Sod-Based Rotation Systems: Research for Whom?

by

Jennie Jane Hargrove

A thesis submitted to the Graduate Faculty of
Auburn University
in partial fulfillment of the
requirements for the Degree of
Master of Science

Auburn, Alabama
May 4, 2019

Keywords: agriculture, sustainable, farmer,
perceptions, barriers, technology

Approved by

Michelle R. Worosz, Chair, Professor of Rural Sociology
Joseph J. Molnar, Professor of Rural Sociology
Brenda V. Ortiz, Associate Professor of Crop, Soil, and Environmental Sciences

Abstract

Over the last two decades, a Southeastern multi-institutional, multidisciplinary research team developed a low-input sod-based rotational system with integrated cattle (SBRC) to improve sustainability for small- to medium-size producers. This study draws on the literatures of adoption and diffusion of innovations and both agricultural science and science and technology studies including technology transfer, as well as the production of actionable science. Findings suggest that while nearly all researchers viewed the SBR as beneficial to the biophysical environment, over 40% believed that modifications were needed to both the SBRC and the research design. In contrast, producers had significant concerns about the system that demonstrate a lack of trust in the researchers who developed and the extension agents who endorsed the SBRC due to a lack of complete information, failure to incorporate regional characteristics, and perceptions of overall system complexity. These findings illustrate the consequences of research initiated without stakeholder input into project objectives, design, and oversight, as well as the challenges of long-term, multi-state, multidisciplinary research that continues to take place within the existing structure of disciplinary science. These findings underscore the need for inclusion of social scientists throughout projects such as SBRC (particularly at the “front-end”) to facilitate a democratic process of technology development that is compatible with existing social and economic structures.

Acknowledgments

I am grateful for the unwavering support shown by my mother, my sister, and my exceptional husband throughout the process of writing this thesis. I am also grateful for Dr. Michelle R. Worosz for the encouragement and support, and to the Auburn University Graduate School for allowing me to finish after a somewhat lengthy, yet necessary, hiatus. Most of all, I am grateful for Reba Louise Hargrove. You not only inspired me to finish, but you inspire me to be a better person daily. Run wild, my child.

Table of Contents

List of Tables

List of Figures

List of Abbreviations

AU	Auburn University
CES	Cooperative Extension Service
EQIP	Environmental Quality Incentives Program
ERS	USDA's Economic Research Service
GCFI	Gross Cash Farm Income
LGCC	Land Grant College Complex
LGU	Land Grant University
NRCS	USDA's National Resources Conservation Service
SBR	Sod-Based Rotation
SBRC	Sod-Based Rotation with Cattle
UGA	University of Georgia at Athens
UFL	University of Florida
USDA	United States Department of Agriculture

CHAPTER 1: INTRODUCTION

Prior to the mechanization of farming in the twentieth century, agricultural producers commonly integrated crop and livestock production. Science and technology, the economy, and the agricultural sector more broadly led to commodity-specific production for most farmers (Conkin 2008). While specialization has proven economically profitable for some, particularly large scale, intensive, and highly industrialized producers, crop specialization is less sustainable when used for long periods of time. A renewed interest in crop and livestock integration has emerged as a result of interest in sustainable agriculture. In the context of this project, agricultural sustainability will be viewed through the lens of economist Gordon K. Douglass. Douglass (1984, 25) explained agricultural sustainability by writing, “Agriculture will be found to be sustainable when ways are discovered to meet future demands for foodstuffs without imposing on society real increases in social costs of production and without causing the distribution of opportunities or incomes to worsen.” This thesis is part of a larger project developed to explore the socioeconomic and environmental benefits of integrating cattle into cotton-peanut rotations in Alabama, Georgia, and Florida. While farming in the Southeast region is extremely diverse, the most prominent crops in the region include timber, peanuts, cotton, citrus, tobacco, rice, fruits, vegetables, and broiler chicks (McNulty et al. 2015).

PURPOSE

The purpose of this thesis is two-fold. First, it explains the development of the sod-based rotation system with integrated cattle by Land Grant Universities (LGU) in Alabama, Georgia, and Florida. The thesis examines both the development of the system itself as well as endorsement strategies used by system developers to disseminate information to agricultural producers. Second, the thesis provides insight as to agricultural producers' perceptions of the sod-based rotation system with integrated cattle (SBRC), as well as their perceived barriers and constraints to adoption of such a system.

BACKGROUND

Researchers in Alabama, Georgia, and Florida began to re-examine integrated cropping systems in 2000 as part of a multi-state, interdisciplinary research project. In a collaborated research effort between Auburn University (AU), the University of Florida (UFL), and the University of Georgia (UGA), a new agricultural system, referred to as the sod-based rotation system with integrated cattle (SBRC), is being studied. These projects have been funded heavily by USDA-NIFA grants (Wright et al. 2015) .

This system was developed as a means to improve soil fertility and diversify "small" farm operations to provide a buffer for ever-fluctuating commodity prices for farmers in Southeast Alabama, North Florida, and South Georgia in a region referred to by project members as the "Wiregrass Region."

SETTING

This study is set in the "Wiregrass Region," which is defined differently in social and biophysical contexts. The area included in the project is loosely defined as Southeastern Alabama, South Georgia, and North Florida. There are SBRC test plots at five locations in the tri-state region, which will be referred to as Northwest Florida, Florida Panhandle, Northeast Florida, South Alabama, and South Georgia,

Ecologically, the Wiregrass Region can refer to the sandy soils on coastal plains of the southern United States which, at one time, was covered in pine and wiregrass (Wetherington 2006). The United States Fish and Wildlife Service defines the Wiregrass Ecosystem as an area spanning portions of the Carolinas, Tennessee, Arkansas, Kentucky, Georgia, Florida, Alabama, and Louisiana (Carolina Sandhills Wildlife Refuge 2010). This area is unique because of the longleaf pines that once covered its approximately 90 million acres, which were prone to burning as a result of natural fires. The ecological boundaries of this region continue to shift in response to deforestation and agriculture (Wetherington 2006). Fewer than two million acres of the naturally occurring Wiregrass ecosystem exist today, primarily on coastal plains. This definition is based on biophysical characteristics, but does not reflect the rough definition used by researchers on the project.

In contrast, Troy University's Wiregrass Archives (Troy University 2013) defines the Wiregrass Region as the following states and counties (See Figure 1.1):

Alabama: Barbour, Coffee, Covington, Crenshaw, Dale, Geneva, Henry, Houston, Pike

Florida: Bay, Calhoun, Gadsden, Holmes, Jackson, Liberty, Walton, Washington

Georgia: Baker, Decatur, Dougherty, Early, Grady, Miller, Mitchell, Seminole

While at first glance this definition appears to be geographically constructed, it is actually socially constructed, as the University claims inhabitants of this region have a shared history (Troy University 2013). Troy's definition of the region more closely reflects the agricultural area focused on in this study.

Figure 1.1: A map of the Wiregrass region (shaded counties) as defined Troy University's Wiregrass Archives.

AGRICULTURE IN THE WIREGRASS

The agricultural economies of Alabama, Florida, and Georgia are very diverse due to their moderate climates and long growing seasons. Historically, Southeastern agriculture emphasized cotton and tobacco production with enough production of food crops for subsistence (Blevins 1998). Tobacco production has since declined drastically. Farms now vary greatly, from large-scale commercial operations to small family-owned operations (Cochrane 1993).

Using Troy's definition, the Wiregrass region is comprised of 25 counties in three states, each state having a unique agricultural economy. A basic description of each state's agricultural economy in the Wiregrass region follows:

Alabama. Alabama's primary livestock outputs are poultry and cattle. In the Wiregrass, cow-calf operations are common, but the number of these producers who also grow row crops is unclear. The most prevalent crops are forages, cotton, peanuts, and corn. Some vegetables and fruit are also produced (U.S. Department of Agriculture 2014).

Florida. Florida's primary agricultural output is fruit and vegetable crops. In the Wiregrass region of the state, commodity crops are common, including peanuts, cotton, corn, and forage. Poultry, beef cattle, and the dairy industry are most important to Florida's livestock production (U.S. Department of Agriculture 2014).

Georgia. Georgia is most famous for its production of peanuts, pecans, and peaches, which make up its most important crops. Georgia is also known for production of some fruits and vegetables, such as sweet potatoes and watermelons. In the Wiregrass, Georgia produces cotton, peanuts, corn, and wheat as commodity crops. Poultry and cattle are Georgia's primary livestock outputs (U.S. Department of Agriculture 2014).

Data collected by the USDA's 2012 Census of Agriculture (See Table 1.2) indicates farms in the Wiregrass area most commonly produce poultry, cattle, forages, peanuts, cotton, and corn (U.S. Department of Agriculture 2014). The 25 counties in the Wiregrass region have 12,575 farms with over 3.6 million acres of land. 66% of land is used to grow commodity crops. Nearly 40% of farms have cattle in part of their agricultural operation with 381,300 cattle in the Wiregrass region. The average farm size is 323 acres. The Wiregrass region has 370,722 acres of cotton and 364,995 acres of peanuts, which are the dominant commodity crops. Only 10% of the 3.4 million acres of land in farms are irrigated. Twenty two percent of agricultural land in the region is rented.

Table 1.2: Agricultural data from Troy's Wiregrass counties from 2012 USDA Agricultural Census

State	County	Farms	Land in Farms	Average Size Farm	Median Size Farm	Total Cropland		Irrigated Land		Cattle & Calves Inventory		Cotton (Acres)	Peanuts (Acres)	Rented Land	
						Farms	Acres	Farms	Acres	Farms	Number			Acres	Percent
Alabama	Barbour	571	204,258	358	186	355	41,301	19	2,301	249	17,369	5,935	3,583	33,835	17%
	Coffee	899	202,255	225	98	634	85,455	36	3,267	311	22,719	22,425	14,784	49,983	25%
	Covington	1,051	208,556	198	80	658	65,452	16	1,436	445	26,691	16,271	9,024	33,835	16%
	Crenshaw	575	129,893	226	120	372	29,013	15	901	286	27,323	(D)	2,174	17,933	14%
	Dale	487	129,788	267	100	326	49,579	30	2,568	149	9,775	13,413	11,877	26,582	20%
	Geneva	1,017	218,805	215	87	628	93,119	57	2,735	375	27,557	24,194	21,639	37,961	17%
	Henry	498	169,809	341	154	317	72,889	42	8,142	192	13,886	25,272	20,308	47,242	28%
	Houston	816	197,974	243	76	538	97,381	75	9,138	279	19,249	23,567	42,939	50,706	26%
	Pike	600	167,272	279	153	393	35,215	33	3,196	313	23,776	2,262	3,245	20,772	12%
Florida	Bay	115	10,490	91	26	44	2,689	17	(D)	41	743	0	0	(D)	(D)
	Calhoun	218	42,850	197	42	140	18,907	30	1,647	62	4,675	7,014	3,333	11,401	27%
	Gadsden	402	50,805	126	40	266	13,068	62	2,650	134	3,895	1,584	(D)	5,427	11%
	Holmes	801	105,535	132	71	498	34,417	43	1,100	395	19,689	5,928	7,471	16,926	16%
	Jackson	1,160	262,312	226	75	781	117,569	120	21,508	493	45,737	37,654	29,180	68,184	26%
	Liberty	80	14,182	177	75	34	1,169	2	(D)	30	1,135	0	0	5,470	39%
	Walton	670	147,937	221	60	440	30,700	55	1,316	286	19,800	1,465	4,934	15,609	11%
	Washington	406	58,278	144	66	245	18,381	45	1,136	145	8,428	4,432	3,726	12,232	21%
Georgia	Baker	150	146,478	977	179	126	60,575	55	30,495	47	7,000	17,141	21,031	38,878	27%
	Decatur	358	198,954	556	125	259	123,602	86	54,744	110	15,723	39,750	34,746	53,443	27%
	Dougherty	121	65,406	541	50	88	19,733	23	12,971	18	1,965	611	1,118	(D)	(D)
	Early	334	169,335	507	160	239	93,765	79	32,700	125	15,411	33,373	28,583	58,881	35%
	Grady	471	130,258	277	84	345	54,392	78	9,230	134	13,017	20,138	7,861	27,449	21%
	Miller	183	95,761	523	140	136	60,969	64	31,721	93	8,581	24,008	44,861	32,748	34%
	Mitchell	443	191,137	431	109	307	117,354	136	67,179	131	18,698	19,497	30,997	44,743	23%
	Seminole	149	88,203	592	136	103	62,041	51	38,939	66	8,458	24,788	17,581	39,066	44%
TOTAL		12,575	3,406,531			8,272	1,398,735	1,269	341,020	4,909	381,300	370,722	364,995	749,306	22%

Source: 2012 Census of Agriculture, USDA, National Agricultural Statistics Service. (D) = Withheld information to avoid disclosing information for individual farms.

THE IDEAL TYPE: SOD-BASED ROTATION SYSTEM WITH INTEGRATED CATTLE

While a traditional crop rotation in the Wiregrass region includes cotton and peanuts in the summer growing season, the sod-based rotation system incorporates bahia grass (*Paspalum notatum* Fluegge) for its root-depth properties, winter cover crops of oats and rye for winter grazing, and cattle for economic diversification and nutrient recycling in the system. In the SBRC ideal type, approximately 50% of total farm acres are taken out of commodity crop production and devoted to bahia grass for a two-year period. In preliminary research, this was shown to increase soil organic matter and nitrogen pools while minimizing nematodes and pests (Marois et al. 2002).

In the SBRC model, farm ground is broken into four equal sizes, the quadrants are irrigated, and the crops are planted in the following rotation: bahia grass (two quadrants), peanuts, cotton (See Figure 1.3). Ideally, cattle eat bahia grass in its second year of growth during the summer months and eat cover crops of oats and rye in the winter from the peanut, cotton, and first year bahia grass quadrants. Winter grazing crops are used to sustain the cattle during the winter months, which reduces or eliminates the need to purchase hay or other winter feed. These quadrants are rotated annually with the exception of first year bahia grass, which remains intact for a second year, and cattle are moved between quadrants as forage availability fluctuates. Some evidence suggests that for this system to succeed, it is necessary for producers to invest in an irrigation system (Quintero 2014). On research plots, center pivot irrigation systems were used.

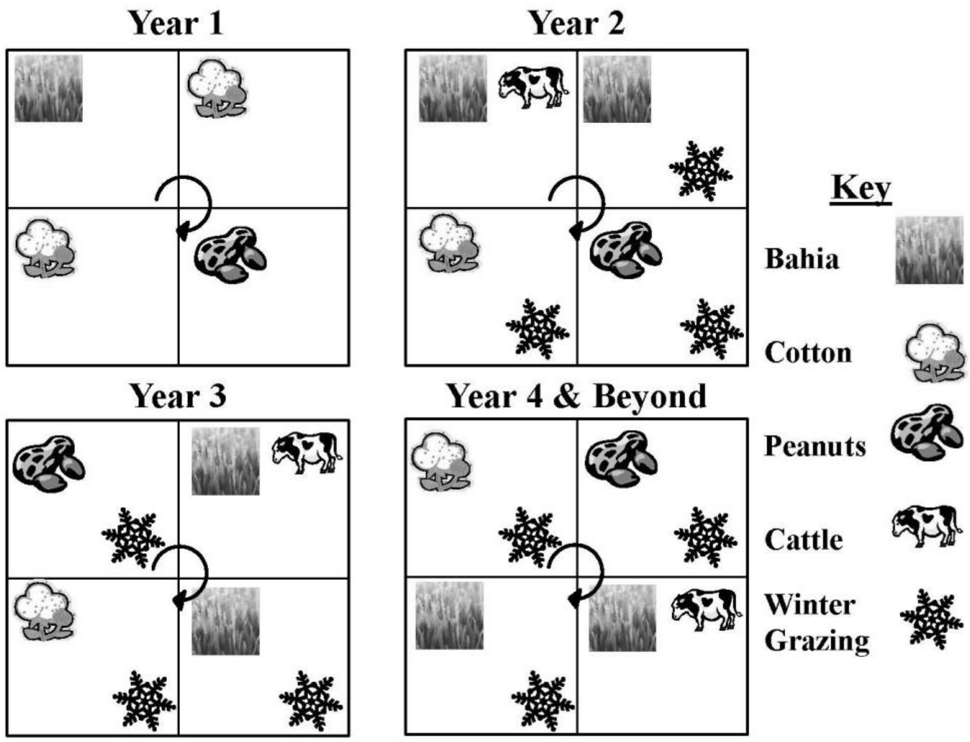

Figure 1.3: Diagram of the establishment of a four-year sod-based rotation system with cattle and perennial grasses.

BIOPHYSICAL FINDINGS AND ADOPTION OF SBRC PROJECT TO DATE

The biophysical aspects of SBRC have been under scientific investigation for nearly twenty years, and the potential benefits of adoption are well documented. First, a dramatic increase can be seen in crop yields with the introduction of a perennial grass such as bahia grass (Katsvairo et al. 2009). This increase has been attributed to an increase in nitrogen pools and soil organic matter, which increases water infiltration as grasses break through the hard-pan under the top soil and contributes to a reduction in nematodes (Gamble et al. 2014). Nutrients are recycled in the system when cattle eat the bahia grass, oats, and rye because nutrients in their feces are returned to the soil, further reducing the need for nitrogen application. The introduction of an irrigation system and the general diversification of the system are believed to reduce economic and environmental risks typically associated with farming (Howe 2012; Quintero 2014; Wright, Marois, George, et al. 2015). While those previously listed are some of the most influential benefits of the system, there are a host of other potential benefits such as reduction in nitrate leeching, enhanced water infiltration, improvement of soil fauna, and more.

Despite initially promising preliminary soil data, a study by Prevatt (2012) analyzed soils that had been in SBRC for ten or more years. When compared to soils in a traditional peanut-cotton crop rotation utilizing conservation practices, SBRC soils showed no significant difference in soil organic carbon accumulation. After ten years, soil organic carbon had equalized in the two systems.

While there has been extensive research on the biophysical aspects of the system since 2000, it was not until the 2010s that the social and economic aspects of the system were studied. According to a target MOTAD model economic comparison by Prevatt (2013), the SBRC ideal type produces "slightly more risk and less returns" than the irrigated traditional peanut-cotton rotation, with the most economically ideal land use in the Wiregrass being rain-fed peanut-cotton rotation. Contradictory information published by Wright et al. (2012) and Quintero (2014) tout greater profitability and reduction in risk for farmers who adopt SBRC. Quintero (2014), who utilized a linear model to estimate SBRC profitability, claims producers can gain net revenue increases of over $270,000 by adopting SBRC.

Sociologists were invited to the research team in 2011 to study and determine barriers and constraints faced by producers when they consider adopting SBRC. By understanding the way producers perceive the system, the researchers may be able to modify the system to fit the current political economy of agriculture where Wiregrass farmers live. Of the three states included in this project, Alabama has the fewest farmers with irrigated land and the least irrigated acres (see Table 1.2). Georgia producers faced similar barriers but have also faced restrictions for digging wells to feed irrigation systems (Hollis 2013). However, more farmers in the Georgia and Florida Wiregrass region have already established irrigation systems (U.S. Department of Agriculture 2014). Because irrigation is both a critical component to this system and the largest barrier some producers face, this thesis will explore irrigation as a barrier to SBRC system adoption.

While variations of a sod-based rotation system are increasingly common in the Wiregrass region, the SBRC ideal type is more challenging to find. Despite the well-documented potential benefits of adopting SBRC and years of endorsement by university researchers and extension professionals, researchers were unable to identify producers who had adopted the system in its ideal type.

This project was initially intended to be an adoption-diffusion study to examine the perceived barriers and constraints for farmers who considered adopting a sod-based rotation system with cattle as well as those who had newly adopted the system. However, as data were collected for the study, it became clear that barriers and constraints were not the only researchable question. It was found that there were no SBRC system adopters thirteen years after this system was developed, which led to the question, “Why?” To answer this question, we studied farmers’ perceptions of the system, as well as the research project itself.

CHAPTER 2: LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

The SBRC system was designed to not only enhance the sustainability of small- to medium-sized family farms in the Wiregrass region, but identified and endorsed as a "sustainable intensification" method of production (Quintero 2014). For the purpose of this thesis, I argue for a farm to be truly "sustainable," it must be functional in four distinct but related dimensions: environment, economic, social, and social justice. This chapter reviews literature relevant to the study and surveys literature regarding sustainable agriculture and diffusion of innovations. These topics were selected to address the researchable questions as well as *a priori* themes.

SUSTAINABLE AGRICULTURE

Consistent with new trends in agricultural research, the Sod-Based Rotation System with Integrated Cattle (SBRC) has been endorsed as a low-input sustainable agriculture (LISA) production system for small- to medium-sized farms (Quintero 2014; Wright, Marois, George, et al. 2015; Wright et al. 2012). The term "sustainable agriculture" has been used widely (Buttel 1993; Cowan et al. 2015; Douglass 1984; Holmes 2006; Jordan and Constance 2008; Lasley, Hoiberg, and Bultena 1993). While the term is generally accepted and the broad goal is considered desirable, rural sociologists have utilized a variety of definitions for, and conceptualizations of, sustainable agriculture. Some (i.e., many who are proponents of LISA) see sustainability as pertaining to two distinct dimensions in agriculture: economics and environment (Daberkow and Reichelderfer 1988; Schaller 1989). For these individuals, the goal is to maintain profits while protecting the environment. Allen and Sachs (1991) add two additional dimensions to the definition of agricultural sustainability: social and social justice. Agyeman, Bullard, and Evans's (2003, 5) work aligns with Allen and Sachs (1991), defining sustainability as "the need to ensure a better quality of life for all, now and into the future, in a just and equitable manner, whilst living within the limits of supporting ecosystems." Others intentionally define the term more broadly so it encompasses any and all practices that seek to redefine agriculture by dealing with harmful short-term effects and long-term problems often associated with modern agriculture (Lasley, Hoiberg, and Bultena 1993; Lockeretz 1991).

Sustainability has been a popular topic since the farm crisis of the 1980s, when low-input became the poster child for sustainable agricultural practice (Buttel 1993; Schaller 1989). The prevalent thought was that LISA systems reduce producers' investment in agrochemical inputs, thus reducing debt and stress among farmers (Bultena, Lasley, and Geller 1986; Buttel 1993; Schaller 1989). In the 1989 Yearbook of Agriculture, Schaller (1989, 216) explained,

> LISA involves farmers substituting management, scientific information, and on-farm resources for some of the purchased inputs they currently depend on for their farming enterprises. LISA techniques include rotations, crop and livestock diversification, soil and water conserving practices, mechanical cultivation, and biological pest controls.

Though sustainability is perceived as a desirable goal, the broader political economy includes, for instance, global competition and low prices that press agricultural producers to increase their production (Hinrichs and Welsh 2003). One approach to increase food production while reducing environmental harm is sustainable intensification (Baulcombe et al. 2009; Garnett and Godfray 2012). Sustainable intensification has been defined as an agricultural production strategy where "yields are increased without adverse environmental impact and without the cultivation of more land" (Baulcombe et al. 2009, ix). While the concept sustainable intensification has become recognized, few have offered suggestions for what such a production system might look like in practice (Garnett and Godfray 2012). Pretty, Toulmin, and Williams (2011) suggest three intensification methods:

1. increasing yields per unit of land
2. increasing cropping intensity per unit of land or other inputs
3. changing land use from low-value crops or commodities to those that receive higher market prices

Pretty, Toulmin, and Williams (2011) suggest that challenges exist when adopting methods of sustainable intensification. However, they provide seven suggestions for increasing adoption of these methods (Pretty, Toulmin, and Williams 2011):

1. science and farmer inputs into technologies and practices that combine crops—animals with agroecological and agronomic management
2. creation of novel social infrastructure that builds trust among individuals and agencies
3. improvement of farmer knowledge and capacity through the use of farmer field schools and modern information and communication technologies
4. engagement with the private sector for supply of goods and services
5. a focus on women's educational, microfinance, and agricultural technology needs
6. ensuring the availability of microfinance and rural banking
7. ensuring public sector support for agriculture

Farms and Farm Size

The United States Department of Agriculture (USDA) defines a farm as “any place from which $1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the year” (U.S. Department of Agriculture Economic Research Service 2017). The USDA’s Economic Research Service (ERS) utilizes annual gross cash farm income (GCFI) to classify farms by size. USDA-ERS defines GCFI as “a measure of the farm’s revenue before deducting expenses that include sales of crops and livestock, Government payments, and other farm-related cash income, including fees from farm production contracts” (U.S. Department of Agriculture Economic Research Service 2018). The USDA’s farm typology focuses on family farms, which make up 99% of U.S. farm operations (U.S. Department of Agriculture Economic Research Service 2018).

The USDA-ERS defines small family farms as operations with a GCFI of less than $350,000 (2018). This farm category is the broadest, encompassing not only farming-occupation farms with low- to moderate-sales, but also retirement farms and off-farm occupation farms. USDA-ERS defines off-farm occupation farms as “small farms whose operators report a primary occupation other than farming (2018).” Midsize family farms have GCFI between $350,000 and $999,999 (U.S. Department of Agriculture Economic Research Service 2018).

<u>Rented Land and Sustainable Farming Practices</u>

Alabama, Florida, and Georgia have a considerable amount of rented farm land, and decisions related to rented land have been an overlooked factor in the adoption of conservation or sustainable agricultural practices (Carolan 2005). While historically rented farmland was independently owned or co-owned, ownership has shifted to more complex arrangements, including partnerships, trusts, and limited liability companies (Pieper and Harl 2000). In their work on rented farmland in Wisconsin, Gilbert and Beckley (1993) found that most landlords and tenants shared decision-making power or that landlords were willing to give more power to tenants; furthermore, they found most tenants and landlords were satisfied with their leasing arrangement However, sustainability and conservation techniques are known to require considerable investments of capital or management (Fraser 2004). Competitive markets for rented farmland increase rental rates and reduce profit margins (Edwards 2003), creating an environment where only larger operators have the capital required to secure loans (Fraser 2004). Short-term, unstable rental arrangements create a “bottom-line approach” to farming (Fraser 2004); this, when paired with differing goals and poor tenant-landlord communication, creates further barriers to implementing conservation techniques (Moss et al. 2001). Furthermore, while tenants may be interested in implementing sustainable agriculture management techniques, they tend to be resistant to discuss such topics with landlords for fear of changing the status quo and losing access to the rental property, a self-censorship practice likely rooted in a lack of trust between parties (Carolan 2005).

DIFFUSION OF INNOVATION

Scholars have written about the adoption process for more than 100 years. King defines innovation as “the act or process of introducing a new, qualitatively different element into society, and the element itself is often termed an innovation” (1956, 50). Innovations were not instantly adopted, however; as a driving force for change, the innovation of new agricultural technologies was typically followed by a cultural lag, where individual attitudes, values, and social relationships had to be modified before the innovation could be adopted (Ogburn 1922).

The theory of diffusion, however, is most commonly associated with the work of Rogers (2003). According to Rogers (2003), diffusion is “the process in which an innovation is communicated through certain channels over time among members of the social system.” Messages about new ideas, or innovations, are shared between adopters of technology and potential adopters. Innovations that are compatible with potential adopters’ values, beliefs, and past experiences in the social system are more likely to be adopted at a higher rate (Rogers 2003).

Rogers (2003) identifies five stages to the innovation-decision process:

1. Knowledge occurs when an individual is exposed to an innovation's existence and gains an understanding of how it functions.
2. Persuasion occurs when individuals form a favorable or an unfavorable attitude towards the innovation.
3. Decision takes place when an individual engages in activities that lead to a choice to adopt or reject the innovation.
4. Implementation occurs when an individual puts a new idea into use.
5. Confirmation takes place when an individual seeks reinforcement of an innovation-decision already made, but he or she may reverse this previous decision if exposed to conflicting messages about the innovation.

Innovators, the earliest from of adopters, which represent approximately 2.5% of individuals, tend to be active information seekers with a high degree of mass media exposure; they tend to be well-connected in their communities; and they are able to manage uncertainty (Rogers 2003). Early adopters, the second category of adopters (which represent 13.5% of individuals), tended to be more highly educated, highly capitalized, and often subscribed to more cosmopolitan ideas than their late-adopting counterparts (Busch, Bonanno, and Lacy 1989).

While the diffusion of innovation model has been widely cited, it has also been criticized. Page and Walker (1991) argue that adoption of new technologies is more complex than the simple adoption of new ideas. Technologies are developed and changed to satisfy human wants and needs, which vary according to group membership; for this reason, technology is not neutral (Busch, Bonanno, and Lacy 1989).

Extension's Role in Technology Transfer

Land grant university extension has played a key role in the dissemination of agricultural technologies since its establishment by the Smith-Lever Act in 1914 (Hightower 1973). The Cooperative Extension Service (CES) became the third leg of the existing land grant college complex (LGCC), which had previously included teaching and research (Hightower 1972). Extension quite literally extended the resources of the land-grant college to communities across each state. The third leg's outreach mission was established to provide education and research-based information to agricultural producers in rural communities, which often included the introduction of agricultural innovations and practices to producers. The diffusion of these technologies had mixed results (Hightower 1973). The LGCC has been both praised and criticized for its role in the consolidation of agriculture, increase in yields, mechanization of agricultural production, and the out-migration of rural citizens (Hightower 1972).

Rogers (2003) defines technology transfer as "the application of information to use." Technology exchange is not a unilateral process; rather, it is a two-sided exchange between the developer of technology and the user. Rogers (2003) also addresses re-invention, which he defines as "the degree to which an innovation is changed or modified by a user in the process of adoption and implementation," which occurs when an adopter puts a new idea to use.

Because research was conducted and disseminated through the public sector, information was common property and open to those who wanted it (Boehlje 1998). Through CES education, farmers could initiate or continue their agricultural production education and keep up with constant technological change. Historically, many of these technological changes were achieved through individual mechanical and chemical innovations (Lockeretz 1991). Today, most technologies are bundles or packages of technologies, including two or more products, machines, or management practices intended to increase agricultural productivity and profits (Goodman 1991). CES's processes tend to be top-down, reinforcing the LGCC technology transfer concept of the expert from the university providing information for the lay-person in rural areas (Warner 2008).

Hightower (1973) uncovers the inequality of LGCC research by acknowledging that the LGCC and CES tends to associate with wealthier, more successful farmers while leaving smaller farmers and farmworkers out of the decision-making process. To ensure funding, LGCC research has historically associated with private industry in their research projects (Goldberger 2001). By working in collaboration with agribusiness, Extension once had access to the newest innovations and larger budgets, which they used to improve their research. However, the privatization of research and development efforts has led to the decline of innovative research from CES. In response to difficult research questions and the complexity of the agroecosystem, some research has changed to an agricultural systems approach within CES, where agricultural systems are developed and endorsed rather than mechanical or chemical technologies (Goodman 1991).

Warner (2008) argues that CES' practice is much more complex than the technology transfer discourse. The system by which farmers learn about and obtain information regarding new technologies has changed drastically with the privatization of information and industrialization in the agricultural sector (Boehlje 1998). Today, information disseminated through both the public and private sectors are a key source of strategic competitive advantage and control for producers who adopted the technology (Boehlje 1998).

The trend today is the inclusion of stakeholders on the front end of research projects so their feedback can help develop and shape the research agenda (Middendorf and Busch 1997; Ostrom, Cha, and Flores 2010; Percy 2005; Trauger et al. 2008; Warner 2007). Busch et al. (1989) advocate for making change more democratic by including marginalized segments of the population in the decision-making process and scrutinizing the direction of technological changes.

The LGCC has been criticized for contributing to industrialized agriculture that is harmful to the environment and producer socioeconomics (Buttel 2005). Beus and Dunlap (1992) found that women, younger faculty, faculty members not raised on farms, and faculty who got their degrees at non-land grant institutions tended to endorse alternative agriculture more than their older, land-grant educated peers, who tend to prefer conventional methods. Faculty in the social sciences also tend to endorse alternative agricultural methods at higher rates (Beus and Dunlap 1992).

Research on Iowa farmers by Lasley et al. (1993) indicated larger scale producers were more likely to have negative attitudes about sustainable agriculture. This could be related to more management-intensive practices which could prove labor-intensive over a more acres, such as planting cover crops, non-chemical weed control practices, and non-traditional insect-control methods (Buttel and Gillespie Jr. 1988).

For farmers, adopting new technologies can be challenging. Limited resources, a lack of access to credit, a lack of knowledge or training about the new technology, ecological limitations, or limiting factors related to a farmer’s social structure can serve as barriers to adoption of new technologies (Shadi-Talab 1977). The complexity of a technology (the degree to which an innovation is deemed challenging to understand or use) or the trialability of a technology (the degree to which a new technology may be experimented with on a small-scale basis) may both serve as challenges to adoption for producers (Rogers 2003). The technology's compatibility (consistency with existing production structure, past experience, existing values, and needs) plays a role in a technology's rate and likelihood of adoption (Rogers 2003). Producers may struggle to adopt less compatible technologies, which may slow the rate of adoption. The trialability, compatibility, and complexity of innovations influence producers' attitudes about them. According to Rogers (2003), the perceived complexity of an innovation is negatively related to its rate of adoption while the trialability of an innovation is positively related to adoption.

Multidisciplinary Science and Research

Multidisciplinary research has become a popular yet complicated strategy for accomplishing research to answer complex questions, particularly in sustainable agriculture. Lockeretz (1991) defines multidisciplinary as "more than one discipline is involved," but argues that sustainable agriculture research can be successfully completed by both a single discipline or by several disciplines together. In his article "Multidisciplinary Research and Sustainable Agriculture," Lockeretz (1991) categorized four modes of multidisciplinary research:

1. Additive multidisciplinary research is the least interactive among disciplines, and occurs when people from different disciplines simply coordinate their studies of the same topic, with each concentrating on one aspect of it, almost as if only that discipline were involved.
2. Integrated multidisciplinary research divides a topic into disciplinary components, but gives special attention to the linkages among them and to questions that either overlap or fall between different disciplinary domains.

3. Synthetic multidisciplinary research occurs when several disciplines try to explain the same phenomenon and may come up with a new answer very different from the combination of their separate answers.
4. Nondisciplinary research ignores disciplines entirely and is appropriate when the topic does not come close to being dividable along disciplinary boundaries or when conducting purely exploratory work with no guiding theories.

Lockeretz (1991) goes on to explain that additive and integrated studies may be extensive or intensive. The additive extensive mode is identified as a suitable means to evaluate new agricultural systems because the strategy offers both breadth and depth. However, he argues that "multidisciplinary in form does not guarantee multidisciplinary in spirit" and that "includ[ing] the right resumés doesn't guarantee the 'right' kind of multidisciplinary" (Lockeretz 1991).

Participatory Research and Extension

There has been a call for participatory methods of engaging diverse groups of stakeholders in the United States' LGCC system (Middendorf and Busch 1997; Ostrom, Cha, and Flores 2010; Percy 2005; Trauger et al. 2008; Warner 2007). Participatory research and extension processes include collaborative learning between scientists and producers, and together, they determine possible solutions to challenges based on producers' experiences, constraints, and knowledge (Percy 2005). Middendorf and Busch (1997) argue that "a closer approximation of the 'public good' can be achieved by encouraging the participation of the fullest range possible of constituents as an integral part of the process of setting research priorities." They argue that the university must facilitate the democratic process by engaging all stakeholders in conversations to increase the likelihood that research decisions are more responsive to the needs of the broader public (Middendorf and Busch 1997).

Producers are becoming more diverse (Middendorf and Busch 1997; Percy 2005), and a one-size-fits-all system of public research may not be adequate for farmers with limited access to resources, including land, water, and capital (Ostrom, Cha, and Flores 2010). Ostrom et al. (2010, 90) argue a new approach is needed for public agricultural research to benefit smaller-scale or non-traditional producers—one that focuses less on "export-oriented, high-input, industrial-scale commodity production that requires intensive capital investment." Ostrom et al. (2005) found it was critical for trusting personal relationships to be built between educators and participants to build meaningful program participation; however, this was considerably harder when working with producers with different backgrounds than research or educational staff. The values of non-traditional producers may vary considerably from their commodity-producing, production-oriented counterparts and researchers. For example, Trauger et al. (2008) looked at women farmers finding that those with small- to medium-sized farms tended to value civic agriculture and seek value in their agricultural work in a variety of different ways. Rather than focusing on large-scale commodity production, the women tended to draw on educational programs to add value to their farm products, agrotourism, and to fostering local food systems (Trauger et al. 2008). Trauger et al. (2008, 51) exposed that female farmers feel they are taken "less seriously" than their male counterparts in communities and "attribute their marginalization to the combination of their lack of conformity to traditional gender roles and their choice to practice agriculture outside of the commodity farming system."

Cowan et al. (2015) call for the use of tactile space, a concept introduced by Carolan (2007), during Extension Field Day Events. They define tactile spaces as "sensuously rich learning environments where participants interact with each other and the environment in an 'embodied' and 'embedded' manner leading to long-lasting attitudinal and behavioral change"

(Cowan et al. 2015). The concept of tactile spaces is a participatory method of engaging diverse groups in LGU's research, education, and extension system, and include a combination of hands-on, experiential learning opportunities with discussion or focus groups over a period of time. By incorporating tactile space in planning field days, disseminators of knowledge can increase the lasting impact of the learning event; producers interact with the technology, one another, field day organizers, and the scientific concept or aspect in question, resulting in co-production of knowledge (Cowan et al. 2015). Beier et al. (2016) define the co-production of science as "collaboration among managers, scientists, and other stakeholders, who, after identifying specific decisions to be informed by science, jointly define the scope and context of the problem, research questions, methods, and outputs, make scientific inferences, and develop strategies for the appropriate use of science," using the term 'partners' to refer to co-producers. However, a significant barrier that field days pose to creating more embedded experiences is the short-term, one-day nature of the programs.

Actionable Science and the Coproduction of Science

Beier et al. (2016) suggest coproduction to be the most reliable method of creating actionable science. Actionable science means "data, analyses, projections, or tools that can support decisions in natural resource management… which includes not only information, but also guidance on the appropriate use of information" (Beier et al. 2016). Actionable science should be credible, salient, and legitimate, and that it must be developed between producers and scientists (Beier et al. 2016; Cash et al. 2003; Lemos and Morehouse 2005; Nel et al. 2016).

Co-production of actionable science is a relatively new concept which is a direct response to the top-down approach of technology transfer. Beier et al. (Beier et al.) share three guiding principles of co-production:

Guiding Principle 1: Coproduction begins with decisions that need to be made.

Guiding Principle 2: Partners should give priority to processes and outcomes over stand-alone products

Guiding Principle 3: Build connections across disciplines and organizations, and among scientists, decision makers, and stakeholders.

Beier et al. (2016) encourage scientists to share any uncertainty in their findings with producers, but to be clear on its consequences, so producers are able to put findings to work. Because the reward structures for science and practice vary, connecting information users and producers can be challenging; however, differences must be respected for successful co-production (National Research Council 2009). While there may be distinct benefits to coproduction, it often takes more time to develop and publish than other forms of research, which does not align well with the promotion and tenure structure of public universities (Beier et al. 2016).

CHAPTER 3: METHODS

This study was part of a larger study titled "Economic Viability and Agro-ecology of Integrating Beef Cattle and Short-Term Perennial Grasses into Peanut and Cotton Rotations." This sub-project is qualitative and follows a research process based in grounded theory to explore the Sod-Based Rotation System Project with Cattle (SBRC); however, this research was conducted with some basic assumptions. These assumptions are:

- Producers' decisions may or may not be rational from an economic standpoint.
- Producers consider factors like profitability, insurance, and government payments when making decisions about their farm operation.
- There is nothing natural about agroecosystems.
- Producers make decisions about land use for rented land differently than owned land.

OBJECTIVES AND RESEARCH QUESTIONS

This study had two key objectives, each with two sub-objectives.

Objective 1: Understand producers' perceptions of SBRC.

Sub-Objective 1: Provide insight into producers' perceptions of SBRC.

Sub-Objective 2: Understand perceived barriers and constraints to SBRC adoption.

Objective 2: Understand the scientific process that led to SBRC.

Sub-Objective 1: Understand system development and challenges.

Sub-Objective 2: Understand system endorsement strategies.

Qualitative analysis based on *a priori* and emergent themes was used to explore the following research questions as they relate to the study objectives:

Objective 1: Understand producers' perceptions and beliefs about SBRC

- What challenges do you think you or others would face if adopting SBRC?
- Do you think this system would work for your operation?
- Do you have the management skills that you think are necessary to adopt SBRC?
- Would you consider adopting an agricultural system such as SBRC?

Objective 2: Understand the scientific process that led to SBRC

- Who developed the SBRC and why?
- How has the research been funded and why?
- What types of research have been done to develop and explore SBRC?
- What challenges have been faced during the SBRC research process?
- Who are the beneficiaries of this research?
- Why were social scientists added to this project after years of prior research?

To explore these objectives, the data collection was divided into three phases. The phases were as follows:

1. Participant observation at field days and workshops held to illustrate and endorse the sod-based rotation with cattle.
2. Semi-structured interviews with users of sod-rotation system variations, identified by bio-physical researchers on the sod-based rotation with cattle project ("users").
3. Semi-structured interviews with investigators and other key personnel on the sod-based rotation with cattle project ("researchers").

In the following sections, I will identify the phases of this study and explain the research process for each.

PHASE I: PARTICIPANT OBSERVATION AT FIELD DAYS AND WORKSHOPS

The population of individuals at field days included, but was not limited to farmers. Participants from other professional backgrounds were represented, including insurance agents, extension agents, agricultural product dealers, university faculty, and others. Because of the nature of field days, a broad spectrum of audiences attends.

Sample

Four separate "Field Day" events were held at two separate locations with approximately 200 unique participants. In many cases, participants attended more than one workshop since the Agricultural Experiment Stations are geographically close to one another. Field Days are held at these locations regularly to discuss ongoing research station projects with local farmers and stakeholders. SBRC was often a showcase item at these Field Days, which introduced individuals to this farming system. Individuals at field days became an important group of study participants. No compensation was offered for participants. Attendees of the Field Days had the option to opt out of the study[1]. As a result of the unique nature of this study, there was no enumerated population to identify. Where possible, producers were divided into a separate group

---

[1] This study was approved by Auburn University's Human Research Protection Program (IRB Protocols # 11-237, #11-237 EX1107, and #18-412 EX1810).

to discuss SBRC. This data was used to better understand producers' perceptions of and barriers and constraints to adopting the SBRC. Data was collected at the following events:

- One Climate Change Consortium workshop for row crop farmers at the University of Florida experiment station in Marianna, Florida (August 4, 2011)—approximately 50 participants.
- One row crop field day at the Auburn University experiment station in Headland, Alabama (August 19, 2011)—approximately 120 participants.
- One cattle producer field day at the Auburn University experiment station in Headland, Alabama (April 5, 2012)—approximately 50 participants.
- One agricultural producers' field day at the University of Florida experiment station in Marianna, Florida (June 21, 2012)—approximately 75 participants.

Data

Participant observation was conducted at field days and workshops that endorsed the SBRC. The purpose of the observation was to collect a list of all the questions asked by participants. When necessary, verbal probes were used by facilitators to gain clarity in answers or to get more information about producers' perceptions of SBRC. All sessions of participant observation occurred on university agricultural experiment stations and lasted between fifteen minutes (at field days) and three hours (at workshops). Handwritten field notes were taken during observation and typed later. Eighteen unique recordings totaling over ten hours of audio were also taken. Data was collected until saturation, meaning no new information was being acquired. At each event, participants were solicited for interviews about the SBRC system at a later date and given a form to return to investigators if willing. Although several forms were returned, none were from producers; instead, they were primarily from Extension staff and University faculty. Written feedback was also provided by attendees at a field day event who were asked to, “Write three questions you have after learning about SBRC” on provided notecards, which were color-coded to sort responses based on role: Extension, Farmer, Researcher.

PHASE II: INTERVIEWS WITH SOD-ROTATION USERS

The population for this phase of the project was made up of agricultural producers from the Wiregrass region as defined by this project--southeast Alabama, north Florida, and south Georgia--who used some form of a sod-rotation in their farm operation. The sod-rotation was not necessarily the endorsed system being studied in this phase, but rather some type of cropping system that included sod and may or may not include livestock.

Sample

Participant producers were identified by researchers affiliated with the SBRC project as individuals who used some form of a sod-rotation on their farm. Interviewed producers had adopted or planned to adopt a sod-based rotation system—either in the “true form” (i.e., the way it was performed at the experiment stations) or in a modified version to fit a particular farm operation. The farmers I interviewed had rotations that included a selection of the following commodities in rotation with grass: cattle, pine, oats, rye, grain sorghum, tobacco, pine trees, sweet potatoes, melon, corn, soybeans, cotton, peanuts (see Table 2).

Data

Data were collected using a semi-structured interview schedule during one or two sessions. This schedule was developed using data gathered and questions raised during Phase I. Producers were asked questions about the size, nature, and history of their farm operation. They answered general questions about their level of education and the methods by which they gather information that helps them make decisions. Producers then answered questions about their use of sod-based rotation, including decisions to adopt, challenges faced in adoption, system modifications, and recommendations for other possible users. Interviews lasted between thirty minutes and two hours.

Table 3.1: Pseudonym Table of Agricultural Producers Interviewed

Pseudonym	Gender	Age	Role
Charles Martin	Male	60-80	Producer, medium-scale (cattle, peanuts, bahia grass, rye grass, hay)
Donald Pierce	Male	50-70	Producer, large-scale (pine, peanuts, cotton, corn, soybeans, citrus, cattle, pine)
Everett Swift	Male	40-60	Producer, medium-scale (peanuts, corn, cattle, sweet potatoes)
Garret Foster	Male	40-60	Producer, medium-scale (cotton, corn, peanuts, cattle, soybeans)
Hank Anderson	Male	40-60	Producer, medium-scale (peanuts, cattle, pines)
James Decatur	Male	40-60	Producer, large-scale (corn, peanuts, melons)
Mark Moore	Male	40-60	Producer, industrial-scale (peanuts, corn, silage, bahia, cattle)
Shane Adams	Male	30-50	Producer, medium-scale (tobacco, cattle, grass, pines)
Shawn Anders	Male	40-60	Producer, large-scale (cattle, peanuts, corn, Bermuda hay, bahia, sweet potatoes)

Interviews were conducted at a location of the producers' choosing and were commonly held at their farm. All interviews were audio recorded, and handwritten field notes were taken during the interview. In total there were four and a half hours of audio recordings. Data were collected until it was determined that the sample was saturated. Nine Wiregrass producers were interviewed. The analysis includes all interviews.

PHASE III: INTERVIEWS WITH BIO-PHYSICAL SCIENTISTS & KEY PROJECT PERSONNEL

The population for this phase of the project includes all bio-physical researchers and key personnel related to and working on the project. This included faculty from the University of Georgia, University of Florida, and Auburn University, plus extension and agricultural experiment station personnel. To better understand the research process, researchers in the bio-physical sciences and key personnel on the SBRC project were interviewed about their role in the research process. Snowball sampling was used to identify anyone who had played a role in the project, including several former personnel who had since retired. No compensation was offered for participants. Everyone working on the project was interviewed.

Data

A semi-structured interview guide was used to interview participants. Questions included topics such as researcher's educational attainment, roles in the research project, their findings to date, and their perceptions of the success of the project thus far. Probes were used when necessary for greater clarity or detail. Interviews were conducted one of two ways: phone interviews and face-to-face interviews at a location of the participant's choice. In total, twenty-nine interviews were completed. The geographic and professional breakdown of participants can be found in Table 3.2 and Table 3.3.

Table 3.2: Phase III Study Participants by State

Phase III Participants by State	Number of Participants
Alabama	11
Florida	16
Georgia	2

Table 3.3: Role of Phase III Participants in SBRC Research

Phase III Participants by Role	Number of Participants
University Faculty and Staff	12
Graduate Students	3
Extension and Outreach Staff	5
Experiment Station Personnel	8
Other	1

Handwritten field notes were taken for each interview and audio recordings were taken when consent was provided. Interviews lasted from fifteen minutes to one and a half hours. Over fourteen hours of audio recordings were made.

ANALYSIS

All audio recordings were transcribed and coded using NVivo 12 in a two-step process. First, they were coded based on *a priori* themes. Then, they were coded based on emergent themes to identify new topics and common threads, particularly those related to barriers or constraints to adoption, producers' perceptions of SRBC, new topics, or common threads. See Table 3.5 for a list of *a priori* themes.

Table 3.4: Pseudonym Table of Investigators with Characteristics

Pseudonym	Gender	Age	Role	Funded by Grant	Area of Expertise
Andrea Green	Female	40-60	University Professor & Researcher	No	Nutrient Management & Water Quality
Andrew Lake	Male	50-70	University Professor & Researcher	Yes	Plant Pathology
Bill Jones	Male	60-80	Retired; Emeritus Professor of Animal Science	No	Animal Science
Darla Moon	Female	30-50	University Researcher, Campus	Yes	Rural Sociology
Doug Henderson	Male	40-60	University Professor & Researcher	Yes	Agricultural Economics
Emily Chattsworth	Female	20-40	University Post Doc	Yes	Molecular Biology & Biochemistry
Frank O'Connor	Male	60-80	University Researcher at Experiment Station, Extension Appointment	Yes	Agronomy
Jacob Petersen	Male	50-70	University Professor & Researcher	Yes	Agricultural Economics
James Ivey	Male	40-60	Extension Specialist at Experiment Station	Yes	Agronomic Crops
Margaret Jacobson	Female	30-50	University Professor & Researcher	Yes	Agronomy
Maria Rodriguez	Female	30-50	Extension Agent, Agriculture	No	Agriculture & Natural Resources
Matt French	Male	40-60	Experiment Station Employee	Yes	Agronomy
Richard Lincoln	Male	30-50	University Professor & Researcher, Extension Appointment	Yes	Agronomy & Ag Operations Management
Stephanie Johnson	Female	40-60	University Researcher with Extension Appointment	Yes	Forage Agronomy & Bahia Grass Breeding
Theodore Richardson	Male	50-70	University Professor with Extension Appointment	Yes	Peanut Agronomist
Adam Clark	Male		Retired, Experiment Station Coordinator	Yes	Peanuts & Water Quality
Edward Boyd	Male	30-50	University Research & Extension at Experiment Station	Yes	Animal Science

Table 3.4: Pseudonym Table of Investigators with Characteristics

Pseudonym	Gender	Age	Role	Funded by Grant	Area of Expertise
Jarrad Hull	Male	50-70	Producer Employed by Experiment Station, Row Crops Management	Yes	Producer, Agriculture
Jason Black	Male	30-50	Manager at Experiment Station	Yes	Animal Science
Lucas Jeffers	Male	30-50	Farm Supervisor at Experiment Station	Yes	Cattle
Mickey Lewis	Male	30-50	Experiment Station Engineer	Yes	Conservation & Best Management Practices
Mike Hartman	Male	50-70	Associate Director of University Experiment Station	Yes	Agronomy
Carlos Waters	Male	20-40	Graduate Student	Yes	Agronomy
Ella Hunt	Female	20-40	Graduate Student & Research Assistant	Yes	Agronomy
John Burke	Male	20-40	Post Doc doing work with Cooperative Extension	Yes	Ag & Biological Engineering
Kevin Spencer	Male	20-40	Graduate Student	Yes	Agricultural Economics
George Fetters	Male	50-70	Assistant Research Scientist	No	Agricultural Operations Management, Climate Change
Patricia Knight	Female	40-60	Post Doc Research Associate	No	Climate Change, Botany, Genetics
William Franklin	Male	40-60	State Department of Agriculture, Specialist	No	Agronomy, Environment

Table 3.5: *A priori* Themes Used for Coding Data.
Participants is number of individuals who mentioned the topic. References is the number of times that code was used in data.

Codes	Participants	References	%
Anticipated future of SBRC research	27	32	5.0
Barriers to Adoption	34	87	13.6
Characteristics of producers	9	37	5.8
Characteristics of research & extension staff	29	31	4.8
Criticisms of SBR by producers	3	8	1.2
Criticisms of SBR by research & extension	21	52	8.1
Sources of information about farming for producers	17	33	5.1
Endorsement strategies	18	53	8.3
Factors leading to adoption	5	7	1.1
Farmer perceptions of SBRC	1	5	0.8
How can government help make adoption possible?	10	12	1.9
How to make SBRC easier to adopt	5	8	1.2
Opinions of SBRC research from researchers	30	252	39.3
System development process	11	24	3.7
Total *a priori* themes		**641**	**100**

LIMITATIONS

Because of the nature of this project, there were several limitations to data collection and analysis. First, the sample used for participant observation was not limited to agricultural producers, so some of the comments and questions recorded during those sessions may not be representative of all Southeastern producers. Also, the sound quality of some of these recordings were poor as a result of location (e.g., riding on a wagon behind a tractor), which limited my ability to transcribe word-for-word at times. When necessary, handwritten notes were used to supplement gaps in the recordings.

A second limitation was the lack of SBRC users in its “true form,” thus making it difficult to determine how producers would actually fare using the system or their opinions of the system after having used it. Researchers were unable to identify any of these individuals. In the absence of SBRC farmers, users of some form of sod-rotation were interviewed.

Finally, during interviews with research personnel, it became clear that many participants felt strongly about their involvement with the project—some positively, some negatively. Some participants went into great detail about their role in, and their opinions about, the SBRC project; however, many were reserved or noncommittal. It is unclear to what extent the subjects withheld information so as not to mar the image of their research project. Also, it is possible that some participants framed their answers in a more favorable direction to improve others’ perceptions of their work. Several of these individuals have worked on the SBRC project for ten or more years, and are thus invested in its success. While these limitations do not greatly affect my analysis, it is important to keep them in mind when digesting the findings of this study.

CHAPTER 4: FINDINGS

This chapter addresses development and endorsement strategies of the SBRC project according to researchers, as well as challenges they experienced. Feedback will be shared from grower-cooperators who were paid to conduct an on-farm pilot of SBRC.[2] The chapter also details perceptions of the system and perceived barriers and constraints to adoption by growers who attended Extension Field Days.

THEMES

Although *a priori* themes were used in the coding process, nineteen emergent themes also appeared during analysis (Figure 4.1). The most commonly mentioned themes were “irrigation,” “livestock,” and “economics of SBRC,” each representing greater than 10% of emergent themes coded. The least discussed themes were “lack of feedback from growers in research process” and “early adopting farmers.”

DEVELOPMENT OF SBRC PROJECT

While there is no easily identified starting date for sod-based rotation (SBR) research and experimentation, the establishment of a sod rotation project began in North Florida around 2000. Frank O’Connor, an extension agronomist working in cropping systems and conservation tillage, and Andrew Lake, a plant pathologist, established the project. Lake cited a desire to find an agricultural system that would help smaller farms become sustainable (i.e., reduce negative impacts on the environment) to be the primary goal that led to the creation of the SBRC.

---

[2] Participant pseudonyms are found in Tables 3.1 and 3.2 in the preceding chapter.

Table 4.1: Themes that emerged during coding. Participants is the number of individuals who mentioned each theme. Reference is the number of times each theme was coded in the data.

Objective	Theme	Emergent Themes	Participants	References	% Refs	Total % Refs
Objective 1: Understand producers' perceptions of SBRC.	Decisions about land	Conservation-based decisions	5	9	1.4	
		Rented land	14	24	3.6	5.0
	Producer & farm characteristics	Early adopting farmers	4	6	.9	
		Tobacco	4	16	2.4	3.3
	Barriers and constraints to adoption	Destroying or burning down sod	10	15	2.3	
		Economic-based decisions	13	13	2.0	
		Economics of SBRC system	27	76	11.5	
		Farm management & management abilities	17	32	4.8	
		Irrigation	31	92	13.9	
		Livestock or cattle	34	134	20.3	54.8
Objective 2: Understand the scientific process that led to SBRC.	Strategies to improve sustainability	Benefits realized by producers using SBR	6	10	1.5	
		Climate	2	7	1.1	
		Low-input agricultural system	16	36	5.4	
		Partial adoption of SBRC or adaptation/variations	5	49	7.4	15.4
	The Science of Research	Ag systems research	17	33	5.0	
		Challenges of multidisciplinary research	19	48	7.3	
		Lack of feedback from growers in research process	2	3	.5	
		Providing research-based information to producers	5	12	1.8	
		Research funding	14	46	7.0	21.6
		Total Emergent Themes		19	100	

In contrast, O'Connor indicated a desire to find a conservation tillage system that increased yields. At the project's inception, O'Connor had completed more than 20 years of work on strip tillage. Project leadership was divided with Lake focusing on communication with scientists and O'Connor on communication with producers. Both wrote grants, hired support staff, contributed to manuscripts, gave presentations, and, in the words of Lake, "drummed up support." Their first findings were published in 2002.

A second rotation was soon established at another Florida location, which incorporated cattle with winter grazing. This took the project closer to its current, ideal-type SBRC form. As the project grew, so did the number of personnel and represented academic disciplines. A rotation was also established in South Georgia in 2001 and in South Alabama in 2002.

As data were gathered and analyzed, the principal SBRC investigators modified the system in ways they believed would increase productivity. Stocker steers were chosen because their costs and profits were easy to quantify (i.e., weight gain, sale price). However, a cow-calf operation was determined to be a better economic fit with the available forage through most of the year. The research design had three components. First, productivity of the dry corners of the land, which was irrigated on a center pivot, were used to compare dryland farming to irrigated land. Second, previously grazed cropland was compared to cropland free from cattle, made possible by the use of exclusion cages. The bahia grass was grazed intensely, fertilized, and watered so seed would produce in abundance and could be cut. Finally, researchers aimed to explain the effects of SBRC on the bio-physical characteristics of the farm (i.e., water quality, soil organic matter, etc.).

When asked about his work on the SBRC project, O'Connor stated,

> We've done a lot of different research looking at nutrient and water needs, comparing crop yields in traditional conservation system to SBRC. We've developed an economic model. We've looked at many different things including earthworms, organic matter build-up, yields of crops, rooting patterns in systems, root mass. We have 10 or 15 publications. We've got an overview, a book chapter, an article in an agronomy journal—the main journal in our society. We don't have very much information yet with cattle, but we've tried to be all-inclusive [in our research including] people from all departments.

The multi-disciplinary nature of the project was mentioned by 19 scientists, representing 7.3% of emergent themes coded. "There's an opportunity to create a multi-disciplinary project, which doesn't happen very often," said Boyd. "In order to do a project of this magnitude, often the price is tremendous, but for this one, as somebody just starting, I think the biggest benefit I get is the opportunity to collaborate with more established scientists and piggy-back on some of those projects." Twenty-seven scientists (11.5% of emergent coding) spoke about the economic data that was being developed in the research, three shared their excitement about having economists working on the project, and another was enthusiastic about the sociology component.

<u>Challenges of Multidisciplinary Research</u>

Of the nature of multidisciplinary research, Jones said, "There are a lot of challenges but when you look at the positives, they outweigh the negatives by far." Margaret Jacobson shared her concerns, stating, "System-wide experiments in multiple locations and with multiple investigators are challenging. Our research lacks organization, and decisions are not well coordinated." Though a number of benefits were shared, comments about the multi-disciplinary, multi-state nature of the SBRC project were overwhelmingly negative. During interviews, nineteen scientists made 48 statements (7.3% of emergent) that spoke to the challenging nature of the project. These statements addressed issues such as communication, project management, and coordination.

Poor communication was a common thread among the complaints. “Information doesn’t seem to percolate down,” said Chattsworth. “On very few occasions, like field days, have I really seen other members of the team or interacted with others.” Jones shared similar sentiments, saying,

> We have a lot of different people involved in the research, and they all seem to have their little opinions of how to do it. I think we need to sit down more often…and at least when we do meet, we have a better understanding of exactly what we want to do and have more coordination on what we are doing on the project. Because sometimes I feel we keep changing it as time goes on.

Other scientists struggled to collect meaningful information in a project with an ever-changing structure or where mismanagement occurred. This includes the way data were collected. Jones stated, “There’s ten different people doing ten different things.” Of managing one state’s SBRC project, Lincoln said,

> The way the fields were being managed was not replicated in a way we could really get appropriate research data. That was challenging, trying to alter the method or the way things had been managed prior to my being here. A few management mishaps from my own crew when I started here, and we ended up losing some data off some projects. It just compounds the difficulty of a rotation

> project in a three-year cycle when you have to wait that long just to get the first cycle done. It makes things even more challenging to get good information for the project as a whole.

Boyd had experienced similar challenges in trying to collect data about forages and cattle in the project. “The biggest challenge is coordinating the research to try to make sure that everybody can collect everything without affecting everybody’s project. . . The project isn’t very well coordinated.” A large volume of data were collected on SBRC’s productivity and costs. Ivey, a project manager, said, “It’s hard to keep up with everything due to the high level of management skills required for this rotation. It is also lots of paperwork.”

<u>Challenges of Agricultural Systems Research</u>

The SBRC project is unique, because it incorporates the study of a “system” and its various components rather than a single innovation or practice. According to scientists, these interactions create additional complexity. “[Our work] shows that one aspect, like cattle, greatly impacts another crop in the system,” said O’Connor. The results may also take years to quantify. “That takes a long time!” said Green “That’s why, a lot of times, these things don’t get funded.” Seven percent of data are comments from scientists who claim that securing funds to do this research had been and would continue to be difficult. Perhaps more important are concerns that systems research does not fit funding cycles. Franklin illustrates this point saying,

> We’ve got to get the regulators who control the funding to understand when you do a project like this, you don’t just do it for four years. You need to do it longer than that to see the long-term benefits. [Frank] has been working on his project for ten years, and he’s still learning. The longer you do it, the better they get when

> you examine things like water quality and ground water. Man, it takes years to figure out what's going on with that. Granting cycles don't fit the SBRC cycle.

Of his challenges, Lake said,

> Get[ting] general acceptance from the scientific community [is hard] because it is a systems level project, and it's difficult to explain in a manuscript. One of the things that we [were asked] early on was, 'Where is your control?' Well, you can't compare a three-year rotation to a four-year rotation because they are two different systems. Scientific journals usually only like to change one variable at a time. We had a number of manuscripts that we've really struggled with before we got them published. We did finally, but it took a long time for us to get the scientific community to get what we're doing as science instead of just farming.

A noteworthy disconnect seemed to exist between at least one bio-physical scientist and the needs of agricultural producers. When asked about project shortfalls, one principal investigator said, "I'm still really limited from a researcher's standpoint. I'm not as plugged into what's going on out in the state. That's not so much my job responsibilities." When asked if he thought producers might face barriers or constraints to adopting SBRC, he expressed similar sentiments. "I'm really just plugged into the research side of things and manage scientifically the specific projects. I'm not as plugged into things from an Extension standpoint to know what growers' needs are. So, I really can't offer any input there." Despite his acknowledgment of a disconnect between his science and the real needs of farmers, he recognized his role in determining research priorities and projects at the experiment station.

DISSEMINATING FINDINGS AND SYSTEM ENDORSEMENT STRATEGIES

SBRC scientists have utilized a variety of methods to disseminate information about the system to stakeholders. Research findings have been shared at a variety of academic conferences around the country and disseminated via outreach events such as workshops and direct one-one-one communication with producers. In one-on-one consultations, a lead investigator encouraged producers with segments of marginal land, or land that consistently fails to produce acceptable yields, to attempt a small, on-farm trial. For instance, during Experiment Station field days O'Conner said: "Put non-productive acres that you're losing money or breaking even on into SBRC. Whether its five, ten, or fifteen acres, see what will happen. In most cases, when farmers do that, they're happy. The yields increase."

In partnership with Extension, the research team employed Experiment Station field days at as a means to disseminate research findings and system information such as the structure of SBRC and anticipated benefits for adopters. Attendees included agricultural producers, crop insurance agents, university staff, extension staff, and representatives from local ag-related agencies among others. Staff from the research station and university scientists presented their findings verbally and visually, utilizing posters with graphics and charts to illustrate their findings. Claims were made such as, "The system will reduce erosion and inputs," and, "You can double your organic matter—but who knows how high we'll go! We're already up to 2.5%. If we make it up to 4%, we'll look like Iowa!" Riding people-moving wagons through the SBRC fields, attendees asked questions about the system's structure, benefits, challenges, and more. Print materials were disseminated to attendees, including an agenda, a survey, information from partnering organizations, and a brochure about SBRC.

O'Connor shared the challenges of disseminating SBRC findings with producers saying,

> Most research data that is presented at meetings, even extension meetings, is from a plant pathologist talking about diseases, for instance. Here we're talking about the entire system, and the complexity of it is one of the difficult things to [communicate] to growers--what you're doing this year or on this crop impacts the next crop. Conservation tillage took about 20-25 years to get farmers to really adopt it, and we think this is going to take an equal amount of time.

A number of articles have been published in popular press magazines and peer reviewed journals, dating back to 2002. Extension publications have been developed and distributed electronically through all three participating LGUs. A full-color, professionally developed brochure was also developed and disseminated, displaying infographics about the order of the rotation, diagrams of SBRC's perceived benefits, and the claim, "Two years of sod-based rotation can increase peanut and cotton yields up to 100%." The back of the brochure makes four claims in large, bold letters: increase yield, reduce inputs, improve soil, and conserve water.

<u>Perceived Barriers and Constraints for Potential Adopters</u>

When asked what barriers to adoption they anticipated, a variety of possibilities such as equipment, system complexity, production knowledge-base, on-farm infrastructure, rented land, time, and finances were shared. Rodriguez stated that many producers do not follow conservation tillage practices, and therefore do not own the equipment necessary to begin the recommended system. Additionally, producers would have to learn how to do things differently in this system, indicating there may be a steep learning curve for some producers. Of the system, she also shared,

> Farmers [have] to understand that this is a long-term commitment. You can't adopt it one year and abandon it. You have to stick with it in the long run.

> Another barrier is the misconception you have to have cattle. They're not as likely to adopt if they have to have cows, and in their mind, they can't justify putting the land in grass two years. If you have cattle, it's a different deal. If they have cattle, the reason they aren't implementing it is probably because they don't understand the value of the entire sod-based rotation system.

Sometimes researchers disagreed about what barriers existed. Non-integrated producers (i.e., producing only row crops or cattle) were perceived as less likely to adopt the SBRC. This was based on the required production-knowledge to be successful in both ventures. Lack of necessary equipment (i.e., planters, combines, irrigation systems) or infrastructure (i.e., fencing, cattle watering systems, wells) were also barriers for non-integrated producers. Green stated,

> It's not going to happen overnight if you're building up a system from scratch. With cattle, which really make the system economically advanced beyond a traditional system, a lot of people don't have the fencing in place or it's too costly, or you've got people that are strictly cattle folks versus row crop folks. For them to expand into a whole other industry is scary, and they may not want to do that.

She also cited the amount of time required to earn profits as a barrier for producers. Of the system, Boyd shared, "The main constraint [producers] will encounter, I think initially, is the fact that the income they would normally get will be reduced."

Irrigation was a controversial topic. Some members of the research team indicated irrigation was essential to the success of the system. Jeffers said, "I really feel strongly about the irrigation system for this to work properly." When speaking about the merits of irrigation in SBRC, Black said, "I'm struggling to see the benefit of SBRC in a dryland situation. We haven't done any research to have the information.” In contrast, Burke stated, “As far as I know, the rotation should provide even more benefits in a dryland system than it would in an irrigated system.” Forty one percent of those interviewed (n=12) indicated the need for dryland SBRC studies.

More than 40% (n=12) indicated that rented land was a barrier to SBRC adoption. Franklin said,

> A lot of land is leased and fragmented. If [farmers] own the land already, I think it will be easier because they have more long-term control of the property, and they’re willing to invest in infrastructure… If you’re leasing, you can spend a whole lot of money and next year you lose it.

How Can We Reduce Barriers?

When asked how to reduce producers’ barriers, a variety of possibilities such as long-term leases, structural modifications to the system, and education, including increasing awareness of available government programs, cooperation among producers, and adoption across small segments of land.

Three scientists said long-term leases would reduce barriers related to SBRC on rented land. An agricultural economist shared, “Long term leases [would] avoid having the farmer put this in and then not recouping the benefits.” Ivey suggested development of SBRC over four fields rather than four quadrants of one field for those without large enough tracts of contiguous land, but acknowledged that irrigation may be a barrier in this scenario. Knight stressed the importance of talking about barriers with farmers rather than ignoring them, as scientists and producers may be able to begin working toward real solutions.

Three individuals cited the need for more farmer education. Of producer outreach, Rodriguez said, “It will require time from everyone who works with producers one-on-one to show them this is the way to go. The research team really needs to focus presentations in areas where we want them to adopt SBRC.” Spencer desired more explicit, written instructions for how to manage SBRC’s complex system. According to Boyd,

> Extension is key in this process to be able to translate our findings into something producers can use. Sometimes it boils down to dollars and cents, and that’s probably what they’ll be after. But the other question will be a rotation system like this versus planting a crop every year. The challenge for us is to be able to demonstrate a reduction of risk when they diversify their income by having four different sources. When you do it, it’s to educate producers on our findings and be very clear about the constraints we’re having so they know it’s something they should expect. We should not try to oversimply the system, because it may not be simple in the beginning.

Green said she believed one major barrier related to education was science literacy. “America, in general, is very science illiterate.” As a possible solution, Green suggested getting 4-H youth involved. “We don’t use the 4-H people much on this kind of [project]. I don’t know how much you can do with the farmers who are 50 or 55 years old. How willing are they to change in the middle or end of their career?”

Jones cited the need to connect producers to government programs. Burke suggested identifying conservation programs that provide financing to help reduce barriers associated with infrastructure or equipment. “There’s probably some kind of conservation help if [SBRC] qualifies [for those programs]. You might be able to get some kind of financing for a seed drill or [other equipment].” Similarly, Clark identified the EQIP program as a source of funding for establishing bahia grass as part of a rotation. “This is where the extension service can have a big role, to help some of these farmers be aware of these programs and to help them with the knowledge gap that they may have [to adopt],” said Jones. Knight suggested that a way to reduce barriers is to work with the insurance industry as they may not be aware of this cropping system as a risk-reduction strategy.

Several researchers expressed the desire to develop a more flexible system such as the use of temporary electric fencing in lieu of costly permanent fencing and chicken litter for a nitrogen source for those without cattle. Other strategies included incorporating organic practices, producer cooperation, and seeking new markets. Others considered design features such as flexibility in crops or the length of the system, non-irrigated systems, different crops (i.e., corn, vegetables, soy), longer rotations (i.e., 3-4 years of bahia), and adopting less productive spaces. Burke, for instance, stated “Maybe [trying] it in a corn/soybean rotation, or putting it in a continuous corn system would be a good next-step… We can help adapt the system to the needs of different producers.”

Lincoln and Johnson suggested rather than relying on producers to have both row crop and livestock production knowledge, row crop farmers could cooperate with cattlemen to coordinate grazing on the bahia grass quadrants, utilizing a cash-rent system. “A little bit more teaming up, or teamwork,” suggested Johnson. “Maybe someone in their county could supply the livestock in the event that they choose not to [purchase their own cattle].” Of such a system, Lincoln said,

> They’re used to managing crops or cattle for maximizing a commodity, not both. It’s going to be a system where they’re rotating with each other and possibly the

> guys who manage forage manage it a couple years. Then invite a row crop farmer to come in, manage for peanut and cotton depending on the rotation. That just takes some management and agreement from whoever the land holder is to come in and manage that land.

For farmers who choose not to diversify into cattle, Chattsworth and Richardson suggested identifying alternate markets for bahia grass or identifying a different variety of grass with similar benefits that had an existing market. "If there is a way to make bahia grass more profitable, it would help," said Chattsworth. "Common sense says we need to create a market for bahia grass. Maybe we need to try other grasses that have a market."

Three Experiment Station employees agreed that it was unlikely farmers would adopt SBRC across all of their agricultural land. Instead, they envisioned adoption on segments of land that were less productive or fragmented from the larger farm operation. "I don't see someone adapting the whole system to the whole farm. I think it's going to be [on a] tract of land has not produced like [they] think it should," explained Hartman.

Three scientists indicated they did not know how to reduce barriers for producers, but most had at least one idea they were willing to share.

<u>Who Will Benefit?</u>

When asked who benefits from SBRC research, researchers' responses varied, indicating that farmers of different sizes and characteristics would have the most to gain (Table 4.2), as well as researchers and consumers (i.e., lower prices from reduced risk). Five respondents (17.5%) said there were "no losers" with SBRC.

Farmers were the most common perceived beneficiary of SBRC research. When asked to be more specific, 45% (n=13) said small-sized farmers would benefit most, 45% (n=13) indicated medium-sized, 34% (n=10) indicated large-sized, and 14% (n=4) indicated very large-sized. Twenty-four percent of researchers (n=7) said farmers who were already diversified (i.e., already producing cattle, peanuts, and cotton) would benefit most from SBRC, five indicating diversified small to medium sized operations stood to benefit most. However, one respondent who indicated diversified farms would benefit indicated she didn't think small farms would benefit "at all." In fact, when asked who would benefit least, small farmers were the most common response among scientists (n=6 or 21%). Ten percent of participants (n=3) said large-size farmers would not benefit, and 10% said very large-size farmers would not benefit. Interestingly, no one said medium sized farmers would not benefit from SBRC. Respondents also gave characteristics of farm who would not benefit, including dryland farms (n=2), farms with marginal land (n=1), and farms with operators who were unwilling to change (n=2).

Seven respondents (24%) said researchers working on the project stood to benefit from the work. "Who wins more than another guy? In the short term, of course researchers. They got funding, so they're the shortest-term winners," said Green. "I think the University will benefit, because they're pushing for collaborative research—and [SBRC] provides a good opportunity for this," said Boyd. "It provided an opportunity for scientists, but it also has to be a meaningful project."

Despite being asked "who" (i.e., a person or group of people) would or would not benefit, respondents also gave non-human responses. Nine respondents (31%) said that the environment would be the biggest beneficiary from the use of a system like SBRC, which would translate into benefits for all people. Two scientists (7%) suggested government agencies could benefit from the research findings. Three scientists (10%) shared that companies selling inputs to farmers (i.e., seed companies and agrochemical companies) would not benefit from SBRC research since it used fewer inputs and took land out of production.

Table 4.2.: Scientists Perceptions of SBRC Benefits to Producers

Variable		Yes, They Will Benefit	No, They Will Not Benefit
Farm Size	Small	45% (n=13)	21% (n=6)
	Medium	45% (n=13)	0%
	Large	34% (n=10)	10% (n=3)
	Very-Large	14% (n=4)	10% (n=3)
	All (Regardless of Size)	14% (n=4)	0%
Soil Type	Sandy	7% (n=2)	0%
	Marginal	14% (n=4)	3% (n=1)
Irrigation Use	Dryland	3% (n=1)	7% (n=2)
	Irrigated	7% (n=2)	0%
Producer Type	Diversified	24% (n=7)	0%
	Innovative	10% (n=3)	0%
	Unwilling to Change	0%	7% (n=2)

<u>On-Farm SBRC Pilot</u>

SBRC Scientists were able to secure funds to provide cash rental payments to producers for four years of an SBRC pilot on their farms. Three farmers—Moore, Decatur, and Swift—were identified as good candidates as they were well-connected in their communities (i.e., universities and other growers; Table 3.1). All three producers were men; two were white, and one was African-American.

Swift had the smallest farm, planting approximately 1,000 acres and housing a small cow-calf operation. Approximately half of Swift's land was irrigated. Swift cited his relationship with Franklin, an environmental specialist with the state's department of agriculture, as the leading factor in his willingness to pilot SBRC. Franklin had spoken at length with Swift about nematode problems in his peanut fields, and the possibility of dealing with fewer nematodes was appealing.

Decatur farmed 1,500 acres and housed a 250-head cow/calf operation on his farm. Most of his land was irrigated. Decatur cited the desire to be a good environmental steward as his primary reason for piloting SBRC. It is noteworthy that Decatur served on the Farm Service Agency's state committee. He was excited for the opportunity to learn using this hands-on approach. Decatur also indicted he was hopeful for cost-savings on agricultural inputs, as he had in his melon production. Decatur had used a sod rotation in his melons for over 25 years.

Moore had the largest farming operation with 8,500 acres of row crops. He purchased stocker cattle seasonally, with the number contingent on prices and available forage. Half of Moore's land was irrigated. Moore cited his close, trusting relationship with Hartman of the local experiment station as his rationale for piloting SBRC. He was hopeful the program would aid in the suppression of nematodes, and he was motivated for the opportunity to learn. While his peers were entirely positive about the pilot program, Moore expressed serious reservations as an intensive, cash-flow focused operator, stating,

> We're basically doing it because we want to learn. But from a cash flow standpoint, planting in bahia grass sod, picking seed, and running cattle isn't always profitable. It may not lose you any money, but it may not make you any

> money. So if I had any advice to the people that administer this program and helped this program to get off the ground, get some realistic numbers when you come up with your incentive. Like, I don't know what the pay is exactly for this program that we're doing here, but it's not enough, because they base their figure on non-realistic numbers."

In fact, Moore expressed anger about the information he'd been given, declaring it inaccurate and articulating that he would lose money because of the project, especially during a time of high commodity prices.

FEEDBACK FROM USERS OF SBR VARIATIONS

Seven agricultural producers were interviewed about sod-based rotations they utilized on their farm. All producers were male, and one producer operated a farm in Alabama, another in Georgia, and five in Florida. All producers had farmed for more than 20 years, with two having farmed for 35 and two others having farmed more than 40. Of the seven producers interviewed, six reported they farmed full-time. One producer farmed part time and held off-farm employment throughout the year. All producers had integrated farming systems including combinations of cattle, bahia grass sod, winter grazing, cover crops, and commodity crops. Two producers farmed fewer than 500 acres, three farmed 1,000 acres, one farmed 1,500 acres, and one farmed over 3,000 acres. All farmers included only a portion of their farmland in a rotation system. A variety of crops were included in the sod rotations, including corn, soybeans, cotton, peanuts, tobacco, and melon. The producers studied also grew a variety of other agricultural products, including but not limited to sweet potatoes, pine timber, wheat, millet, and Bermuda grass for hay.

Six producers had a sod-rotation on their farm for more than twenty years, with three having used a sod-based system for more than thirty-five years. Five producers had used a variation of SBR for the entirety of their farming careers, with one adopting it within the first ten years of his farm operation. Only one producer, Foster, was new to a sod-based system, having used it fewer than five years. He adopted a sod-based system as part of the EQIP program, which provided compensation of $200 per acre for sod establishment the first year and $100 per acre in the second year to maintain the sod. He received information via consultation with university research staff and contributed data, which informed their work.

Two producers had SBR without irrigation, while five producers incorporated irrigated land. Of the latter, three had approximately half of their cropland acres irrigated while two irrigated nearly all their cropland.

At the time of this study, no producers interviewed used the ideal-type SBRC, though three were slated to begin its use during the on-farm pilot study. All producers using some form of sod rotation had cattle, including a mixture of both cow-calf operations and stocker operations (i.e., purchasing calves to feed on pasture, then later sell to a feedlot). One producer had approximately 100 head of “mama cows,” six producers had 200-300 head of “mama cows,” and one producer had 600-800 stockers he fed seasonally.

Producers gave widely varied reasons for having adopted SBR systems. Foster adopted the system because it was financially incentivized via EQIP, and he self-identified as an innovator. Adams utilized a sod-rotation as part of a tobacco rotation for its nematode-protection properties because his father had done the same. Anders also used sod in a tobacco system, and continued the practice when he changed to a peanut-corn system. Several producers listed disease, pest, crop failures, as well as nematode control as a factor in their adoption decision. In contrast, others were interested in yield advantages on poor and/or dry soils. Of his SBR adoption, Decatur said,

> When I was no more than in my early 20s, and I'm 58 years old now, [a successful old tobacco farmer] told me to plant bahia grass, enough to put my tobacco crop on every year, and I'd make a better crop. It took me years to get set up to do it, but I did. I tell you, it works.

Benefits and Challenges of Sod Rotations as Perceived by SBR Users

Producers shared benefits they had realized by using a sod-based system, including yield increases, reduction in fertilizer costs, increased soil organic matter, and the increased seed production of younger, newer bahia grass. Producers indicated that bahia grass helped suppress weeds, pests, diseases, and parasites, namely nematodes.

Producers also shared challenges of SBR. Of the seven users interviewed, only one indicated he intended to discontinue the SBR, adopting cover crop and strip-tillage instead. He cited establishment costs for sod, the low nutritional quality of bahia grass, and challenges related to digging peanuts as cause to discontinue system use. Several producers stated that harvesting peanuts was especially challenging. Cattle tended to compact the soil, requiring rain or irrigation to soften prior to planting. Sod was hard to kill and harder to break up, requiring multiple costly passes of a cultivator or bottom plow to prepare soils for peanuts. Bahia's thick root system also made digging peanuts difficult, particularly when the sod is burned down with glyphosate and seed strip-tilled into sod. Of this challenge, Foster said,

> They were saying the bahia loosen the soils so loose, this is why peanuts would work successfully in the root zones. That, I doubted all along. I found out the one flaw that he never told me about, which cost me a bundle of money! I got in real trouble with my first field to dig peanuts. We plowed them up, but they came with such a massive root that it stripped off hundreds of pounds of peanuts. We were

> picking up tons of dirt along with the peanut harvester. It really tore me up. Had I went ahead and disked it up and broke all that sod up, I wouldn't have had nearly the problem. I spent a heap of money trying to stay within the program with what they wanted us to do.

Of the dense sod, Martin echoed saying, "I've tried what they've done with not tearing up the bahia grass, but…where I don't tear it up a little bit, I can't plow up the peanuts. I don't understand quite how [the research station has] done it yet."

Anderson, who utilized his irrigation system to aid in the establishment of bahia grass, stated, "It's hard to get a sod-base without irrigation." Adams echoed similar sentiments, sharing, "Down here, it seems like the key to everything is irrigation. With these sandy soils, it seems like we're always three days from a draught." The grass was also deemed problematic for cash-flow reasons, but Adams explained, "As long as cattle and [grass] seed prices are good, it's not that big of a deal."

Barriers to Adoption

SBR users identified a variety of potential barriers to adoption. Some responses were economic in nature, including the additional expense of land that was rented rather than owned, fencing, establishing water systems, grass establishment, and installing irrigation. When asked about irrigation, Pierce said, "I don't have irrigation. I could get irrigation around here if I wanted to, but I don't know if economically I could." In contrast, Foster cited a moratorium on drilling wells for irrigation as a barrier in the Flint River Basin.

Planting grass instead of a cash-crop for two or more consecutive years was seen as a barrier, particularly when commodity prices are high. Of the lost opportunity Anders said,

> We were starting to question what we've got going, because corn might bring $9 a bushel, and we're sitting here with wells and pivots that aren't in use. We don't water grass, we just let it be. For three years, the irrigation will sit here doing nothing. When the markets are good, you want to push everything you can get out of it. You hear some farmers say they don't have as much input costs [with sod], and you don't. But you aren't going to make as much either.

Martin suggested producers with some soil types were more likely to benefit than others, citing "red" soils as less likely to benefit from such a system. Decatur cited land that was farther away from a farmer's home as a barrier to adoption. He indicated cattle needed to be closer to home so they could be easily checked, particularly in a cow-calf operation. He shared moving cattle between grazing areas as a barrier, especially if there were a large number of cattle to move to grazing on non-contiguous, fragmented land holdings.

PRODUCERS' PERCEPTIONS OF SBRC

While producers at field days, tours, and workshops overwhelmingly thought the SBRC science was interesting, none seemed willing to consider adopting it after learning about the system. Written feedback from one climate-focused workshop indicated that more questions remained after exposure to the research, and many producers seemed to question the accuracy of economic models and yield data that was shared.

<u>Learning about SBRC</u>

Participants had a variety of questions about SBRC including the use of other crops, specifically soybeans or substituting something instead of cotton; comparisons to traditional cropping systems; data regarding cattle as compared to cattle housed elsewhere on the experiment station; as well as questions about the soil's microbes, diseases, and pests.

Profits and the system's economic feasibility were the most prevalent topic (46%) in written responses. One producer asked for a comparison of the crops under irrigation compared to non-irrigated dry corners. One producer asked about the costs of managing SBRC. One producer wrote, "Do the economic models take into account the recent higher prices of corn, cotton, soy, peanuts, etc., and how do they input those numbers?" Another wrote, "What does it cost to establish a stand of bahia grass, including seed, fertilizer, equipment, and other inputs?" Two producers asked about whether insurance would cover his crop in the system.

A number of questions were asked about the bahia grass such as whether or not it might be harvested for bioenergy. Another wanted to know how long it would take with cover crops to gain the amount of organic matter as SBRC. Questions were asked related to the establishment process and cost, seed varieties, seeding rates, process for killing the grass, and sod inputs, including water and nitrogen. Questions were also asked about the over-seeding process for planting cover crops, variety of rye grass, and any challenges related to the rye grass.

Many questions were asked about the experiment's design and other specific components of the project. These included: tracing nitrogen through the soil, use of fencing, plot boundaries, the order of crops in the rotation, the farm's water source for irrigation, and the movement of cattle within the system. Several producers asked where they could find more information about SBRC or if handouts with information would be available. Producers were interested in information about how the system worked with only one crop or with alternative crops.

Barriers/Constraints to Adoption from Field Days

Feedback from producers at Field Days shed light on a number of potential barriers to adoption. One barrier that farmers articulated was that there were producers who do not currently grow peanuts and cotton. Farmers were concerned about getting grass and rye grass established, particularly in dryland farming operations. Of this challenge, one producer said, “You’ve got to get that grass up to begin with. It’s all got to be on time. If it’s not, the system is a bust.”

Concerns related to cattle seemed to pose some barriers. Of cattle, one farmer said, “I don’t want ‘em.” Fencing and the associated costs were a barrier, as well as having contiguous land that allowed for the movement of cattle from pasture to pasture. For producers who wished to omit cattle from the system, a lack of marketable uses for bahia grass was seen as another barrier.

Many producers who attended the field days rented some portions of their crop land, which proved to be a barrier for many. “You can’t do this on rented land,” said a farmer. “My leases are year to year. If I go out and put grass in and my neighbor sees it, he’ll go offer to rent it for $20 per acre more, pulling the land out from under me.” About improvements on rented land, one producer said, “You can maintain it, but you can’t invest.” Producers perceived rented land as a deterrent to implementation, since investments in irrigation or other improvements might increase the likelihood of higher offers to landowners by competing tenants.

Irrigation and access to water was a barrier. One producer stated that he had limited access to water to drill wells for irrigation. One farmer said, “There’s a reason we’re not irrigated. If it was feasible on our places, we’d be irrigated. We don’t have the water or we don’t have the field size. There’s something there that keeps us from pursuing irrigation.”

Producers seemed doubtful that SBRC could function at all in a dryland situation. “If we’re depending on the weather to make this work, it’s not going to work,” said one producer. “Show us the real deal. Pull the pivot, and show us what the system can really do,” said another. “If water isn’t the key, how come there’s so many pivots going in?” asked a third. Overwhelmingly, non-irrigated producers believed SBRC was not a good fit for their farming operation. One producer stated, “No one has an enterprise that could do this system.” Another said that the system “looked good on cardboard.”

One producer mentioned he thought SBRC might be an option for new, young farmers to begin their operation. Most of the farmers disagreed, breaking out in uproarious laughter and animated remarks such as, “Stop. Don’t do it. Buy yourself a set of golf clubs. It’ll cost you a lot less money.” Another said, “We don’t need the competition. We’ve got enough competition.” Concerns about needing more labor were expressed, and management issues were discussed at length. Producers perceived SBRC to be management-intensive, requiring more time and coordination of on-farm activities. “Dryland-wise, we choose to go with cover crops. It’s been good. But it’s a management-oriented deal. You have to have a plan for next year this fall, or it will throw you off course. If one harvest is late, it pushes everything else back.” Another producer agreed, stating, “I may not speak for the group, but cover crops gonna be the key for us. It’s a whole different management scheme, but that’s where we’re going.”

CHAPTER 5: CONCLUSIONS

This thesis had two primary objectives. First, I sought to understand producers' perceptions of the sod-based rotation system with integrated cattle (SBRC), including perceived barriers and constraints to adoption. To address this objective, I used qualitative data collected through participant observation and semi-structured interviews with users of sod-based rotation variations, producer-cooperators, and potential SBRC users. Second, I sought to understand the scientific process that led to the development of SBRC including perceived challenges with the project and the system endorsement strategies. To address this objective, I conducted semi-structured interviews with SBRC scientists and others supporting the project. I also examined the content of articles and publications used to disseminate information related to SBRC. Data were coded for both *a priori* and emergent themes.

PRODUCER'S PERCEPTION OF SBRC

Despite the efforts of scientists to develop an environmentally-minded, diversified agricultural system to reduce risk for small to medium-sized farmers, the feedback received from farmers indicates they have little willingness to adopt SBRC in its ideal type regardless of information suggesting the potential non-economic benefits. While producers who toured SBRC on experiment station farms showed an interest in the work, it became clear that none planned to adopt the technology. Many were skeptical about the presented budget and yield data, illustrating a wariness about LGU work. Although some scientists believe SBRC would fare well in a non-irrigated situation and have endorsed it as feasible on "dryland," farmers at field days were overwhelmingly skeptical. They wanted to see more research conducted in a rainfed setting before considering SBRC for personal use.

While some farmers did, in fact, intend to adopt the system at the time of the interviews, they were to be compensated financially and receive one-on-one guidance to adopt the system. Without those incentives, it is unclear if they would have chosen such a path. In fact, one farmer who had received benefits through EQIP to establish a similar system was opting to discontinue the system at the time of the interviews.

Barriers and Constraints to Adoption

While the principal investigators of the SBRC project have both endorsed the system and encouraged producers to conduct an on-farm trial on non-productive or unprofitable segments of land, many producers perceived SBRC to be incompatible with their current farming practices. This finding aligns with Rogers (2003) work on adoption, which underscores the need for a technology's compatibility within a producer's existing production structure, past experience, existing values, and needs. Rogers (2003) indicates there are five perceived attributes of innovations: relative advantage, compatibility, complexity, trialability, and observability. Because SBRC requires significant investment in equipment and infrastructure, it lacks "trialability." Only farmers who are currently producing SBRC commodities and practices (i.e., peanuts, cotton, grass, cattle, winter grazing) may have the knowledge, skills, infrastructure, and equipment needed to conduct an on-farm trial with minimal financial and educational investments. Trialability is positively related to an innovation's rate of adoption (Rogers 2003), which may explain the lack of SBRC users despite nearly two decades of project work. Rogers (2003) also argues the perceived complexity of an innovation is negatively related to its rate of adoption. Because SBRC includes producing numerous products and producers require a high level of management capabilities, this system is viewed as overly complex by many producers.

Producers also pointed out that the system also lacks flexibility (i.e., adaptation for different farm situations) and the capacity to be adopted incrementally.

Of the producers who had planned to participate in the on-farm trial, the largest producer (i.e., 8,500 acres of farmland) had the greatest concerns. He was concerned about the management of such an intensive system as well as effects on cash-flow if tillable acres are taken out of crop production. In spite of recognizing SBRC's benefits to the biophysical environment, producers' attitudes align with work by Lasley, Hoiberg, and Bultena (1993), who found that large scale producers are more likely to have negative attitudes about sustainable agriculture because such practices are often management intensive which, for large producers, are more labor intensive over more acres.

Rented land was identified as another factor of concern due to the lack of long-term decision-making on the property and the risk of making land improvements only to have the land rented to another producer in a time of competitive rental markets. Work by Fraser (2004) underscores the investments in equipment and management necessary to adopt sustainable agricultural practices, which may prove risky when short-term leases or unstable rental arrangements are at play. Constance, Rikoon, and Ma (1996) addressed environmental decision-making, finding landlords often choose not to have much control over their land, having relinquished use rights for payments. While land use decisions may add an additional layer of complexity to some rental situations, it seems that volatile cash-rental markets are perceived to be a more problematic barrier for SBRC adoption.

DEVELOPMENT OF SBRC

SBRC is a bundle of technologies including two or more management processes intended to increase productivity and profitability. Goodman (1991) referred to such bundles of technology in his work, citing a shift to system development in LGU research. Based on feedback from scientists on the project, the development of SBRC was a top-down process. Participatory research and extension processes were not considered, or they were utilized minimally at best, throughout the SBRC development process. Scientists who developed the SBRC system did so independently in a top-down fashion, reinforcing the land-grant college complex (LGCC) technology transfer concept of an expert from a university providing information for the lay-person in rural areas (Warner 2008).

Historically, farmers have adapted agricultural systems to improve conservation practices, protect agrobiodiversity, maximize returns, and improve the system's stability or production by using indigenous practices to reduce risk (Altieri 2004). The findings of this study suggest that the SBRC project would have benefitted from the inclusion of stakeholders at the beginning and throughout the research project to ensure a more democratic development process. By including stakeholders such as farmers, insurance agents, lenders, policymakers, and representatives from agricultural industry, researchers could have utilized feedback to develop a technology that was more compatible with existing agricultural operations and easier to adopt. Producers would have brought indigenous knowledge about the local conditions and constraints to the table, enabling scientists to develop an agricultural system more compatible with local needs and practices (Altieri 2004). This process would have illustrated that there is not a "one size fits all" or even "most" approach to sustainable agricultural practices, as producers' needs vary by farm size, farm type, socioeconomic characteristics, and more. Scientists may have considered a more flexible, adaptable system based on such feedback. Long ago, Middendorf and Busch (1997, 45) argued that "a closer approximation of the 'public good' can be achieved by encouraging the participation of the fullest range possible of constituents as an integral part of the process of setting research priorities." Universities are in a position to facilitate the democratic process by engaging all stakeholders in conversations to increase the likelihood that research decisions are more responsive to the needs of a broader public rather than an elite or well-connected few (Middendorf and Busch 1997).

The use of tactile spaces is a participatory method of engaging diverse groups in research, education, and extension (Cowan et al. 2015). Carolan (2007) describes tactile spaces as sensuously rich learning environments where participants interact with each other and the environment in an 'embodied' and 'embedded' manner leading to long-lasting attitudinal and behavioral change (Cowan et al. 2015, 456). This approach would be appropriate for increasing other voices in the research process. While some concepts associated with tactile spaces were included in field days (i.e., focus groups, tours), a more hands-on, experiential, longitudinal process could have been implemented. Stakeholders could have benefitted by spending time engaging with the system in a hands-on way, having a more diverse focus group to enrich discussion (i.e., include industry professionals, cattlemen, crop consultants, extension professionals). By incorporating tactile space in planning field days, scientists could have increased the lasting impact of the educational experience on producers. Since most are non-local experts, scientists could have engaged farmers (i.e., local experts) at these events to determine research goals, to provide feedback on technology development, and ultimately to address the problem of "epistemic distance" to co-produce a technology that is more appropriate for the needs of local farmers (Carolan 2007).

Though scientists have endorsed SBRC as a production system for small to medium-sized farmers, the producers invited to participate in the on-farm pilot would likely be considered medium to large in size. Not only were the producers larger in size, they also tended to be more connected within their communities, having lived in their areas for many years, and consequently have a large social network. This finding aligns with the inequality that has long been a critique of agricultural research. Hightower (1973), for instance, was one of the first to note that CES tends to associate with wealthier, more successful farmers, leaving smaller farmers behind. To create a more equitable, socially just research environment, researchers should have made efforts to include smaller operations and unrepresented farmers (i.e., low-income farmers, women, racial or ethnic minorities). Data from these groups may have revealed, for instance, that typically unrepresented farmers were more open to considering the SBRC as a form of sustainable agriculture. For example, Trauger (2004) found that women farmers in Pennsylvania were up to three times as likely to operate a farm using a sustainable agriculture model than productivity models, demonstrating that "the sustainable agriculture community provides spaces that promote and are compatible with women's identities as farmers."

While the SBRC was intended to be a multidisciplinary project, it is unclear to what degree the project intended to integrate the perspectives and approaches of a range of disciplines. Using the various multidisciplinary modes described by Lockeretz (1991), the SBRC project can be labeled as "additive extensive" in type because each discipline acted as if it were the only study involved, with the study acting as an aggregate of its various disciplinary components. A range of disciplines were included, which allowed the study to cover a wider range of researchable questions, but feedback from SBRC project scientists indicated a lack of communication or collaboration between disciplines and sub-projects, often indicating that they saw other scientists only at field days. Further, conflicting information has been published by different members of the research team, particularly regarding budgets and profitability. As Lockeretz (1991, 108) might describe, this project appears to be "multidisciplinary in form," but the format did not "guarantee multidisciplinary in spirit." Furthermore, "Just making sure the team includes the right resumés doesn't guarantee the 'right' kind of multidisciplinary (Lockeretz 1991, 108)."

Challenges of SBRC

One huge challenge faced by the SBRC research team is the inertia of decades of the LGU's focus on large-scale, monoculture, productivist agricultural methods that were promoted through research farms, publications, and one-on-one consults with extension agents. Furthermore, it is unclear whether scientists considered CES's nearly singular focus on large-scale monoculture, extraordinarily intensive production practices in past decades. Farmers were further encouraged to adopt productivist methods through the efforts of private industry research and development. Producers are likely to struggle to adopt SBRC with the knowledge required to produce such diverse commodities in a farming culture that has pushed intensive monoculture or simple rotations over the course of their working lifetime. SBRC literature endorsed taking acres out of crop production in an era of high commodity prices. SBRC is a shift in course, moving to highly diversified, yet still intensive form of production.

SBRC System Endorsement Strategies

SBRC was endorsed as a method of sustainable intensification by several members of the project. However, for a farm to be truly sustainable, I argue it must be functional in four distinct, but related dimensions: environment, economic, social, and social justice. Based on the findings of biophysical researchers, there appears to be an environmental benefit to SBRC, one that is recognized by producers. However, the economic and social sustainability of the system remain to be determined, as illustrated by farmers' attitudes, and conflicting published economic data.

In terms of social justice, the research process has not followed a democratic or inclusive process that includes the perspectives of individuals from diverse backgrounds and experiences. For instance, while the system is promoted as beneficial to small producers, it is unclear if this technology could truly benefit members of this group, who are less likely to afford the equipment and/or to have the infrastructure or range of resources (i.e., financial, insurance) necessary to implement such a system. The system also lacks the flexibility that many producers indicated would be necessary for implementation on their farms. While "flexibility" might be conceptualized as including an option for row crop producers to partner with local cattle producers to graze the property, this type of arrangement is likely to be difficult to establish and maintain when there is no history of such collaboration. Furthermore, flexibility could include options for farmers who rent property by addressing challenges like investment in infrastructure (i.e., fencing for livestock, establishing irrigation systems), lack of long-term decision-making over rented land, or addressing potentially volatile short-term rental arrangements.

SBRC was marketed as a low-input system, but it is unclear if the system implemented on the research farms is truly low input. Considerable inputs including agrichemicals and water were used on the research plots. Farmers were discontented with these inputs and asked, for instance, to "see what the system could really do" by "shutting off the water." Perhaps, more important, is management. SBRC is a management-intensive system that requires considerable time, money, knowledge, and access to resources such as access to water for irrigation and funding for infrastructure. Furthermore, producers adopting a system must contend with fear of a steep learning curve during implementation and potentially unproductive plots of land.

Pretty, Toulmin, and Williams (2011) provided seven suggestions achieving sustainable intensification. SBRC aligns with only one of their suggestions. Pretty et al. (2011) suggest improving farmer knowledge and capacity through the use of farmer field schools and modern information and communication technologies. Some methods of sustainable intensification may be more complex or require higher levels of management, which this improvement in knowledge and capacity can address. SBRC aligns with this method through the use of experiment station workshops and field days, the development SBRC web resources (i.e., sample budgets, adoption plans), extension publications, popular press magazine articles, web-based articles, and other methods of communicating information about SBRC. However, even this method for scaling up sustainable intensification using SBRC could be strengthened by the use of additional tactile spaces (i.e., creating repeated interactions with producers, engaging a wide range of stakeholders, and offering more opportunities to interact with the complex technology), as discussed earlier in the chapter.

SBRC does not address the six other suggestions that Pretty, Toulmin, and Williams (2011) argue are required for sustainable intensification. First, Pretty et al. (2011) suggest that scientists and farmers each provide input into technologies and practices that combine crops and animals with agroecological and agronomic management. The development of this project did not include producers in the development of SBRC, meaning critical stakeholders were unable to provide input that could have made the technology more compatible given existing social, economic, or political constraints. In their work on climate change, Bartels et al. (2012) and Furman, Bartels, and Bolson (2018) offer a more participatory approach to engage stakeholders. Over more than a decade, these individuals held biannual workshops in the tri-state region (Alabama, Florida, and Georgia) which involved a broad group of stakeholders (i.e., climate scientists, specialists, extension professionals, row crop producers, anthropologists) (Furman, Bartels, and Bolson 2018). Stakeholders were guided through the experiential learning process by using shared experiences, hands-on activities, and discussions where knowledge was co-produced. Over several years, these processes developed the social infrastructure needed to support dialog and decision making by producers related to climate change. Furman, Bartels, and Bolson (2018) suggest a three-part process to develop long-term stakeholder engagement and increase co-production of science; stage one involves fact-finding and relationship-building, stage two is the incubation and the collaborative learning process, and stage three includes informed engagement and broad dissemination of findings.

Second, Pretty et al. (2011) encourage the creation of novel social infrastructure that builds trust among individuals and agencies. Several investigators suggested row crop farmers could build relationships with local cattlemen to graze on grass or winter grazing quadrants within SBRC to avoid purchasing cattle. However, the project team did not facilitate dialogue between groups by including both parties in field days or workshops, or by including both producer groups during the research and development process. Third, Pretty et al. (2011) believe engagement with the private sector for supply of goods and services is necessary. My findings suggest that including these stakeholders from the beginning may have helped reduce barriers related to insurance, government incentive programs, and finance. Fourth, Pretty et al. (2011) articulate the need to focus on women's educational, microfinance, and agricultural technology needs. In the case of SBRC, this can be more broadly stated to include minorities and other traditionally marginalized groups who tend to be ignored by institutions in the South (Bradley Ginapp 2003) (both intentionally and unintentionally) including 1862 land grant institutions (Back and Swanson 2003). Fifth, Pretty et al. (2011) advocate for ensuring the availability of microfinance and rural banking as well as insurance and insurance agents. Yet, financiers were not included in discussions about SBRC, which may cause barriers for producers wishing to invest in infrastructure necessary to adopt SBRC on their farm. Finally, Pretty et al. (2011) advocate for ensuring public sector support for agriculture. SBRC investigators could have included representatives from the cotton, peanut, and cattle industries to engage in meaningful conversations for how to collaborate. For example, the cotton industry is increasingly committed to achieving environmental gains and promoting responsible production and manufacturing (Cotton Inc. n.d.). Thus, the sustainability officer for Cotton Inc., for instance, may have contributed to dialogue about the SBRC project, suggested alternative approaches that would have met the corporation's broader sustainability goals, or played a role in leveraging resources, either as incentives for producers to adopt such a system or to fund further research.

LIMITATIONS AND FUTURE RESEARCH

Several limitations existed in this study. First, we were unable to identify any producers who were thinking about, or planning to, adopt SBRC who were not cooperating on a grant (i.e., receiving financial compensation). At the time of interviews, 2011-2013, none of the compensated producers had used SBRC. Therefore, we do not have feedback from actual adopters of the SBRC ideal type. A follow-up to this research might seek input from on-farm trial study participants who have since adopted (or adopted then discontinued) SBRC to discuss their experiences, and whether they plan to continue system use after funding is exhausted. It has been more than five years since interviews were completed. If a follow up study were to be conducted, it would first be necessary to determine if the the SBRC program of research had continued and what its present objectives might be. Then, adopters and potential adopters could be interviewed or contacted at experiment station learning events to learn in greater detail about potential opportunities and challenges. Furthermore, other stakeholder groups that were omitted from the original project should be included, namely women, minority, small-scale, and low-income farmers.

Though I was able to identify several producers who utilized some form of sod-based rotation on their farm, the sample size was very small. In future work, an effort should be made to identify a larger number of SBR users or producers who have discontinued the use of SBR variations for interviews to see if emergent themes and findings remained the same, or if they varied by region, selected crops, age, education, or other variables.

Alabama still lags behind Florida and Georgia in efforts to irrigate cropland, with farmers in southeastern Alabama irrigating only 15% of cropland compared to farmers in Georgia who are irrigating 40% of land (Hollis 2017). In partnership with the Flint River Soil and Water Conservation District, NRCS has invested over $100,000 to close the knowledge and technology gap to promote precision irrigation technology in southeast Alabama and southwest Georgia. Funding applications to USDA-NRCS indicate adoption of irrigation is increasing in Alabama (Hollis 2017). However, this project, which included funds for irrigation and producer education, was initiated in 2017 after data for this study were collected. It is possible that perceptions have changed in the years since this study began, especially if incentive programs are available.

Finally, conditions affecting agriculture in the Wiregrass Region have changed significantly since the time in which the interviews took place. Crop prices, which were high at the time of interviews, have dropped drastically. During interviews, corn was seen as a huge money maker; producers were talking about pulling land out of conservation programs to plant corn or planting corn under pivots instead of peanuts, a plan that may no longer be viable. Extreme weather events, including hurricanes, droughts, and tropical storms, have also affected the farm economy in the Wiregrass region. Hurricane Michael for example, which occurred in

October 2018, caused an estimated $2 billion in losses to Georgia's agricultural industry (Dowdy 2018) alone, plus $307 million in losses in Alabama (Lawrence 2019) and over $700 billion in losses in Florida (Court, Hodges, and Stair 2018). The political climate has also changed following the 2014 Farm Bill; the 2018 Farm Bill; a new presidential administration; and newly implemented tariffs, which have threatened foreign trade of agricultural products. It is unclear to what extent the findings in this study remain consistent in different political, economic, and trade climates.

CONCLUSION

The story of SBRC illustrates the complexity and challenges that exist with multidisciplinary research. While SBRC's "additive extensive" multidisciplinary form may have provided an opportunity for a larger pool of scientists to address more researchable questions (Beier et al. 2016), it is clear that true collaboration was not achieved. This could be by design, or perhaps the principal investigators were simply ineffective managers of a multidisciplinary research process. Scientists are often trained to practice alone, but the expectations of scientific research have grown to be more collaborative with grants often requiring complex teams (i.e., members with different specialties) without providing any sort of support (i.e., training, oversight, management) for this approach.

Whether intentional or not, the development and endorsement of SBRC is an illustration of CES's historic top-down, expert-gives-information-to-farmer technology transfer discourse. While the concept itself is not inherently bad, it tends to ignore the realities potential adopters face which may lead to the development of incompatible technologies. The statement by a principal investigator acknowledging he does not "know what growers' needs are" underscores the disconnect that exists between individuals who make decisions about agricultural research and the potential users of the science. Furthermore, the SBRC project itself proved to be extraordinarily complex, including a combination of complex teams, complex science, complex funding, and complex Extension work all occurring in one project. This case study of SBRC illustrates several important lessons for investigators on future agricultural systems projects.

The findings of this project have at least six implications for scientists developing and endorsing agricultural systems that are diversified, low-input, or sustainable, as well as scientists engaged in multidisciplinary projects. First, these findings illustrate the need for a more democratic process of research development. This research highlights the need for diverse stakeholder involvement from the beginning in scientific research projects such as SBRC. Second, these findings reinforce the importance of Roger's perceived attributes of innovations, including relative advantage, trialability, complexity, observability, and compatibility. Many of these barriers came up in conversations with producers, and it is unclear if scientists took these into consideration during project development or study. Third, these findings illustrate the need for researchers to connect with producers and work to understand the realities that producers face. Researchers can use stakeholders' feedback to ensure that developed technologies are compatible with producers' beliefs, values, and existing operations.

Fourth, these findings underscore the disconnect that can exist between university scientists and agricultural producers, who are the intended recipients for research developments. By learning producers' perceived barriers and constraints early in the process, researchers presumably can work to develop technologies that are more compatible for and adoptable by target audiences. This study articulates the need for principal investigators and scientists making decisions about research to engage with producers to gain an understanding of their successes, challenges, needs, and values to ensure the compatibility of technology they are working to develop. One method for achieving a more reliable result is focusing on coproduction of actionable science, in which managers, policy makers, scientists, and other stakeholders to inform decision-making and outline the scope of the problem to be studied. By focusing on methods to produce actionable science, scientists will need to learn to collaborate not only with stakeholders and policy makers, but fully interact scientists from different disciplines (i.e., economists, sociologists, psychologists) in a systems approach. Researchers cannot simply hope to get the science “right” and expect a system such as SBRC to flourish for farmers in targeted geographic areas where social, political, and economic forces are simultaneously at play.

Fifth, the feedback from participating scientists as well as publications developed by scientists engaged in this study reinforce the need for improved communication and cooperation across disciplines to ensure that information is shared, appropriate feedback is given and received, and inconsistent or competing information is not published by scientists on the same project. Finally, these findings underscore the need for inclusion of social scientists throughout projects such as SBRC. Social scientists can help to identify the wants or needs of wide range of stakeholders to ensure the developed product is compatible with commercial operations. Rural sociologists have studied agricultural production and agricultural sciences for decades and can offer a range of research techniques that can facilitate a more democratic development process (Busch, Bonanno, and Lacy 1989).

REFERENCES

Agyeman, Julian , Robert D. Bullard, and Bob Evans. 2003. *Just Sustainabilities: Development in an Unequal World*. London: Earthscan/MIT Press.

Allen, Patricia L., and Carolyn E. Sachs. 1991. "The social side of sustainability: Class, gender, and race." *Science as Culture* 2 (1):569-590.

Altieri, Miguel A. 2004. "Linking ecologists and traditional farmers in the search for sustainable agriculture." *Frontiers in Ecology and the Environment* 2:35-42. doi: 10.2307/3868293.

Back, Mary M., and Janice C. Swanson. 2003. "Value-added animal agriculture: Inclusion of race and gender in the professional formula." *Journal of Animal Science* 81 (11):2895-2903.

Bartels, Wendy-Lin, Carrie A. Furman, David C. Diehl, Fred S. Royce, Daniel R. Dourte, Brenda V. Ortiz, David F. Zierden, Tracy A. Irani, Clyde W. Fraisse, and James W. Jones. 2012. "Warming up to climate change: A participatory approach to engaging with agricultural stakeholders in the southeast U.S." *Regional Environmental Change* 13:45-55.

Baulcombe, David, Ian Crute, Bill Davies, Jim M. Dunwell, Mike Gale, Jonathan Jones, Jules Pretty, William Sutherland, and Camilla Toulmin. 2009. Reaping the benefits: Science and the sustainable intensification of global agriculture. London: The Royal Society.

Beier, Paul, Lara J. Hansen, Lynn Helbrect, and David Behar. 2016. "A how-to guide for coproduction of actionable science." *Conservation Letters* 10 (3):288-296.

Beus, Curtis E., and Riley E. Dunlap. 1992. "The alternative-conventional agriculture debate: Where do agricultural faculty stand." *Rural Sociology* 57 (3):363-380.

Blevins, Brooks. 1998. *Cattle in the Cotton Fields*. Tuscaloosa: The University of Alabama Press.

Boehlje, Michael. 1998. "Information and technology transfer in agriculture: The role of the public and private sectors." In *Privatization of Information and Agricultural Industrialization*, edited by Steven A. Wolf, 23-28. Boca Raton: CRC Press, LLC.

Bradley Ginapp, Kristol 2003. "Jim “USDA” Crow: Symptomatic discrimination in agriculture." *Drake Journal of Agricultural Law* 8:237-248.

Bultena, Gordon, Paul Lasley, and Jack Geller. 1986. "The farm crisis: Patterns and impact of financial distress among Iowa farm families." *Rural Sociology* 51 (4):436-448.

Busch, Lawrence, Alessandro Bonanno, and William B. Lacy. 1989. "Science, technology, and the restructuring of agriculture." *Sociologia Ruralis* 29 (2):118-130.

Buttel, Frederick H. 1993. "The sociology of agricultural sustainability: Some observations on the future of sustainable agriculture." In *Agriculture and the Environment: Papers presented at the International Conference*, 175-186. Elsevier.

---. 2005. "Ever since Hightower: The politics of agricultural research activism in the molecular age." *Agriculture and Human Values* 22 (3):275-283.

Buttel, Frederick H., and Gilbert W. Gillespie Jr. 1988. "Preferences for crop production practices among conventional and alternative farmers." *American Journal of Alternative Agriculture* 3:11-18.

Carolan, Michael S. 2005. "Barriers to the adoption of sustainable agriculture on rented land: An examination of contesting social fields." *Rural Sociology* 70 (3):387-413. doi: 10.1526/0036011054831233.

---. 2007. "Introducing the concept of tactile space: Creating lasting social and environmental commitments." *Geoforum* 38 (6):1264-1275.

Carolina Sandhills Wildlife Refuge. 2010. "The longleaf pine/wiregrass ecosystem." United States Fish and Wildlife Service, accessed March 27, 2013. http://www.fws.gov/carolinasandhills/longleaf.html.

Cash, David W., William C. Clark, Frank Alcock, Nancy M. Dickson, Noelle Eckley, David H. Guston, Jill Jåger, and Ronald B. Mitchell. 2003. Knowledge systems for sustainable development. In *Proceedings of the National Academy of Sciences*. Cambridge: National Academy of Sciences.

Cochrane, Willard W. 1993. *The Development of American Agriculture: A Historical Analysis*. 2 ed. Minneapolis: University of Minnesota Press.

Conkin, Paul K. 2008. *A Revolution Down on the Farm: The Transformation of American Agriculture Since 1929*. Lexington: The University Press of Kentucky.

Constance, Douglas H., J. Sanford Rikoon, and Jian C. Ma. 1996. "Landlord involvement in environmental decision making on rented Missouri cropland: Pesticide use and water quality issues." *Rural Sociology* 61 (4):577-605.

Cotton Inc. n.d. "Cotton Incorporated: Dedicated to a sustainable future." accessed January 31, 2019. https://www.cottoninc.com/about-cotton/sustainability/.

Court, Christa D., Alan W. Hodges, and Caleb A. Stair. 2018. County-level economic losses for Florida agriculture resulting from Hurricane Michael. In *Economic Impact Analysis Program*. Gainesville: University of Florida IFAS.

Cowan, Jeremy S., Jessica R. Goldberger, Carol A. Miles, and Debra A. Inglis. 2015. "Creating tactile space during a university extension field day event: The case of a sustainable agriculture innovation." *Rural Sociology* 80 (4):456-482. doi: 10.1111/ruso.12073.

Daberkow, Stan G., and Katherine H. Reichelderfer. 1988. "Low-input agriculture: Trends, goals, and prospects for input use." *American Journal of Agricultural Economics* 70 (5):1159-1166.

Douglass, Gordon K., ed. 1984. *Agricultural sustainability in a changing world order, Westview Special Studies in Agriculture Science and Policy*. Boulder: Westview Press.

Dowdy, Sharon. 2018. Georgia farmers face more than $2 billion in losses from Hurricane Michael. *College of Agricultural and Environmental Sciences News*: http://www.caes.uga.edu/news-events/news/story.html?storyid=7752&story=Hurricane%20Michael%20Totals. Accessed January 30, 2019.

Edwards, William. 2003. Cash rent acres are increasing. In *Ag Decision Maker: A Business Newsletter for Agriculture*. Ames: Iowa State University.

Fraser, Evan D.G. 2004. "Land tenure and agricultural management: Social conservation on rented and owned fields in southwest British Columbia." *Agriculture and Human Values* (21):73-79.

Furman, Carrie A., Wendy-Lin Bartels, and Jessica Bolson. 2018. "Participation, Process, and Partnerships: Climate Change and Long-term Stakeholder Engagement." *Anthropology in Action* 25:1-12.

Gamble, Audrey V., Julie A. Howe, C.Wesley Wood, Dexter B. Watts, and Edzard van Santen. 2014. "Soil organic carbon dynamics in a sod-based rotation on coastal plain soils." *Soil Science Society of America* 78 (6):1997-2008.

Garnett, Tara, and H. Charles J. Godfray. 2012. Sustainable intensification in agriculture: Navigating a course through competing food system priorities. Oxford: University of Oxford.

Gilbert, Jess, and Thomas M. Beckley. 1993. "Ownership and control of farmland: Landlord-tenant relations in Wisconsin." *Rural Sociology* 58 (4):569-579.

Goldberger, Jessica R. 2001. "Research orientations and sources of influence: Agricultural scientists in the U.S. land-grant system." *Rural Sociology* 66 (1):69-92.

Goodman, David. 1991. "Some recent tendencies in the industrial reorganization of the agrifood system." In *Towards a New Political Economy of Agriculture: Special Studies in Agriculture Science and Policy*, edited by William H. Friedland, Lawrence Busch, Frederick H. Buttel and Alan P. Rudy, 37-64. Boulder, CO: Westview Press.

Hightower, Jim. 1972. "Hard tomatoes, hard times: The failure of the land grant college complex." *Society* 10 (1):10-22.

---. 1973. "Hard tomatoes, hard times: The failure of the land grant college complex." In *Radical Agriculture*, edited by Richard Merrill, 87-101. New York: University Press.

Hinrichs, C. Clare, and Rick Welsh. 2003. "The effects of the industrialization of US livestock agriculture on promoting sustainable production practices." *Agriculture and Human Values* 20 (2):125-141. doi: 10.1023/a:1024061425531.

Hollis, Paul. 2013. "Suspension of Georgia irrigation permits said to protect current users." Farm Progress, accessed January 9, 2019. https://www.southeastfarmpress.com/equipment/suspension-georgia-irrigation-permits-said-protect-current-users.

---. 2017. "NRCS funds to demonstrate and promote best irrigation practices in Alabama." Auburn University College of Agriculture, accessed 01/31/2019. https://aers.auburn.edu/news/nrcs-funds-to-demonstrate-and-promote-best-irrigation-practices-in-alabama/.

Holmes, John. 2006. "Impulses towards a multifunctional transition in rural Australia: Gaps in the research agenda." *Journal of Rural Studies* 22:142-160.

Howe, Julie A. 2012. "Effects of sod-based rotations on soil." Cattle Producers Field Day Wiregrass Research and Extension Center, Headland.

Jordan, Jeffrey L., and Douglas H. Constance. 2008. "Sustainable agriculture and the social sciences: Getting beyond best management practices and into food systems." *Southern Rural Sociology* 23 (1):1-22.

Katsvairo, Tawainga W, David L Wright, James J Marois, Jimmy R Rich, and Pawel P Wiatrak. 2009. "Comparative plant growth and development in two cotton rotations under irrigated and non-irrigated conditions." *Crop Science* 49:2233-2245.

King, C. Wendell. 1956. *Social Movements in the United States*. 2 ed. New York: Random House.

Lasley, Paul, Eric Hoiberg, and Gordon Bultena. 1993. "Is sustainable agriculture an elixir for rural communities?" *American Journal of Alternative Agriculture* 8 (3):133-139.

Lawrence, Maggie. 2019. "Agriculture damage ripples through Wiregrass economy." Alabama Cooperative Extension System, accessed 01/30/2019. https://wp.aces.edu/michaelrecovery/agriculture-damage-ripples-through-wiregrass-economy/.

Lemos, Maria C., and Barbara J. Morehouse. 2005. "The co-production of science and policy in integrated climate assessments." *Global Environemtal Change* 15:57-68.

Lockeretz, William. 1991. "Multidisciplinary research and sustainable agriculture." *Biological Agriculture and Horticulture* 8:101-122.

Marois, James J., David L. Wright, J.A. Baldwin, and Dallas L. Hartzog. 2002. "A multi-state project to sustain peanut and cotton yields by incorporating cattle and sod in a sod-based rotation." Southern Conservation Tillage Conference for Sustainable Agriculture, Auburn, June 24-26, 2002.

McNulty, Steve, Sarah Wiener, Emrys Treasure, Jennifer Moore Myers, Hamid Farahani, Lisa Fouladbash, David Marshall, Rachel Steele, Darren Hickman, Jeff Porter, Sharon Hestvik, Rick Dantzler, Wendy Hall, Marlene Cole, Juliette Bochicchio, David Meriwether, and Kier Klepzig. 2015. Southeast regional climate hub assessment of climate change vulnerability and adaptation and mitigation strategies. In *Southeast Regional Climate Hub*, edited by Terry Anderson. Raleigh: United States Department of Agriculture

Middendorf, Gerad, and Lawrence Busch. 1997. "Inquiry for the public good: Democratic participation in agricultural research." *Agriculture and Human Values* 14 (1):45-57.

Moss, Leann E., Peter J. Barry, Gary D. Schnitkey, and Randall E. Westgren. 2001. "A transaction cost economics and property rights theory approach to farmland lease preferences." Regional Research Project NC-221 Conference, McLean, Virginia, October 1-2, 2001.

National Research Council. 2009. "Informing decisions in a changing climate." Panel on Strategies and Methods for Climate-Related Decision Support, Washington D.C.

Nel, Jeanne L., Dirk J. Roux, Amanda Driver, Liesl Hill, Ashton C. Maherry, Kate Snaddon, Chantel R. Petersen, Lindie B. Smith-Adao, Heidi Van Deventer, and Belinda Reyers. 2016. "Knowledge co-production and boundary work to promote implementation of conservation plans." *Conservation Biology* 50:176-188.

Ogburn, William F. 1922. *Social Change with Respect to Culture and Original Nature*. New York: B.W. Huebsch.

Ostrom, Marcia, Bee Cha, and Malaquîas Flores. 2010. "Creating access to land grant resources for multicultural and disadvantaged farmers." *Journal of Agriculture, Food Systems, and Community Development* 1 (1):89-106.

Page, Brian, and Richard Walker. 1991. "From settlement to Fordism: The Agro-Industrial Revolution in the American Midwest." *Economic Geography* 67 (4):281-315.

Percy, Rachel. 2005. "The contribution of transformative learning theory to the practice of participatory research and extension: theoretical reflections." *Agriculture and Human Values* 22 (2):127-136.

Pieper, Charles A., and Neil E. Harl. 2000. Iowa farmland ownership and tenure 1982-1997: A fifteen-year perspective. Ames, Iowa: Iowa Agriculture and Home Economics Experiment Station Publication, Iowa State University.

Pretty, Jules, Camilla Toulmin, and Stella Williams. 2011. "Sustainable intensification in African agriculture." *International Journal of Agricultural Sustainability* 9 (1):5-24.

Prevatt, Christopher G. 2013. "A return-risk analysis of traditional row crop and sod-based rotations in the Wiregrass region of Alabama." Master's thesis, Agricultural Economics and Rural Sociology, Auburn University.

Prevatt, Ronald E. 2012. "Long-term effects of a perennial forage grass in a peanut-cotton rotation on soil properties." Master's Thesis, Agronomy and Soils, Auburn University.

Quintero, Marcela. 2014. "Mixed crop-livestock systems and conservation tillage: Farm profitability, adoption potential, and environmental impacts." Ph.D. diss., Agronomy, University of Florida.

Rogers, Everett M. 2003. *Diffusion of Innovations*. 5 ed. New York: Free Press.

Schaller, Neill. 1989. "Low-input sustainable agriculture." In *Yearbook of Agriculture*, edited by U.S. Department of Agriculture, 216-219. Washington D.C.

Shadi-Talab, Jaleh. 1977. "Factors affecting farmers' adoption of agricultural technology in less developed countries: Iran." Doctor of Philosophy, Sociology, Iowa State University.

Trauger, Amy. 2004. "'Because they can do the work': Women farmers in sustainable agriculture in Pennsylvania, USA." *Gender, Place, and Culture* 11 (2):289-307.

Trauger, Amy, Carolyn Sachs, Mary Barbercheck, Kathy Brasier, and Nancy Ellen Kiernan. 2008. "Our market is our community: Women farmers and civic agriculture in Pennsylvania, USA." *Agriculture and Human Values* 27 (1):43-55.

Troy University. 2013. "Troy: The Wiregrass archives." Troy University, accessed 3/27/2013. http://trojan.troy.edu/community/wiregrass-archives/.

U.S. Department of Agriculture. 2014. 2012 Census of Agriculture. In *Census of Agriculture*, edited by National Agricultural Statistics Service. Washington, D.C.: United States Department of Agriculture.

U.S. Department of Agriculture Economic Research Service. 2017. "Glossary." Last Modified November 29, 2017, accessed September 14, 2018. https://www.ers.usda.gov/topics/farm-economy/farm-household-well-being/glossary/.

---. 2018. "Farm structure: Classifying diverse farms." Last Modified July 2, 2018, accessed September 14, 2018. https://www.ers.usda.gov/topics/farm-economy/farm-structure-and-organization/farm-structure/.

Warner, Jeroen. 2007. *Multi-Stakeholder Platforms for Integrated Water Management*. Edited by Jeroen Warner. Hampshire: Ashgate Publishing Limited.

Warner, Keith D. 2008. "Agroecology as participatory science: Emerging alternatives to technology transfer extension practice." *Science, Technology, and Human Values* 33 (6):754-777.

Wetherington, Mark V. 2006. "Wiregrass Georgia." accessed October 7, 2018. https://www.georgiaencyclopedia.org/articles/geography-environment/wiregrass-georgia.

Wright, David L., James J. Marois, Clyde Fraisse, and Daniel Dourte. 2015. Agricultural management options for climate variability and change: Sod-based. In *Agricultural Management Options*. Gainesville: University of Florida IAFS Extension.

Wright, David L., James J. Marois, Sheeja George, and Tawainga W. Katsvairo. 2015. Sod/livestock-based peanut/cotton production system: The next generation conservation cropping system. Gainesville: University of Florida IAFS Extension.

Wright, David L., James J. Marois, Jimmy R. Rich, and Tawainga W. Katsvairo. 2012. The role of livestock in integrated peanut/cotton cropping system economics. Gainesville: University of Florida IAFS Extension.