatments, N fertilizer rates, and soil sampling times on soil extractable phosphorus and potassium concentrations.

Parameters	Phosphorus	Potassium
	mg kg^{-1}	
Cover crop type (CC)		
Legume	33.9 (1.2) A†	183.9 (2.0) B
Grass & Brassica	28.0 (1.1) B	208.4 (3.5) A
Fallow	29.4 (1.7)	196.1 (5.0)
N fertilizer rates (N)		
0	39.0 (1.6) A	207.4 (3.7) A
90	27.0 (1.4) B	191.1 (3.5) B
179	28.8 (1.7) B	196.2 (4.2) B
269	29.0 (1.6) B	189.9 (4.1) B
Sampling times (S)		
Spring 2017	34.0 (1.7) A	195.7 (2.8) B
Fall 2017	29.2 (1.5) A	213.6 (4.6) A
Spring 2018	29.8 (1.6) A	185.4 (3.7) C
Fall 2018	30.8 (1.7) A	189.8 (4.0) BC

†Same uppercase letters are not significant ($\alpha = 0.05$) between cover crop treatments, N fertilizer rates, or sampling times.

Biomass degradation and production in multispecies mixes – K. Iamjud dissertation Chapter 3 (under L.M. Fultz)

- Inclusions of cover crops significantly reduced weed populations in two research demonstration plots located in NE and central Louisiana when sufficient biomass (approximately > 1200 kg dry weight per hectare) was present. For example (Figure 13) in 2020 central Louisiana wheat + berseem clover plots contained greater weed populations then those measured in fallow control plots.
- Biomass C/N ratios were measured for all individual cover crops included in mixtures and it was found that, even with delayed termination (by Louisiana standards) of 2-4 weeks pre-plant C/N ratios were <30:1 which at which point N immobilization may be a concern for nutrient cycling.
- Cover crop degradation exceeded 40% biomass loss within 8 weeks of termination, often exceeding 60% losses when legumes were present, while winter weeds like Henbit degradation did not exceed 20% biomass loss in that same time frame.
- Soil inorganic N concentrations were greatest approximately 6 weeks post termination.

Cover crop treatments

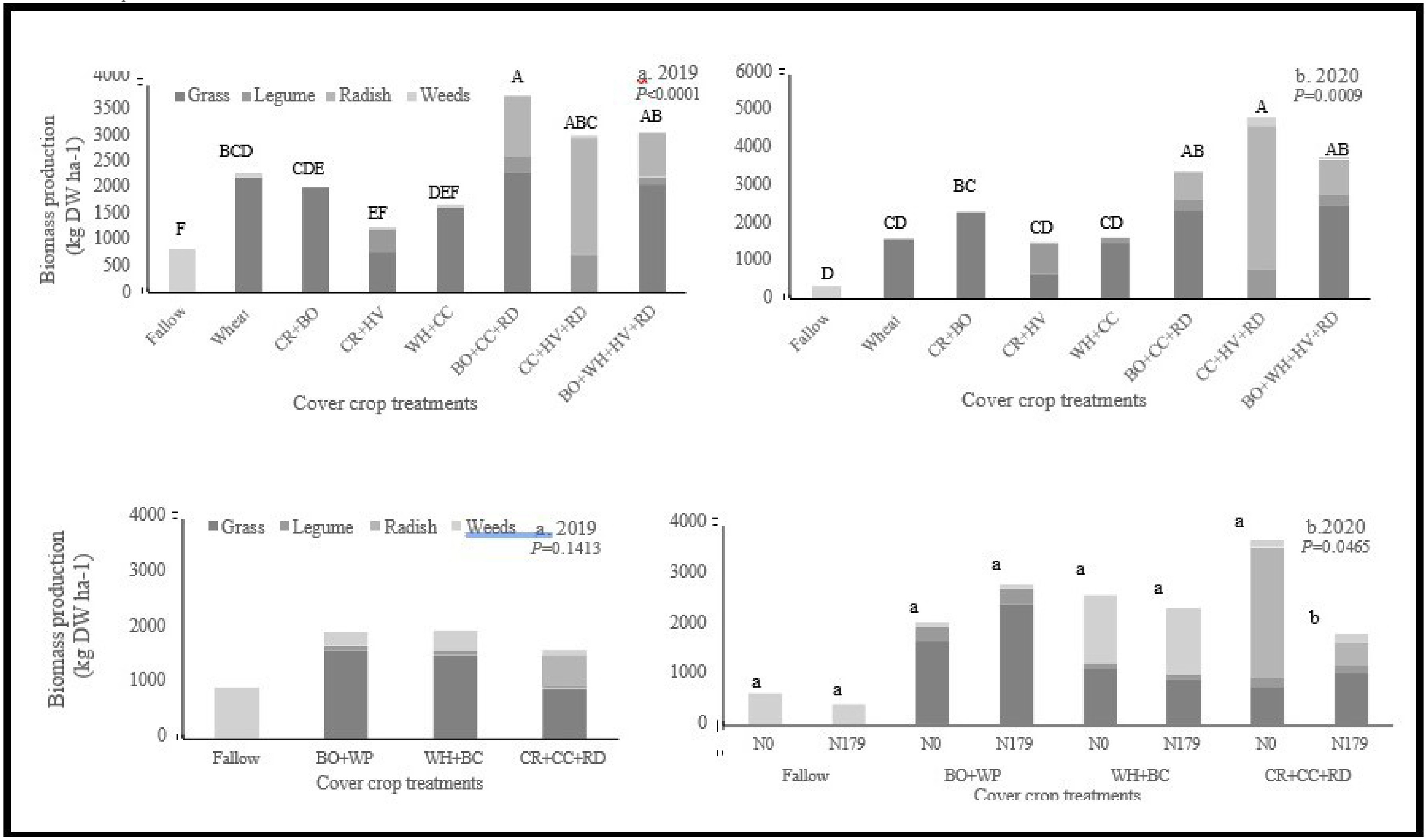


Figure 13. Aboveground cover crop biomass produced in 2019 and 2020 at Macon Ridge and Dean Lee site. Wheat (WH), berseem clover (BC), black oat (BO), winter pea (WP), cereal rye (CR), crimson clover (CC) and tillage radish (RD). Different lower letters indicate the significant difference between nitrogen rates within a cover crop treatment at $P<0.05$ by Turkey test.

Impact of cover crops on soil and plant nutrient content and sugarcane productivity – D. Forestieri dissertation Chapter 2 (under B. Tubaña)

- In first and second stubble sugarcane, cover crops did increase stalk populations, cane yield, and sugar yield.
- Cover crops removed significantly more plant essential nutrients compared to native weed populations, ranging from 40-60% for nutrients like N, P, K, S, Ca, and Mg.
- Although dependent on location, when no N fertilizer was applied, soil inorganic N concentrations tended to be higher following cover crops, with an increase measured as early as 8 weeks after termination.
- Soil P, K, Zn, and Cu concentrations were consistently higher in plots with cover crops during the first years after cover crop termination.

Summer cover crops impact on water quality – T. Elbana

- Soybean, cowpea, and Sunn hemp were planted in April into sugarcane fields at the Louisiana Agriculture Sugar Research Station (St. Gabriel, LA).
- Cover crop biomass and soil samples were collected prior to cover crop termination in July. Water quality samples were collected over the growing season.
- Soybean, Sunn hemp, and cowpea averaged 283, 518, and 283 kg ha^{-1} of biomass, respectively.
- On average, soybean (370 m^3) had the lowest cumulative runoff compared to Sunn hemp (avg 719 m^3) and cowpea (786 m^3). Despite this difference in runoff, there was no measured difference in turbidity or total suspended solids between cover crops species (Figure 14 - Left). However, a decrease in turbidty and TSS was measured over the growing season, which was most evident following heavy rainfall events in 2019.
- There was no significant difference in average dissolved nitrate-N or P concentrations in runoff water collected (Figure 15).

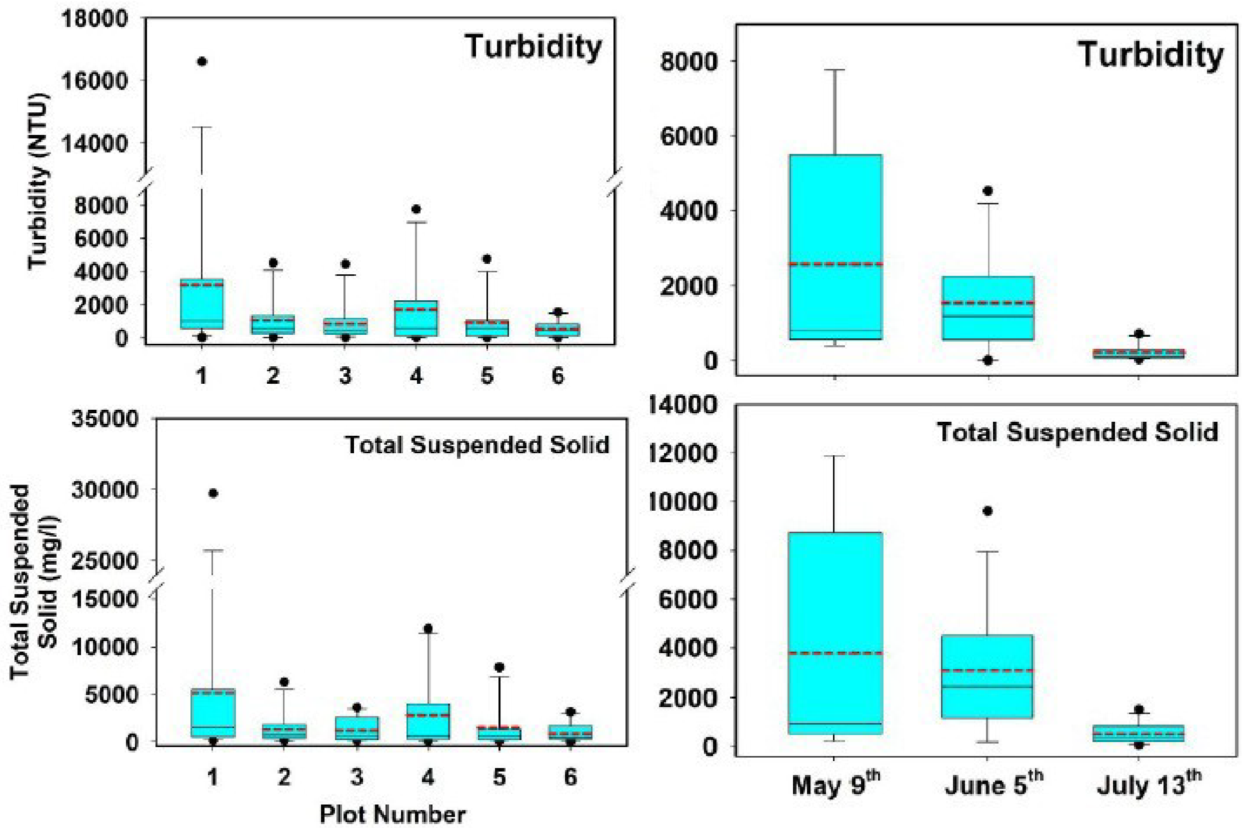


Figure 14. Box plots of turbidity and total suspended soils per cover crop field-plot (No. 1 and 3 = Soybean, No. 2 and 5 = Sunn hemp, No. 4 and 6 = Cowpea) over the growing season (left) and following heavy rainfall events (right) at Sugar Research Station. Red dash lines are average values, with 75th (top), 50th (middle), and 25th (bottom) percentiles. Whiskers represent the 10th and 90th percentile and solid circles are outliers.

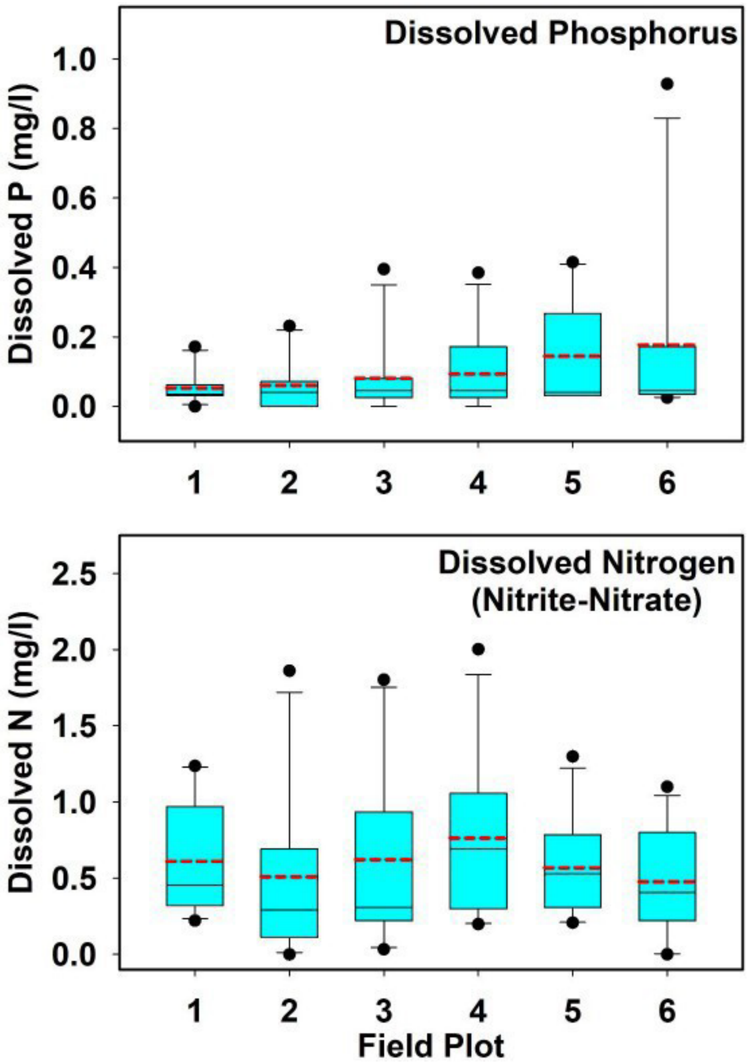


Figure 15. Box plot of dissolved phosphorus and nitrate-N for each cover crop field (No. 1 and 3 = Soybean, No. 2 and 5 = Sunn hemp, No. 4 and 6 = Cowpea) over the growing season at the Sugar Research Station. Red dash lines are average values, with 75th (top), 50th (middle), and 25th (bottom) percentiles. Whiskers represent the 10th and 90th percentile and solid circles are outliers.

- Some variability in the dissolved P concentrations were likely related to increased soil P concentrations, particularly in fields 4, 5 and 6.
- After one season, soybean (0.41 cm h^{-1}) and Sunn hemp (0.54 cm h^{-1}) fields tended to have higher hydraulic conductivity compared to cowpea (0.25 cm h^{-1}) fields.

Impacts of cover crops on water quality at three sites located in St. Gabriel (Sugar Research Station) and Paincourtville, LA (producers fields) – D. Forestieri (under B. Tubaña)

- First flush samplers were used to assess runoff water quality at three locations seeded with cover crops.
- Water samples were collected following rainfall events from May 2017 through October 2018 (Paincourtville) and September 2019 (St. Gabriel).
- Overall, there were few clear trends in water nutrient concentrations between cover crop and no-cover crop areas and tended to vary by location and soil texture.
    - Site 1 (St. Gabriel) – No cover crops tended to result in increased total dissolved solids, total suspended solids, and tubidity
    - Site 2 (St. Gabriel) – At project initiation cover crop fields tended to have higher concentrations of total P, nitrate-N, and total suspended and total dissolved solids.
    - Site 3 (Paincourtville) – Nitrate-N concentrations tended to be higher under cover crops, however, no cover crop controls resulted in increased ammonium-N, total suspended and dissolved solids.

Challenges

- Despite our initial goal of identifying landowners in all watersheds, this proved difficult or impossible. This did, however, allow for increased numbers of demonstration fields in watersheds with the greatest concentration of agricultural production in Louisiana. Specific farms were still selected for more intensive sampling and analysis which allowed us to spread our efforts to additional producers.
- In general, farmer demonstrations fields provide optimal opportunities for information to be shared with their neighbors and peers. However, often these fields are located in areas difficult to access or not easily visible. For this reason, it was beneficial to utilize both on-farm and research demonstration fields. This also allowed use to demonstrate best case scenarios (research stations) and farmer experiences, which did not always agree.
- Many of Louisiana's current cover crop recommendations are based on out-of-date information or data collected from northern climates which do not always correspond to conditions experienced in Louisiana. This led to some initial failures in cover crop establishment in the initial year of the study. However, this also served a queue for what information was most needed (i.e. seeding rates, termination timing impacts, weed management, etc). This was used to adjust recommendations and establish additional studies to answer many of these existing questions.
- All of the producers that were cooperators for this project were enthusiastic to participate. Despite this, maintaining multiple on-farm demonstrations was difficult due to occasional communication issues. This resulted in less optimal cover crop recommendations and management at times, but again replicated on-farm issues to be addressed by future studies.
- The variability between abiotic factors (soil texture, soil health depletion, previous management practices) and the relatively short-term (~3 years) of cover crop establishment may have masked many of the benefits from cover crops, suggesting longer establishment times would be beneficial. This was also hindered by many producers reluctance or inability to adopt no-till production.

Outputs

Workshops/Conferences/Field Days

2018 Louisiana Soil Health and Cover Crop Conference – January 23rd, 2018 – Monroe, LA
2018 Louisiana Soil Health and Cover Crop Conference – January 24th, 2018 Alexandria, LA
2018 Cover Crop and Soil Health Field Day – February 7th, 2018 Winnsboro, LA
2018 Cover Crop and Soil Health Field Day – February 13th, 2018, St. Joseph, LA
Informal producer meeting – L.M. Fultz was invited to advise forage and grassland producers on the potential benefits of cover crops and soil health – Spring 2018
Sugarcane Field Tour & Soil Health Conference – July 26th, 2018 Jeanerette, LA
Soil Health Workshop and Cover Crop Field Day – February 26, 2020 St. Joseph, LA
Soil Health Field Day – October 18th, 2020 St. Joseph, LA

Tools/Infographics

Adusumilli, N. 2018. Cover Crop and Tillage Scenarios
https://www.lsuagcenter.com/~/media/system/b/d/4/4/bd4437aff5c14f251a1be318b8b206a6/infographic_nadusumillipdf.pdf
Adusumilli, N. and Hendrix, J. 2019. Cover Crop Decision Tool
https://www.lsuagcenter.com/profiles/nadusumilli/articles/page1533331282945

PhD Dissertations

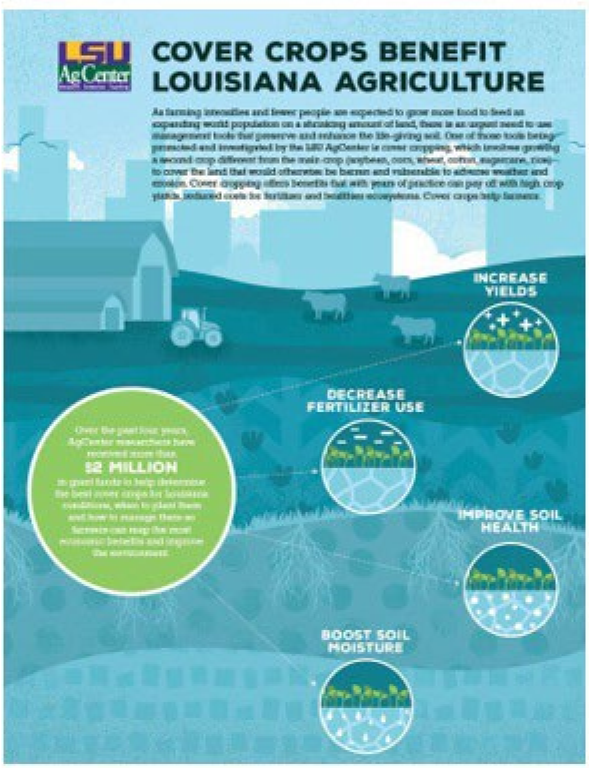
- José Rodolfo Mite Cáceres - Cover cropping in soybean-corn rotation system: Economic, Agronomic and Soil Fertility Impact – Chapters 2, 3, and 4
  https://digitalcommons.lsu.edu/gradschool_dissertations/5665/
- Daniel Forestieri - Integrated nutrient management and cover cropping practices in Louisiana Sugarcane Production Systems – Chapter 3
  https://digitalcommons.lsu.edu/gradschool_dissertations/5292/
- Kritsanee Iamjud - The effect of fallow season cover crops on nutrient cycling and soil health in row crop production in the mid-south – Chapters 2, 3 and 4
  https://digitalcommons.lsu.edu/gradschool_dissertations/5506/

Magazine Articles

Louisiana Agriculture Magazine Fall 2020 Vol 63, No. 4 – Focus issue on covers crops across a variety of productions systems. Work was either a part of the CIG project or was building upon what was learned from the on-going CIG project.
(https://www.lsuagcenter.com/portals/communications/publications/agmag/archive/2020/fall)

- Fultz, L.M. 2020. Providing Tools for Productivity and Sustainability
- Tubaña, B., Campos, B., Forestieri, D., Mite, J. 2020. Plant Date Effect on Cover Crops Biomass Yield and Nutrient Turnover
- Tubaña, B., Fajardo, H., Forestieri, D. 2020. Sensor-Based Prediction of Cover Crops Biomass and Nutrient Recover
- Tubaña, B., Forestieri, D., Fultz, L.M., Mite, J. 2020. Cover Cropping Enriches Soil
- Gentry, D., Fultz, L.M. 2020. Do Winter Cover Crop Seeding Rates and Soil Type Impact Soybean Production?
- Peveto, K. 2020. Cover Crop Comeback
- Orgeron, A.J., Gravois, K., White, P. 2020. Can Sugarcane Production Be Improved with Cover Crops?

- Copes, J., Miller, D., Stephenson, D., Dodla, S., Clark, O., Nettervile, M. 2020. Utility of Zidua (Pryoxasulfone) Herbicide in Winter Cover Crop Weed Management
- Brown, S., Price, P., Towles, T., Davis, R., Purvis, M., Emfinger, K., Walker, W., Ezell D. 2020. Effect of Cover Crop Seed Treatment on Stand Establishment in Corn, Cotton and Soybeans
- Adusumilli, N., Wang, H. 2020. Cover Crop Economics: Analysis from Studies across Louisiana
- Jeong, C., Hendrix, J., Copes, J., Fultz, L.M. 2020. Impact of Cover Crop Residue Management and Nitrous Oxide Emissions in Louisiana
- Iamjud, K., Fultz. L.M. 2020. How Cover Crops Produce Nitrogen Input and Improve Soil Health
- Iamjud, K., Fultz, L.M. 2020. Cover Crop Degradation and Nitrogen Availability for the Subsequent Cash Crops
- Walsh, M., Irving, J. 2020. Planting Seeds for Sustainable Agriculture in Science Class
- Negrete, P.C.M., Fultz, L.M. 2020. Research Brief: Effects of Cover Crops on Soil Health in Pasture Harvesting
- Bridges, K., Fultz, L.M. 2020. Research Brief: Effects of a Diverse Mix of Winter Annuals in Perennial Warm-Season Pastures



Infographic insert included in Louisiana AgMagazine Focus Issue

Popular Press

- Osborne, K. 2018. Louisiana: Soil Health and Cover Crops – Workshop Takeaway https://agfax.com/2018/02/20/louisiana-soil-health-and-cover-crops-workshop-takeaway/
- Smith, R. 2019. Cover crop selection depends on production goals. Delta FarmPress https://mobile.farmprogress.com/cover-crops/cover-crop-selection-depends-production-goals

LSU AgCenter

- Schultz, B., Blanchard, T., Gould, F. 2018. Cover crop research improving yield, enhancing soil health https://www.lsuagcenter.com/profiles/aiverson/articles/page1536782894049
- Louisiana Crops Newsletter. 2018 Vol 8 Issue 8 https://www.lsuagcenter.com/~/media/system/9/a/4/a/9a4aaabf84e535355ed8f7ea585c3821/louisiana%20crops%20newsletter%20september%202018pdf.pdf
    - Copes, J., Hendrix, J., Fultz, L.M., Dodla, S., Adusumilli, N. Make winter cover crop plans
    - Fultz, L.M. Cover crops in corn, soybean production
- Adusumilli, N. 2018. Q&A of conservation policy and crop insurance surrounding cover crops https://www.lsuagcenter.com/profiles/nadusumilli/articles/page1520011387670
- Osborne, K. 2018. Workshop highlight soil health research https://www.lsuagcenter.com/profiles/tblanchard/articles/page1519140172993
- Bogren, R., 2018. Soil health, cover crops to be covered at sugarcane field day https://www.lsuagcenter.com/profiles/rbogren/articles/page1529417032994
- Bogren R. 2019. Researchers look at managing cover crops https://www.lsuagcenter.com/profiles/aiverson/articles/page1573087015497
- Bogren, R. 2020. AgCenter soil workshop, field day set for February 26 in St. Joseph https://www.lsuagcenter.com/profiles/rbogren/articles/page1581005477597

Fact Sheets

- Gravois, K. and Orgeron, A. 2021. Cover Crops for Louisiana Sugarcane Production https://www.lsuagcenter.com/profiles/aiverson/articles/page1620152413689

Abstracts

- Mite, J., B. Tubana, L. Fultz, M. Dalen, D. Forestieri, J. Cruz, W. Paye, J. Bamrungrai, D. Mayorga, and H. Mendoza. 2019. Nutrient contribution and different cover crops species in row crops production systems in Louisiana. ASA-CSSA-SSSA Annual Meeting, Nov. 10-13, 2019, San Antonio, TX.
- Campos, B., J. Mite, M. Dalen, D. Forestieri, D. Galam, H. Fajardo, J. Cruz, D. Mayorga, H. Mendoza, and B. Tubana. 2020. Influence of establishment date on cover crops biomass yield and soil productivity potential. ASA-CSSA-SSSA Annual (Virtual) Meeting, Nov. 9-13, 2020.
- Mite, J., B. Tubana, and D. Forestieri. 2018. Effect of planting date and fertilization on cover crops biomass production in soybean-corn rotation system. ASA-CSSA-SSSA International Annual Meetings. Nov. 4-7, 2018, Baltimore, MD. ASA-CSSA-SSSA International Annual Meetings. Nov. 4-7, 2018, Baltimore, MD.

Presentations (Invited/Poster/Oral)

- Fultz, L.M. (Invited). Louisiana Conservation District Association Meeting – Soil Health Panel (apx. 100 attendees)
- Copes, J. and Hendrix, J. (Invited) 2018. Morehouse Parish Field Day – Focus on black farmers in Louisiana (apx. 200 attendees)
- Copes, J. (Invited) 2018 Louisiana Agriculture Technology and Management Conference. Compatibility of cover crops and fall-applied residual herbicides https://laca1.org/wp-content/uploads/2018-LATMC-Preliminary-Programdoc.pdf
- Josh Copes (invited; contains data slides) 2020 Louisiana Agriculture Technology and Management Conference. Cover crop research at Louisiana State University https://laca1.org/wp-content/uploads/2020-presentations/Cover_Crop_Research_at_Louisiana_State_University_Josh_Copes.pdf
- Mite-Caceres, J., M. Dalen, W. Paye, D. Forestieri, J. Cruz, L. Fultz, and B. Tubana. 2019. Effect of planting date and fertilization on cover crops biomass production in soybean-corn rotation system. 2019. 17th Annual Nitrogen Use Efficiency Conference, Columbia, MO. Aug. 5-7, 2019.
- Mite-Caceres, J., D. Forestieri, M. Martins, S. Kwakye, J. Garrett, M. Dalen, W. Paye, and B. Tubana. 2018. Effect of planting date and fertilization on cover crops biomass production in soybean-corn rotation system. 16th Annual Nitrogen Use Efficiency Conference, Manhattan, KS. Jul 30 to Aug. 1, 2018.

Next Steps

- Establish cover crop recommendations specific the Louisiana and the mid-south production systems
  - This includes assessing current seeding rates, species, and effectiveness of mixtures
  - Data will be made available for use in regional support tools like that in development with the Northeastern and Southern Cover Crop Councils
- Examine cover crops in combination with a variety of conservation practices, i.e. no-till, precision nutrient applications, alternative weed management, etc.
- Complete publication of a cover crop handbook to be distributed to Louisiana producers
  - Develop web resources based on research and demonstration field findings
- Many studies have demonstrated that some benefits of cover crop usage may be cumulative and require multiple years to be detected. For this reason, establishment and assessments of longer term (>3 years) samples are needed.