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Conservation Practices in Outdoor Hog Production Systems: Findings and Recommendations from the Center for Environmental Farming Systems

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North Carolina State University
Center For Environmental Farming Systems

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Raleigh, NC 2012

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I. Purpose

The purpose of this report is to provide information about conservation practices in outdoor hog production systems and to identify recommended practices that conserve natural resources while optimizing animal performance.

The report is intended for outdoor, pasture based hog producers and those who advise them, including extension agents, NRCS District Conservationists, Soil and Water Conservation District workers and third-party auditors. The report draws on research and on-farm demonstration trials conducted by research personnel and consultants affiliated with the Center for Environmental Farming Systems (CEFS) and funded by the USDA's NRCS Conservation Innovation Grant Program.

Historically, hogs were reared in the outdoors and much research was conducted to evaluate how forages could be used to meet their nutritional needs. There is a significant amount of historical research on the effects of forage quality on meat yield, animal health and costs of production. However, there is a very limited amount of published data on the impact of hog production systems on plant survival, soil disturbance, nutrient loading and animal behavior.

This report is designed to provide a summary discussion of key findings and recommendations (See Section IV). For those readers who want more in-depth information, please refer to Sections V and VI.

A key conservation challenge for outdoor hog producers is maintaining stocking densities that both achieve profitability goals and maintain vegetative cover.

II. Introduction

Outdoor hog production systems are an increasingly popular choice for hog farmers interested in marketing niche pork products. This includes products sold with the following types of claims, "pasture-raised," "humanely-raised," and "raised without the use of antibiotics." Consumer demand for niche pork continues to rise and retail and wholesale buyers increasingly seek out these types of pork products. Despite the advantages of outdoor hog production systems, they can present environmental risks if not adequately managed. The environmental impacts of outdoor hog production are related to the natural behavior of hogs and include deterioration of vegetative ground cover, soil compaction, high nutrient input, irregular nutrient distribution and nutrient losses to ground water and to the atmosphere.

A key to minimizing these impacts is maintaining ground cover. Vegetative ground cover reduces erosion by increasing infiltration, trapping sediments, stabilizing the soil, and reducing the effects of intense rainfall. Ground cover ensures that nutrients from swine waste are held within the plants and soil, and are kept from leaching or flowing to surface waters. Vegetative ground cover also influences animal welfare by altering the temperature near the soil surface and improving animal comfort; this means animals have fewer joint problems, sows demonstrate better reproductive performance and, indirectly, soil fauna habitat is preserved.

While expressing their natural behavior pigs raised on pasture can cause environmental damage.

In 2007, CEFS was awarded a Conservation Innovation Grant (CIG) from the US Department of Agriculture's Natural Resources Conservation Service to support the identification and dissemination of conservation practices in outdoor hog production systems that maintain ground cover and reduce the potential for nutrient runoff, while optimizing animal performance. CEFS' CIG project was designed to identify and define outdoor hog production systems that:

- Exhibit flexibility
- Adapt to a wide range of soil conditions, topography and management practices
- Minimize the use of water
- Provide for animal welfare and well-being
- Decrease energy use requirements
- Optimize economic profitability
- Minimize labor needs
- Maintain vegetative ground cover, and
- Limit impacts on soil, water and air.

III. Approach & Methods

CEFS' CIG project primarily involved: 1) conducting field trials at its Goldsboro research facility and 2) coordinating demonstration trials on working outdoor hog farms. The intent was to develop information and recommended management practices based on the rigor of replicated research trials as well as on observations of selected management practices in real-world, on-farm settings.

An additional objective included developing a user-friendly tool for producers to use in evaluating the economic performance of their outdoor hog operations and management decisions. This tool was developed and can be accessed through the NCSU Department of Agricultural and Resource Economics (http://www.ag-econ.ncsu.edu/extension/outdoor_hogs.html).

Research Trials

During the period 2008-2012, a total of 15 field trials were conducted evaluating the impacts of different stocking densities on ground cover using a variety of annual and perennial forage species. The research trials were designed to answer two main questions:

- How many hogs can a pasture sustain while still maintaining an adequate ground cover?
- Which animals and/or equipment management strategies can be implemented to maintain adequate ground cover?

The CIG project hosted two graduate students and six undergraduate students who each developed additional research projects that contribute to the information presented in this report[1]. In addition, the project included five interns. A detailed discussion of the results is provided in Section V.

On-Farm Demonstrations

Five farms were initially selected to participate in CEFS' CIG project, each representing different types of production systems and regions of the state (e.g., mountains, piedmont, and coastal plain). Farmers were selected based on their location, production system, and willingness to participate and implement suggested management changes. At the start of the project, each farm underwent an assessment of their operation, natural resource issues, and future plans.

CEFS' CIG staff worked with each farm to identify and implement appropriate management changes. Producers were paid to implement agreed upon practices and collect and share data (e.g., animal numbers). At the close of the project, due to unforeseen circumstances, viable data and information were available for three of the five farms originally selected. The following identifies each farm and the key focus of CIG Project observations.

(For a complete profile of these farms, see Section VI):

[1]Graduate students who contributed to CEFS' CIG project include: Chris Bordeaux. Soil Science Department. NCSU and Bart Renners, Crop Science Department, NCSU. Undergraduate students who contributed to CEFS' CIG project include in 2009: Arlin Lobo, Jorge Cardona, Walter Maradiaga from the Universidad Nacional de Agricultura, Honduras, in 2010 Juan Carlos Guevara from El Zamorano, Honduras and in 2012 Ariel Saul Zelaya and Vanessa Guifarro from the Universidad Nacional de Agricultura, Honduras. Interns who contributed to CEFS' CIG project include in 2010: Adeia Nevels, NCSU, Gabriella Minchiotti, Universidad de la Empresa, Uruguay, and in 2011, Elizabeth Noblet, NCSU, Catherine May, Cornell University and Deanna Goldner, Clark University.

Triple B Farm (Caswell County): Implementation of selected Best Management Practices (BMPs), including reconfiguration of paddock size and more frequent movement of animals, and impact on ground cover.

Parker Farm (Orange County): Implementation of selected BMPs and impact on ground cover.

IV. Findings & Recommended Practices

The following provides general guidance and recommended practices for outdoor hog producers and their advisors based on the finding of CEFS' CIG project, including both research trials and on-farm observations. This is not intended as a "how to guide" but as a beginning list of practices that producers, whether they are managing established or new outdoor hog operations, can consider incorporating as a way to try and simultaneously meet economic, environmental and animal welfare goals. It is up to each producer to decide which practices are the best "fit" for their operation.

1. Maintain Appropriate Stocking Rates

Hog stocking rates affect two key outcomes: the physical disturbance of forages and soil and the amount of nutrients deposited in the pasture. In other words, the higher the stocking rate, the greater the soil disturbance and nutrient deposition. Stocking rates must be adjusted according to forage species, season, soil characteristics and management systems.

1a. Maintain Low Stocking Rates on Annual Forages

Annual forages are more sensitive than perennial forages to higher stocking rates under a continuous grazing system. Consequently, the number of animals per unit of area should be kept low. A benchmark suggestion is 15 wean to finish hogs/ac per cycle. This rate is recommended based on research trials conducted at CEFS on Sudan grass (summer) and a mixture of cereal rye and rye grass (winter). Stocking rates of 30 pigs/ac were evaluated and the extent and velocity of ground cover deterioration suggests low (15 wean - finish pigs/ac) stocking rates are required on annual forages. (Additional research is needed to determine appropriate stocking rates for sows on annual forages).

Ground cover in a cereal rye and rye grass paddock. 30 pigs/ac

1b. Maintain Moderate Stocking Rates on Perennial Forages

Perennial forages are less sensitive than annual forages and can be managed in the range of 15 to 30 wean-finish hog/ac per cycle. CIG research trials evaluating the effects of pig stocking rates on Switchgrass, tall fescue and bermudagrass, show that vegetative ground cover decreases as a result of animal activity and that paddocks with higher stocking rates demonstrate a faster rate of decrease. Stocking rates of more than 30 to 45 pigs/ac have a negative impact on vegetation survival. Due to its adaptation and growth habit (rhizome and stolons) bermudagrass, a warm-season grass well adapted to the southeastern USA, offers the best potential to provide sustainable cover within hog pastures.

Research trials suggest that under a rotational management system, sow stocking rates on bermudagrass areas can be established at 6 sows/ac.

For a more in-depth discussion of the research behind these suggested stocking rates, see Section V.

Growing pigs on bermudagrass. 15 pigs/ac

Sows on bermudagrass. 6 sows/ac

2. Use Annual Hay Crops to Remove Nutrients

Removal of nutrients deposited in the field by hogs reduces the risk of surface and ground water pollution. For example, planting a cereal rye and annual ryegrass mixture after hogs are removed (on bermudagrass) followed by planting and harvesting of forage sorghum has been shown to effectively remove soil nutrients deposited by hogs. Nitrogen and phosphorus levels can be reduced to those observed before pigs are put in the paddocks and allowed to graze.

(For a more in-depth discussion of the research behind this practice, see Section V.)

Cereal rye and ryegrass crop planted after hog removal.

If carefully managed, flash grazing with another livestock species is an option to remove nutrients from paddocks previously occupied by hogs.

3. Select Well Drained Soils & Follow Land Contours

Ground cover deterioration and soil compaction are exacerbated in wet conditions. If possible, outdoor hog operations should be established on well-drained soils. Flat land presents water-logging risks, but steep slopes exhibit more potential for erosion and runoff.

Following the contour of the land while designing the paddocks and establishing grass filter strips (50-100 feet wide) are strategies that have proven effective for erosion and runoff control. Paddocks that include drainage areas, ditches or surface water-courses should be bordered by vegetated buffer strips. Corridors for machinery access must also be considered. Animal access to the grass buffer areas can be avoided by fencing.

Areas with an abundance of stones must be avoided to prevent hog injuries, particularly to the legs and feet.

Hogs tend to root near fence lines, therefore this behavior can be taken advantage of in sloped areas by placing fences on the contour of the land, resulting in a berm that reduces the slope length and improves water flow patterns.

The risk of soil erosion is effected by soil texture, rainfall, slope and ground cover.

Observations on one demonstration farm indicate that use of linear, rectangular paddocks with feed on one end and water on the other end of the paddock appear to minimize the amount of damage to the vegetation within the paddocks. This is because the hogs spend less time in one place near the feed and water and instead walk back and forth between the two, which helps to evenly distribute nutrient deposition and soil disruption (See Triple B Farm Case Study, Section XI).

Hogs tend to root near fence lines.

4. Consider Animal Behavior & Maintain Consistent Routines

Understanding the natural behavior of hogs in an outdoor environment can help illuminate adjustments to herd management that reduce potential environmental impact. During summer months, for example, animal activity levels peak during the cooler hours of the day, typically early in the morning and evening. Consequently, rooting and ground cover damage is greatest during this time.

Furthermore, rooting and other activities are related to changes in management routine. Maintaining a consistent feeding routine each day, especially in animals receiving a restricted diet, helps to minimize cover damage. Also, undesirable behaviors can be more pronounced in some individual animals than in others. Close observations of animal behavior can help identify "problematic" animals to remove from the herd.

Observation on demonstration farms indicates that sows appear to root most actively immediately after entering a paddock; it is worth considering the use of large round bales of hay or some other "toy" (straw, roughage, substrates, wood, rope or rubber can be used as paddock enrichment materials) to reduce the amount of rooting action, especially during the first few days sows occupy a new pasture.

Providing hay or straw helps to reduce rooting and contributes to animal welfare and wellbeing.

5. Limit Compaction in Heavy Use Areas

Some areas of the paddock are more prone to the impact of rooting and wallowing behavior. Areas close to shelters, shade, feeders, drinkers and fence lines typically suffer greater disturbance, loss of ground cover and soil compaction.

Using perforated platforms or slats under feeders and waterers can help protect these sensitive areas. Heavy use areas (HUAs) can be further protected with straw, hay, wood chips, leaves and/or any other inexpensive biodegradable material locally available.

Rotating hogs between paddocks and strategically locating feed and water will contribute to a better distribution of manure and soil nutrients and prevent soil compaction, which limits pasture and cover crop root growth.

Hogs create trails, which they follow over and over, leading them to feeders, water and resting areas. If hogs are kept in a paddock a long time or the stocking rate is high, trails can become deep and the soil can become extremely compacted. Frequent movement of feeders and waterers can reduce trail creation within paddocks.

Protect HUAs with locally available organic materials.

The use of perforated slats under feeders and drinkers can help reduce soil compaction.

6. Move Hogs Between Paddocks in a Rotational System

Pigs' natural behaviors - grazing, trampling and, especially, rooting - damage the vegetative ground cover and create bare areas. When forage cover is seriously reduced (e.g., 25 % of the paddock is bare), pigs should be moved and the paddock rested or cropped. To protect vegetative ground cover and minimize the impacts of pigs' natural rooting behavior, rotational grazing systems can be used. A rotational grazing system involves dividing the pasture into small enough paddocks that allow for frequent (e.g., weekly) movement of animals around a central sacrifice area for waterers, feeders and shade.

There are a variety of designs and systems, including the use of electrical fencing, which can be flexible and relatively easy to manage. (It should be noted that CEFS' researchers identified that "strip grazing" or frequent movement of hogs and shelters, feeders and drinkers produced similar results but was extremely labor intensive.) The intent is to give paddocks a chance to rest, which allows for re-growth of vegetative ground cover. In addition, rotating hogs frequently allows for better distribution of nutrients (i.e., manure and urine). This latter outcome is a key advantage of a rotational approach since it supports development of good quality forage, which has the possibility of reducing feed costs.

A rotational grazing system for pigs should include good quality forage species adapted to climate and soil conditions, fencing equipment, water supply and shelter/shade.

Rotating hogs between paddocks provides rest periods for forages to recover. This picture shows three paddocks with different rest periods. Notice the condition of the grass in the far right paddock, after a one week rest period.

7. Consider Use of Humane Nose Rings to Protect Ground Cover

One option for minimizing ground cover disturbance is insertion of nose rings, which limit rooting behavior in hogs. In one CIG demonstration farm, nose rings (allowed on farms certified by the Animal Welfare Approved program) were inserted in the nasal cartilage of sows. After 67 days of occupation (during winter months) by sows (5 sows/ac), vegetative ground cover was kept as high as 87 percent. After 42 days of occupation (during summer-fall months) by sows (2 sows/ac), ground cover was kept over 94 percent. Subsequently, 84 days later and after these two sows lost their nose rings, the ground cover was reduced to 46 percent.

Rings are used to reduce the likelihood that hogs will hunt for edible products in soil such as roots, tubers, grubs, snails, and earthworms.

Controversy regarding the use of nose rings includes the concern that rings reduce the opportunity for hogs to express their natural rooting behavior. Use of nose rings should be considered on a site-specific basis bearing in mind other strategies for achieving conservation goals, including managing stocking rates and implementing rotational strategies.

Humane nose rings discourage rooting behavior.

Ground cover in paddock managed with 5 nose ringed sows/ac.

8. Manage Wallow Areas

Access to wallows allows hogs to reduce heat stress. Additional benefits include protection from: parasites (e.g., ticks and lice), sunburn, insect bites, and wound healing.

While creating wallows, hogs damage the vegetative ground cover, resulting in bare soil exposed to erosion and nutrient leaching. When practical, wallow development should be encouraged at higher elevations or where they can be surrounded with a wide vegetative buffer. Locating wallows away from drainage areas, ditches and water sources can minimize the possibility of nutrient and soil loss during heavy rain. Wallow areas can be encouraged by using shade, drips, or mist, in the site of interest. Wallow consistency should be more liquid than mud, and they should not be allowed to become stagnant. Regular wallows cleaning should be implemented so as limit ingestion of water contaminated with excreta. Water from wallows can potentially contain pathogenic bacteria.

Mud helps protect the skin against insect bites.

Wallowing is a natural behavior for hogs and is important for skin care and cool off .

9. Consider "Potty Training" Strategies

Potty training strategies can be implemented by locating bedding material containing excrement and urine in a designated area of the paddock. The odor of the manure will remind the pigs where they are supposed to go.

At the outset, it is useful to keep the pigs confined to that area, one to two days usually is enough for them to make it a habit. A wooded frame is helpful to keep the bedding in place.

A section of the paddock can be designated as a dunging area.

10. Consider Composting Hog Waste

Hog waste combined with bedding material can be collected at the end of the production cycle and composted. Preliminary research at CEFS indicates that different mixtures of swine bedding and hay can be a good substrate for vermiculture and vermicomposting.

Swine bedding has the potential to be a good substrate for earthworms.

11. Consider Integrating "Deep Bedded Structures" to Protect Pastures

Observations suggest that hog producers can successfully maintain ground cover if they have a structure, such as a hoop house, to move hogs to when weather conditions or vegetation is not ideal for keeping them in the field.

Excellent vermicompost has been obtained with swine bedding .

Hoop houses can be incorporated as part of an outdoor swine production system.

12. Integrate Hogs into Crop Rotation to Utilize Nutrients

Integrating the pigs as part of the farm crop rotation is a strategy that can decrease soil nutrients through their uptake into high requirement crops.

As the price (and environmental consequences) of applying chemical fertilizers rises, the value of livestock manure as a source of nutrients for forages and crops increases. The manure contributed by a typical grouping of hogs on pasture from farrow to finish (e.g., 1 sow, 1 boar and 16 piglets per year) has been estimated to be worth $ 163 (see Table 1).

Rotating an annual crop into the finishing pasture should be considered after two production cycles of animal feeding. This strategy maximizes the agronomic utilization of the nutrients deposited by the hogs, and at the same time, minimizes the pollution of ground and surface water, soil erosion, and damage to vegetation.

Pigs integrated in a rotation with vegetable production in North Carolina

Table 1. Economic value of hog manure

Fertilizer Value of the Plant Available Nutrients passing through 1 sow and 1 boar and 16 pigs finished on the farm.		
lbs produced		**$ value**
PA N	89	$ 51.18
PA P2O5	95	$ 53.89
PA K2O	116	$ 57.90
		$ 163

Commercial fertilizer 2012 prices			
Fertilizer type	**$/ton**	**P $ - N$**	**$/lb**
Urea 45-0-0	$ 520		$ 0.58
18-46-0	$ 730	522.00	$ 0.57
0-0-60	$ 600		$ 0.50

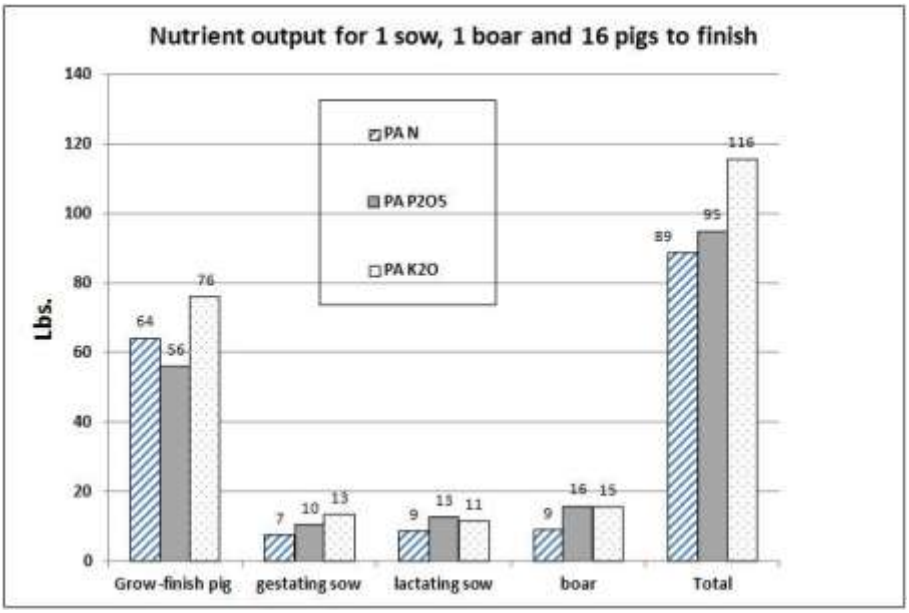

Figure 1. An Example of Hog/Crop Rotations

"Walk behind" equipment can be used to harvest and remove nutrients deposited into the system.

13. Develop a Budget for Your Outdoor Hog Enterprise

Outdoor hog production is an alternative enterprise for small scale farmers. Consumers are searching for local pasture-raised pork, produced in a more natural way and they are willing to pay a premium price for it, creating a niche market.

A budgeting tool for outdoor hog enterprises was developed through this project. The tool allows producers to estimate production costs and returns, based on different management practices, stocking rates, and market outlets.

The worksheets included in the budgets can be modified to adapt to different types of farm circumstances and include dry lot farrow-to-finish and pasture-based, farrow-to-finish operations. This tool allows for a careful assessment of the financial implications of changes in production costs, marketing, pricing and stocking density.

http://www.ag-econ.ncsu.edu/extension/outdoor_hogs.html


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Budget Sheet: OSH

Outdoor Hogs: Pastured Farrow-to-Finish. A template to estimate annual revenue, operating expense, feed costs, and returns to land, overhead and management.
24 sows and 3 boars managed on 24 acres of cool season perennial pastures. *Land for [hogs does not include land for buildings, gas/office areas, farm lanes, or farm buildings.*

Date Prepared: August 2011

Category	Description	Unit	Price/Unit	Quantity	Value	Comments
OPERATING INPUTS						
	Perennial pasture	Renovation	Acre	$140.00	4.0	$560
	Perennial pasture		Acre	$0.00	0.0	$0
	Annual pasture or cover crop	e.g., winter annual	Acre	$0.00	0.0	$0
	Annual pasture or cover crop		Acre	$0.00	0.0	$0
	Sow Feed 1	Gestation	Cwt	$10.00	264.0	$2,894
	Sow Feed 2	Lactation	Cwt	$10.00	270.0	$5,144
	Sow Feed 3	Dry, open	Cwt	$10.00	94.8	$1,010
	Creep feed		Cwt	$20.00	79.7	$1,708
	Boar feed		Cwt	$10.00	46.1	$503
	Growing hog feed		Cwt	$10.00	1623.2	$16,644
	Finishing hog feed		Cwt	$10.00	1648.9	$20,007
	Other feed		Cwt	$0.00	0.0	$0
	Minerals	In feed	Head	$0.00	0.0	$0
	Vaccines, dewormers, meds		Head	$2.50	352.0	$880
	Vet services		Year	$200.00	1.0	$200
	Breeding stock	1 Boar, 8 gilts	Head	$300.00	9.0	$2,700
	Supplies	Bedding	Head	$20.00	24.0	$480
	Other	E.g., Predator control	Head	$0.00	0.0	$0
	Miscellaneous	5% or less	Head	$5.00	28.0	$136
	Fence & Water Repair	% of initial investment	%	2.0%	$19,875	$398
	Facilities Repair	% of initial investment	%	2.0%	$32,399	$648
	Equipment operating	From Table 2				$1,817
	Sales Comm. & transport	Boar pays	Head	$0.00	0.0	$0
	Annual operating capital*	Interest rate, annual	$	5.0%	$29,319	$1,559
TOTAL OPERATING COSTS						$44,434
OWNERSHIP COSTS						
	Facilities, fencing, water	Depreciation, interest, prop. tax, insurance				$2,370
	Machine & equipment	Depreciation, interest, prop. tax, insurance				$1,739
	Permanent pasture	Interest, prop. tax, insurance				$0
	Livestock	Interest, prop. tax, insurance				$278
TOTAL OWNERSHIP COSTS						$4,386
LABOR COSTS						
	Machinery operator labor, From Table 2					$2,115
	Livestock labor	Work, check livestock	$/hr	$10.00	366	$3,660
TOTAL LABOR COST						$5,775
TOTAL COST						$55,735
GROSS REVENUE*						
	Male feeder pigs	Note numbers, weight, etc.	Head	$70.00	0	$0
	Female feeder pigs	" "	Head	$70.00	0	$0
	Finished male hogs	180 head at 250 lb/head live		$1.00	45,720	$45,720
	Finished female hogs	" "	Head	$1.00	45,720	$45,720
	Cull sows	" "	Head	$220.00	6	$1,760
	Gilts for breeding stock	" "	Head	$0.00	0	$0
	Boars	" "	Head	$220.00	1	$220
TOTAL REVENUE						$93,440
RETURNS OVER OPERATING EXPENSES						$14,307.87
RETURNS OVER OPERATING EXPENSES AND OWNERSHIP COSTS						$9,419.13
RETURNS OVER ALL LISTED EXPENSES*						($3,041.87)
RETURNS OVER ALL LISTED EXPENSES PER SOW		Average No. of Sows		24		-$126.37
RETURNS OVER ALL LISTED EXPENSES PER ACRE		No. of Acres		24		-$126.37

* Annual operating costs can be either costs or estimated using NCSU or other Forage Enterprise Budget.
* Interest calculated on one-half of operating input costs, except sales expense.
* Revenues from sales of feeder pigs and cull breeding stock depend on numbers, pay weight at sale and price. Selling rules vary with type of market outlet, time of year, weight, frame, and fleshiness.
* Returns to Land, Overhead, Management, and Risk

Spreadsheet and data development by:
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FARROW-TO-FINISH HOG ENTERPRISE ON PASTURE

Budget Sheet: OSH
August 2011

Table 1. Investment in specialized facilities & equipment and prorated share of annual ownership expenses

Category	Life	Initial Cost	Salvage Value	Depreciation*	Interest*	Tax & Ins.*	Total OFE	Share to Enterprise	Share to Enterprise
	Years	$	$	$	6.00%	0.50%	$	%	$
Interest and Tax + Insurance Rates-->									
Facilities*									
Sow huts	10	3,000	0	300	75	8	375	100.0%	375
General purpose bldg	15	10,000	0	1,067	400	53	1,480	50.0%	740
Perimeter fence, gates	5	7,500	0	1,500	195	0	1,725	100.0%	1,725
Internal fence	5	2,800	0	560	72	7	639	100.0%	639
Water Supply	10	6,500	0	650	234	17	1,101	100.0%	1,101
Handling facilities	20	0	0	0	0	0	0	100.0%	0
Shade structures	10	7,800	0	780	195	9	984	100.0%	984
Feedbins, Feed Storage	10	15,000	0	1,500	300	19	1,799	100.0%	1,799
Other facilities	0	0	0	0	0	0	0	0.0%	0
Feeding, pastures & livestock management									
4-wheeler	10	12,000	3,250	935	390	15	1,340	20.0%	267
Tractor	20	50,000	4,000	735	1,000	23	1,758	20.0%	351
+ spinner seeder	10	2,200	500	170	72	3	245	10.0%	25
+ front end loader	10	5,000	750	322	95	4	420	10.0%	32
+ blade or box rip	10	1,600	500	88	19	1	108	25.0%	14
+ other tractor mounted	10	1,800	200	74	22	1	97	25.0%	17
Pickup	10	27,500	6,875	3,063	550	33	3,646	10.0%	295
+ stock trailer	10	7,000	1,000	600	227	9	837	100.0%	743
Other equipment	1	0	0	0	0	0	0	0.0%	0
Pasture establishment	5	0	0	0	0	0	0	100.0%	0
Pasture establishment	5	0	0	0	0	0	0	100.0%	0
Fertilizer, control, animal	10	0	0	0	0	0	0	100.0%	0
Sows*	3	4,800	4,800	--	288	0	288	100.0%	288
Boars*	3	800	800	--	48	3	51	100.0%	51
TOTAL									9,556

* Depreciation = (Initial cost - Salvage value) / years of life
* Interest on average investment = ((Initial cost + Salvage value) / 2) X interest rate specified.
* Property taxes and insurance on facilities and equipment = Initial investment X tax + insurance rates specified.
* Specialized hog facilities and equipment are movable to facilitate the subsequent cropping on the area used by the hogs.
* Items and boars are not depreciated. Cost of maintaining the herd are captured through replacement purchases and cull animal sales.

Table 2. Operating expense for machinery and equipment

Operation and Item	Horse Power	Repairs & Maint.*	Repairs & Maint.	Share to Enterprise	Est. Fuel Use	Fuel Cost	Fuel & Labor*	Hours of Use/Year	Total Op. Cost/Year	Labor Cost*	Total Expense
		%	$/Year	$	Gal/hr	$/Hour	$/Hour	Hours	$	$	$
Fuel cost per gallon & Labor cost per hour ------>						3.75				10.00	
Feeding, pastures & livestock management											
4-wheeler		2%	240.00	20.00	1.0	3.75	4.31	180.0	$12.00	$1,800.00	$2,032.00
Tractor	55	2%	1000.00	70.00	1.24	3.75	4.84	180.0	$70.21	$1,800.00	$2,338.21
+ spinner seeder		1%	22.00	4.80	0	0.00	0.00	10.0	4.00		$4.80
+ front end loader		2%	50.00	10.00	0	0.00	0.00	6.0	16.00		$16.00
+ blade or box rip		1%	6.00	1.20	0	0.00	0.00	30.0	5.50		$1.50
+ other tractor mounted		2%	20.00	2.00	0	0.00	0.00	32.0	2.00		$2.00
Pickup		1%	275.00	27.50	2.5	9.38	0.00	180.0	27.50	$1,800.00	$1,827.50
+ stock trailer		2%	140.00	35.00	0	0.00	0.00	120.0	35.00		$35.00
Other implement		1%	8.00	0.80	0	0.00	0.00	0.8	0.80		$0.80
TOTAL									1,877	0.0%	0.0%

* Repairs and maintenance costs are calculated as a % of the initial cost in Table 1. Percentages are higher for equipment that is bought used.
* Fuel cost plus labor costs estimated as 15% of the fuel cost.
* Labor cost or charge includes an additional 10% allowance for inspection, equipment adjustments, cleaning up, travel, etc. Includes labor that does not require equipment (see "Livestock labor" directly in the budget, e.g. working cattle, moving fence, checking cattle).

Table 3. SENSITIVITY ANALYSIS

This table shows the net returns over all listed expenses (also called returns to land, overhead, management and risk) a measure of profit, under various assumptions about costs and returns. Specifically, the cost and returns shown in the enterprise budget on the first page are believed to be fairly representative of conditions in North Carolina. However, there is a wide variation in farm performance from one farm to another and costs and sale prices can change rapidly from year to year. The table shows the effects of returns that are 10 percent higher and lower than in the base budget. Similarly, the effects of total costs that are 10 percent higher and lower are shown also.

NET RETURNS ABOVE ALL LISTED EXPENSES (Returns to land, overhead, management and risk)

		REVENUE 10% Lower	REVENUE Base Budget	REVENUE 10% Higher
		-10%		+10%
COST	Base			
	+10%			

Pasture based farrow- to finish -budget

V. Research Trials

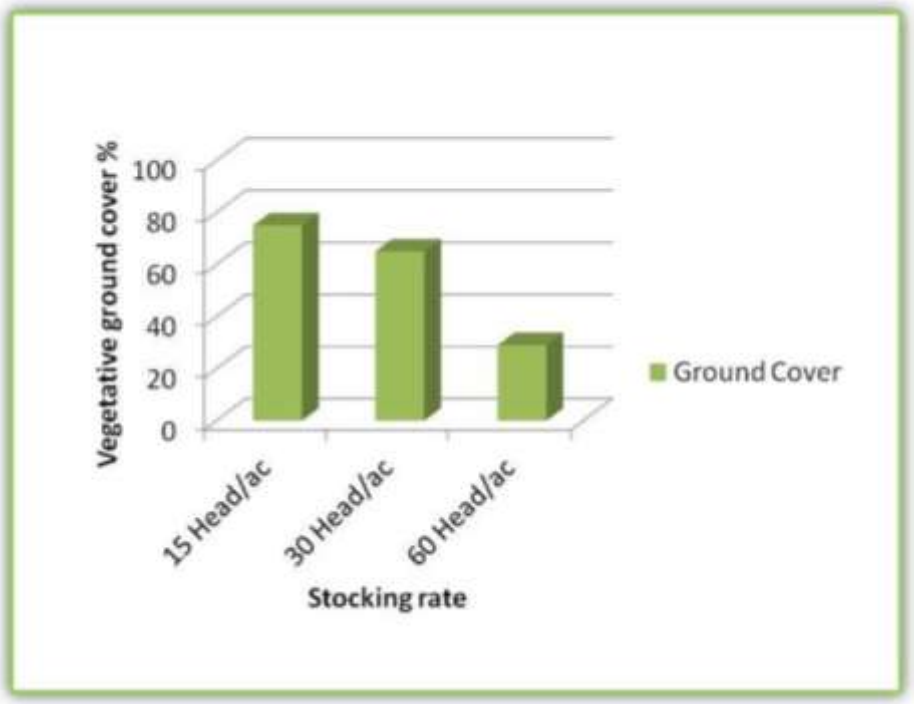
We conducted a series of demonstration trials at the Center for Environmental Farming Systems (CEFS) located in Goldsboro, North Carolina, between 2008 to 2012. Forage species were compared under different management strategies to determine the feasibility of maintaining vegetative ground cover and minimizing soil nutrient build up when managing outdoor swine. Forages used included annual (winter: cereal rye *Secale cereale* L., ryegrass *Lolium multiflorum*; summer: sorghum- Sudan *Sorghum bicolor*) and perennial species (summer: switchgrass *Panicum virgatum*; spring/summer/winter: tall fescue *Schenodorus phoenix*; summer/fall/ winter: bermudagrass *Cynodon dactylon*).

In the paddocks, animals were provided shelter, water and feed (16 % CP) free choice. Sows were given a restricted diet (6.5 lb of feed/d). Initial animal body weight was recorded and used to arrange similar initial total weight groups, which were randomly allotted to the experimental paddocks. Periodic recording of ground cover was performed through a modified step-point procedure, following evenly distributed transect lines in the paddocks. Soil samples were taken with hand probes at the beginning and at the end of the trials. The treatments had three field replicates.

1.Tall Fescue (*Schedonorus arundinaceus* (Schreb) Under Continuous Management

In spring 2008, the effect of managing 15, 30 or 60 hd/ac (250 -300 lb BW) under a continuous management system in tall fescue paddocks was evaluated. After 36 days, only the paddocks with 15 head/ac maintained a ground cover over 70 %. The negative effect of the highest stocking rate was observed just one week after having the animals in the field (see Figure 2).

Figure 2. Final ground cover (%) in tall fescue paddocks managed with different stocking rates in a continuous management system during six weeks



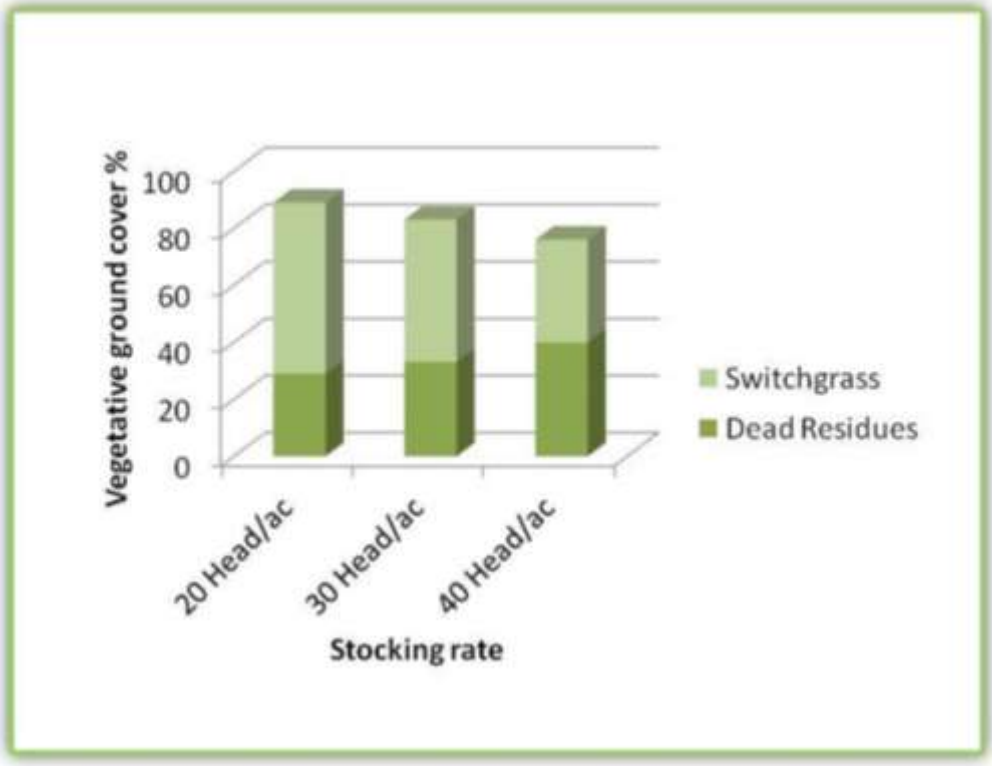
Stocking rates were equivalent to 4125, 8250 and 16500 lb/ac, respectively.

2. Switchgrass (*Panicum virgatum*) Under Continuous Management

To evaluate the effect of stocking rate (20, 30, 40 head/acre) 300 lb hogs were used in a switchgrass field under a continuous management system. After 15 days, ground cover was affected by the stocking rate, resulting in a loss of 42% of the cover when the stocking rate was equivalent to 40 head/ac (see Figure 3).

Hogs on switchgrass 20 head/ac

Figure 3. Final ground cover (%) in switchgrass paddocks managed with different stocking rates in a continuous management system during 15 days



Stocking rates were equivalent to 6000, 9000 and 12000 lb/ac, respectively.

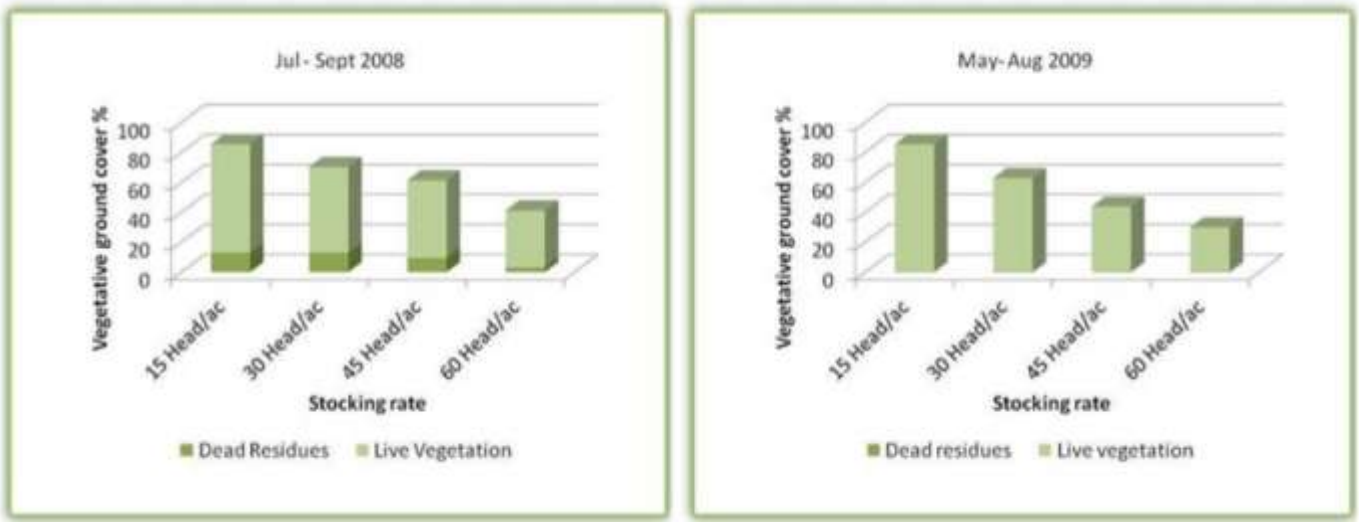
3. Bermudagrass (*Cynodon dactylon*) Under Continuous Management

Managing a mature bermudagrass stand during two seasons (Jul-Sep 2008 and May-Aug 2009) with four stocking rates (15, 30, 45 and 60 head/ac) (60 to 270 lb BW) under a continuous management system, resulted in a reduction in ground cover of up to 40 % when the stocking rate exceed 15 pigs/ac (see Figures 4a and 4b).

After removal of the hogs in the fall of 2009, soil samples taken at 12 inches showed that nitrogen nitrate NO3 levels were 16, 29, 41, and 65 kg NO3/ ha for stocking rates of 15, 30, 45, and 60 pigs/ac, respectively. Similarly, values of 69, 91, 105, and 85 kg of nitrogen ammonium NH4/ha were detected for stocking rates of 15, 30, 45, and 60 pigs/ac, respectively. Soil P was unaffected by swine occupation at any stocking rate, although insignificant increases in mean P values, averaged across all pastures, were observed. Based on feed analysis, and assuming 7% P content in the animal carcass, there was approximately 49, 95, 146, and 202 kg/ha P incorporated into the pasture in the form of dung, urine, and spilled feed at stocking rates of 15, 30, 45, and 60 pigs/ac, respectively.

These results indicate that as stocking rates increase the percent of ground cover is reduced and soil nutrients increase. The lack of vegetation is likely to influence erosion and runoff rates, and as a consequence, nutrients reaching surface and ground water.

Figures 4a and 4b. Final ground cover (%), including heavy use areas, in bermudagrass paddock managed with different stocking rates in a continuous management system during 12 weeks cycles



Stocking rates were equivalent to 2400, 4800, 7200 and 9600 lb/ac, respectively

Bermudagrass. Continuous management system. 15 hogs/ac

Bermudagrass. Continuous management system. 30 hogs/ac

Bermudagrass. Continuous management system. 45 hogs/ac

Bermudagrass. Continuous management system. 60 hogs/ac

4. Bermudagrass (*Cynodon dactylon*) within Rotational Grazing System

A rotational grazing management approach was implemented, dividing the paddocks in nine sections, with the central section (11 % of the total area) being defined as a heavy use area where shelter and water were provided and with permanent access for the animals. The other eight sections were managed in a weekly rotational pattern. The rotational system was employed to provide the forage a resting period and to obtain a better distribution of nutrients (wasted feed, urine and feces).

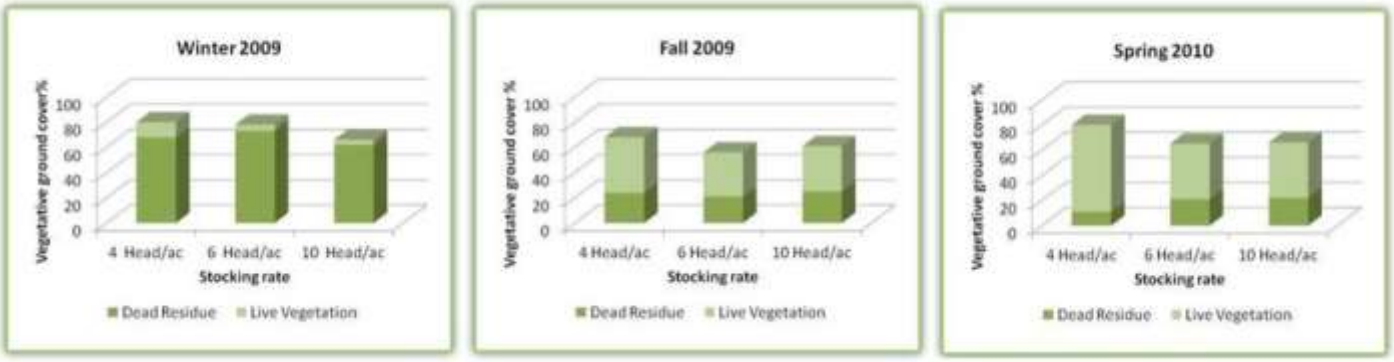
The experience was replicated during three seasons Winter 2009, Fall 2009 and spring 2010, testing three sow stocking rates (4, 6 and 10 head/ac) (average body weight: Winter 09: 648; Fall 09: 467; Spring 10: 410 lb). Under this management no differences were observed in ground cover percent across the paddocks even with different stocking rates (see Figure 5a, 5b and 5c).

Interestingly, a more pronounced effect of the heaviest stocking rate on the ground cover was observed during the winter 2009 trial. This could be explained by the dormant condition of the grass and because heavier animals were employed than those used during fall 2009 and spring 2010. Expressing stocking rate as head per area unit is easier, but to make more accurate comparisons between management systems it is better to use the Steady State Live Weight (SSLW). More discussion about this concept is presented in section VI.

Implementing rotational management was shown to be advantageous, providing a rest period to the forages, better distribution of soil nutrients, the possibility to support heavier stocking rates, and a potential reduction in parasite loads.

Bermudagrass. 10 sows/ac

Figures 5a, 5b and 5c. Final ground cover (%) including heavy use areas, in bermudagrass paddocks managed with different sows stocking rates (4, 6 and 10 sows/ac) in a rotational system during 8 week cycles.



Stocking rates were equivalent to: Winter 2009: 2592, 3888 and 6480 lb/ac, respectively; Fall 2009: 1868, 2802 and 4100 lb/ac, respectively; and Spring 2010: 1640, 2460 and 4100 lb/ac, respectively.

4. Bermudagrass (*Cynodon dactylon*) within Rotational Grazing System

Soil compaction

Soil compaction was measured as part of the rotational grazing system trial, with a penetrometer in spring 2009. The soil in the paddocks with 10 sows/ac showed more resistance to penetration in comparison with the 4 and 6 sows/ac paddocks (see Table 2.)

Excessive soil compaction limits root growth, decreasing the capacity of plant roots to move through the ground and take up water and nutrients. Soil compaction also leads to runoff, soil and water losses, and ultimately increased erosion.

Additional care is needed when managing outdoor hog herds in wet circumstances or close by wallows and drinking areas, because wet conditions favor soil compaction.

Soil analysis

Soil analysis results showed a higher content of sulphur S, copper Cu and sodium Na in samples from the paddocks with the highest stocking rates (see Table 3.). These findings could be of interest as some of these soil nutrients could reach toxic levels for crops or animals. The critical level for these nutrients varies according to soil type and to the nutrient requirements of the following crop.

Table 2. Soil Compaction rate* after one grazing cycle

Stocking Rate (Sows/ac)		
4	6	10
Moderated	Moderated	Severe

* Estimated according to Duiker. 2002

Table 3. Soil Nutrients (mg/dm³) in a mineral soil of bermudagrass grazed at different sow stocking rates after one grazing cycle.

	Stocking Rate (Sows/ac)			Paddock Section		Depth	
	4	6	10	HUA	OS	D1	D2
p	465[a]	483[a]	452[a]	456[a]	477[a]	473[a]	460[a]
K	178[a]	212[a]	195[a]	201[a]	189[a]	238[a]	152[b]
Ca	801[a]	909[a]	809[a]	838[a]	841[a]	976[a]	703[b]
Mg	161[a]	199[a]	172[a]	181[a]	173[a]	213[a]	141[b]
S	19[b]	18[b]	22[a]	20[a]	19[a]	22[a]	18[b]
Mn	16[a]	17[a]	18[a]	17[a]	17[a]	20[a]	15[b]
Zn	8[a]	8[a]	10[a]	9[a]	9[a]	11[a]	6[b]
Cu	0.9[b]	1[a,b]	1[a]	1[a]	1[a]	1[a]	0.9[b]
Na	21[b]	22[b]	28[a]	25[a]	23[a]	26[a]	21[b]
Fe	1168[a]	1199[a]	1095[a]	1099[b]	1209[a]	1084[b]	1224[a]

Means with different letters are different ($P \leq 0.05$) .

HUA Heavy use area, OS Other sections, D1 0-6 inches, D2 6-12 inches

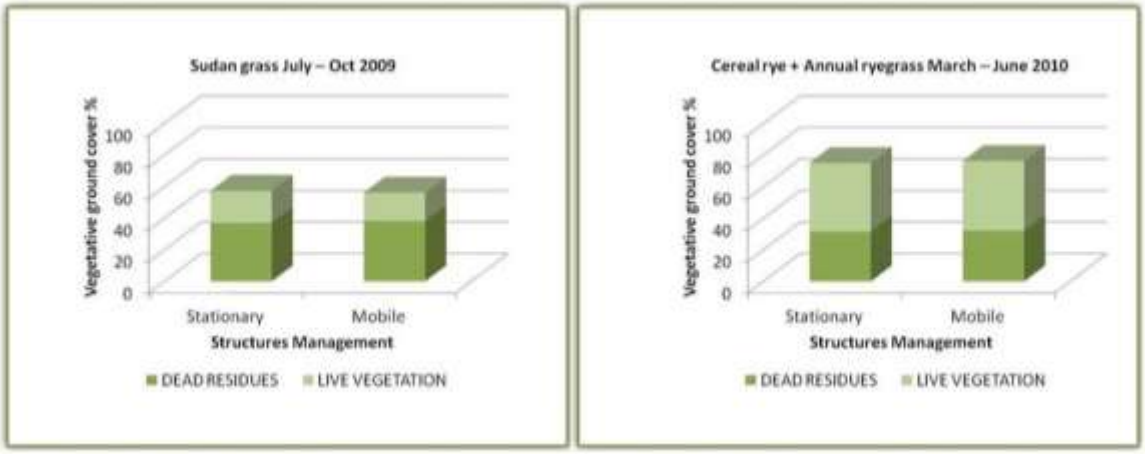
5. Movement of Shade, Water and Feed Structures

Shelters and feeding areas are the most prone to ground cover deterioration in outdoor hog plots. References from the scientific literature suggest that periodic movement of shelters, feeders and waterers could help to maintain ground cover and attain a better distribution of soil nutrients.

Sudan grass paddocks (July-Oct 2009) and a cereal rye and ryegrass mixture (March-June 2010) were used to demonstrate the effects of periodic movement of shade and nipple waterers on ground cover when the paddocks were managed during 12 weeks with 30 wean-finish hogs/ac (50-220 lb) in a continuous management system.

Implementing the strategy of weekly movement of equipment did not produce the expected results in these trials. We did not observe an improvement in ground cover maintenance nor differences in soil nutrients (nitrogen and phosphorus) distribution. A reduction of soil compaction was observed under the shade structures in the paddocks where we implemented weekly movement of equipment (see Figures 6a and 6b).

Figures 6a and 6b. Final ground cover (%) including heavy use areas, in sudangrass and cereal rye and annual ryegrass paddocks managed with 30 pigs/ac in structures rotation management schemes in 12 week cycles.



Stocking rates were equivalent to 4050 lb/ac.

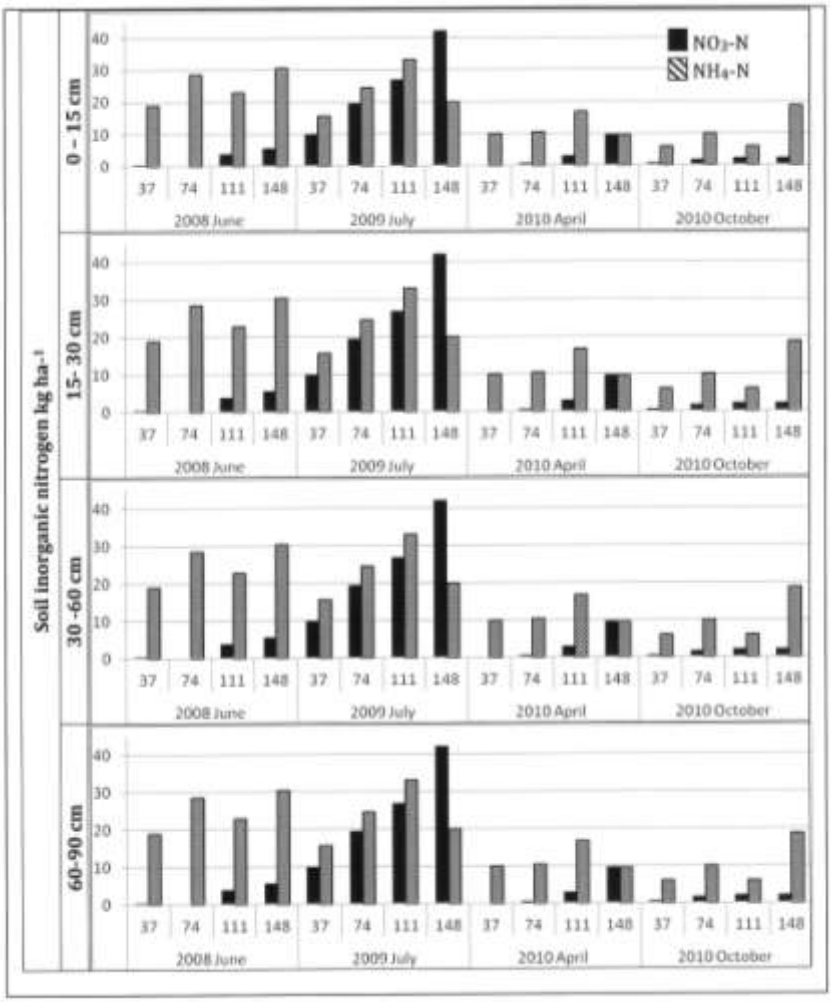
Growing pigs in a cereal rye and annual ryegrass mixture. 30 pigs/ac

6. Soil Nutrient Removal

To assess the effect of establishing hay crops to remove the nutrients deposited in the system by swine, two crops were planted (cereal rye and ryegrass mixture (Spring 2010) and sudangrass (Summer 2010). These crops were established after pigs were removed from the bermudagrass stocking rate plots. Following pigs with two hay crops was shown to be effective in removing soil nutrients deposited by the pigs. Soil nutrients lowered to levels similar to those presented before having pigs on the paddocks (see Figure 7).

Cereal rye and ryegrass mixture planted as hay crop after the paddock was used for outdoor swine

Figure 7. Soil inorganic N (KCl extracted) by depth, stocking rate (hogs/ha) and sampling date



2008 June: before swine occupation; 2009 July: following 2 cycles of swine occupation; 2010 April: following cereal rye/annual ryegrass forage harvest; 2010 October: following forage sorghum harvest

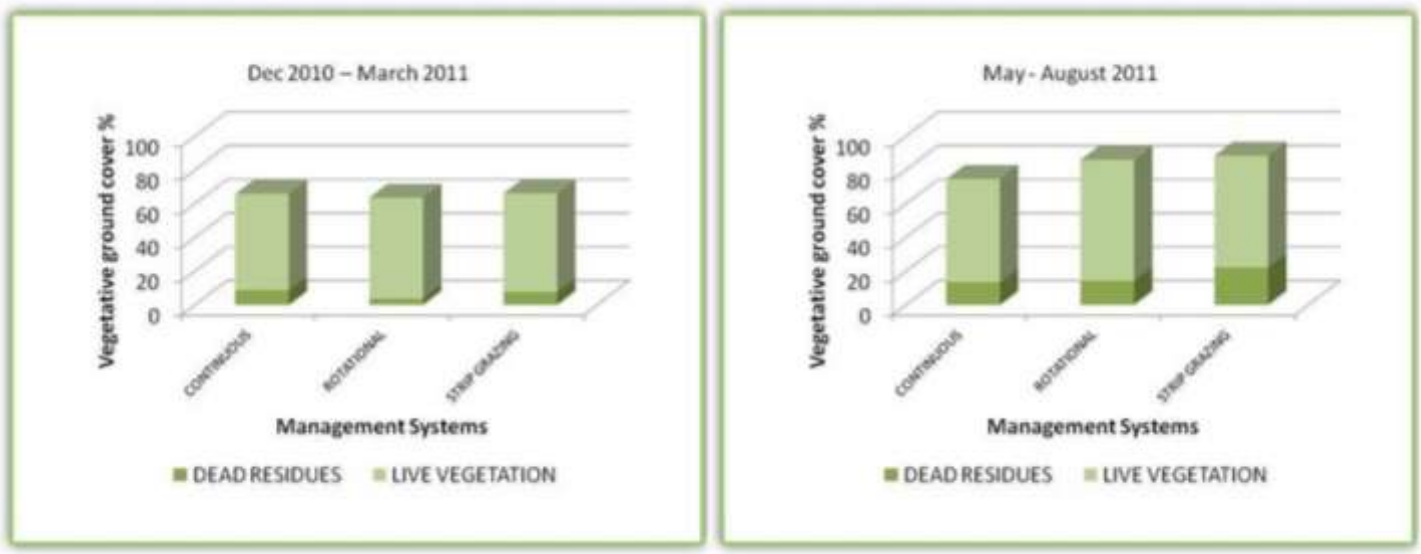
7. Comparison of Continuous, Rotational & Strip Grazing Systems

Two experiments were conducted during 2011 (Dec 2010-March 2011 and May- Aug 2011) in tall fescue paddocks to demonstrate the effects of three management systems.

The systems consisted of Continuous (hogs had access to the entire paddock during the length of the evaluation), Rotational (the paddocks were divided into 9 sections with the central section used as a heavy use area [HUA]); hogs had permanent access to the HUA and were moved weekly to one of the other 8 sections), and Strip Grazing (the paddocks were divided into 8 strips, and the hogs were moved once a week along with shelters, feeders and drinkers without an established central HUA).

The stocking rate was equivalent to 20 wean to finish hogs/ac and the demonstration was implemented twice. Percent ground cover did not differ among the management systems (see Figures 8a and 8b). This lack of difference in ground cover is interesting if you consider that the animals were concentrated in 22.22 % and 12.5 % of the area during one week for the rotational and the strip grazing systems, respectively, in comparison with the continuous system where the animals had access to the

Figures 8a and 8b. Final ground cover (%) including heavy use areas, in tall fescue paddocks managed with 20 pigs/ac in three different management systems.



Stocking rate was equivalent to 2600 lb/ac.

Continuous system

Rotational system

Strip grazing system

entire paddock. This finding supports the importance of providing a rest period to the forage. It is possible that higher stocking rates than the ones tested could show differences in ground cover between management systems.

Soil analysis

Soil analysis results showed lower soil nutrient contents of nitrogen NO_3, phosphorus P, potassium K, manganese MN, zinc Zn and copper Cu, in the paddocks managed under the rotational system compared with the continuous system (see Table 4). These findings could reflect a better usage of nutrients in the rotational system, due either to the rest period or to a better distribution of nutrients in the paddocks.

Soil testing is essential to monitor soil nutrients build up.

Table 4. Soil nutrients (mg/dm3) in tall fescue paddocks under three outdoor hog management systems and two depths

	C	R	S		D1	D2
P	49.0 [a]	40.2 [b]	39.6 [b]		50.4[b]	35.4[b]
K	97.6[a]	78.7[b]	78.5[b]		113.3[a]	56.6[b]
Ca	643	650.5	655.5		654.5	644.8
Mg	151	155.9	157.9		151.8	158.1
S	14.4	14.4	13.4		15.6	12.5
Mn	47.5[a]	41.0[b]	46.3[a]		46.4	43.5
Zn	4.2[a]	3.4[b]	3.8[a,b]		4.6[a]	3.0[b]
Cu	1.8[a]	1.6[b]	1.7[a,b]		2.0[a]	1.5[b]
Na	23.1	26.1	25.6		26.8[a]	23.0[b]
NO_3**	21.8[c]	16.9[d]	18.1[c,d]		25.2[c]	12.8[d]

*C, R, S values averaged over depths **Composite sample/paddock. Means with different letters differ (a, b: p<0.05; c, d: P<0.09). D1 0-6 inches, D2 6-12 inches

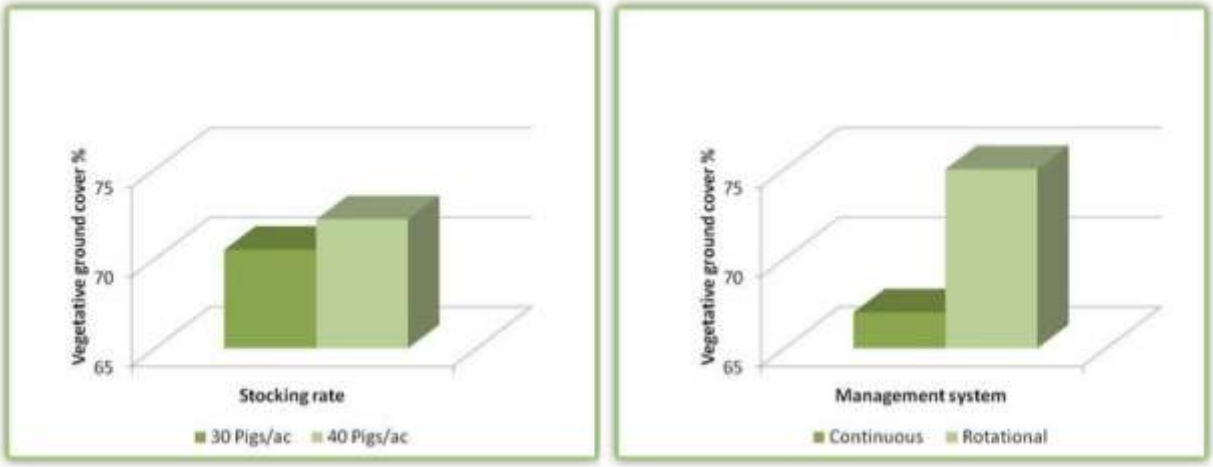
8. Impact of Stocking Rates on Ground Cover within Continuous & Rotational Systems

Two experiments were performed during 2012 to demonstrate the effect of pig (30 and 40 pigs/ac) (31-126 lb BW) and gestating sows (6 and 11 sows/ac) stocking rate and management systems (continuous vs. rotational) on ground cover of bermudagrass.

No differences were observed in ground cover from paddocks managed with different pig stocking rates, but the paddocks managed with the rotational system showed 6.9 % more ground cover than those managed with the continuous system (see Figures 9a and 9b).

Continuous management. Bermudagrass. 40 pigs/ac

Figures 9a and 9b. Final ground cover (%) including heavy use areas, after an eight week cycle, in bermudagrass paddocks managed with different: a pig stocking rates and b management systems



Stocking rates were equivalent to 2500 and 3330 lb/ac, respectively

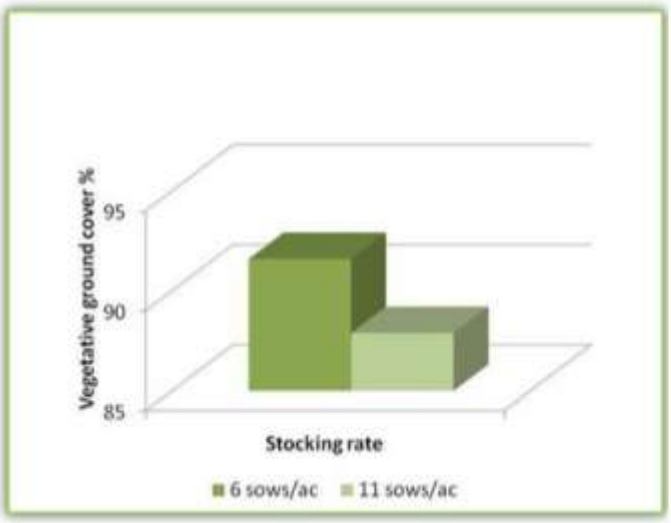
Central/heavy use area in the rotational management system. Bermudagrass. 30 pigs/ac

Gestating sows

When the system was managed during five weeks with gestating sows, no statistical differences were observed either among stocking rates or management system (see Figures 10a and 10b). It should be noted that the short length of the evaluation could have caused the lack of statistical differences.

Continuous management system. Bermudagrass. 11 sows/ac

Figures 10a and 10b. Final ground cover (%) including heavy use areas, after a five week cycle, in bermudagrass paddocks managed with different: a sow stocking rates and b management systems .



Stocking rates were equivalent to 3120 and 5720 lb/ac, respectively .

Rotational management. Bermudagrass. 11 sows/ac

VI. On-Farm Demonstration

CEFS' CIG project included a total of six on-farm demonstrations located throughout North Carolina, including coastal plain, piedmont, and mountain areas. The intent of the demonstrations was to illustrate different hog management practices that producers can implement to address site-specific conservation concerns. All of the suggested practices that were adopted were geared toward meeting the needs and constraints of the individual producer. The demonstration farms were selected to represent a cross-section of outdoor hog production systems and geographic regions. Most importantly, the demonstration farms enabled CIG staff to host a series of educational workshops and pasture walks for producers, extension agents, district conservationists, pork buyers, and others interested in outdoor hog production systems and conservation issues.

Two of the demonstration farms were selected for extensive examination and these are described in detail later in this section of the report. Four of the demonstration farms were used to showcase selected practices and were primarily used for educational purposes. An overview of these demonstration sites follows:

Rainbow Meadows Farm
Snow Hill, NC

At Rainbow Meadows Farm outdoor hogs were being produced on bare dirt lots. Due to the heavy stocking rates and limited labor available for controlled grazing, these dirt lots had the potential to quickly exceed the nutrient holding capability of the sandy clay soils. Through the CIG project, a rotation was developed to relocate these dirt lots to fresh ground twice a year. The vacated areas could then be used for forage crops that could be harvested for hay or flash grazed by the cattle and sheep on the farm. This practice removes nutrients from concentrated areas of hog production. This producer appreciated this rotational approach because it required a minimal amount of additional labor and it helped lower fertilizer inputs by making use of hog waste.

Finisher paddocks in use for only one production cycle. At the back can be observed the crop that was planted (following the previous pig group) to remove nutrients deposited to the soil.

Farrow-to-wean paddock on annual ryegrass

Leigh's Pork & Beef Farm
Jamesville, NC

With increasing feed prices and a lack of viable commodity markets for his conventionally raised hogs, Mr. Leigh was finding it increasingly more difficult to make independent swine production a profitable business venture. At Leigh's pork and beef, the CIG project worked to develop a rotation of hogs with grain crops and forages that allowed Mr. Leigh to incorporate hogs into his row cropping operation.

When a profitable niche marketing opportunity appeared for pasture-raised hogs, Mr. Leigh began transitioning to a pasture-based model. By establishing pastures in a manner that allowed for both planting and cropping, Mr. Leigh was able to utilize his existing cropland as pasture and still maintain grain production. The pasture also helped offset some of his feed cost for low maintenance animals such as gestating sows. By following the hogs with a grain or forage crop, Mr. Leigh was able to remove nutrients from the pastures and lower nutrient loading.

Incorporating hogs into the farm rotation allowed Mr. Leigh to explore the niche market for outdoor swine.

Rooting and excretory behavior of pigs were exploited in Underwood family farms using "hog tractors".

Underwood Family Farms
Lawndale, NC

Michael and Christy Underwood exemplify the low input, diversified small farms that have become prevalent in the Piedmont and mountain regions of North Carolina. With their wide range of farm products (including hogs, sheep, cattle, and vegetables) and their limited capital, all on-farm resources must be used to their fullest capacity. As part of the CIG demonstration project, a system was developed to incorporate hogs into a rotation with vegetable crops as a means of supplying nutrients. By calculating the estimated nutrient production expected using NRCS waste management tables, a stocking rate was determined that matched the expected nutrient requirements of a planned crop. Cover crops were planned for the periods between hogs and vegetables to help break up compaction from the hogs, mine nutrients from the soil, and minimize the risk of fecal contamination to the vegetable crop.

Wild Turkey Farms
China Grove, NC

Wild Turkey Farms is a small, diversified family farm focused on producing Berkshire hogs (farrow-to-finish). While not an official CIG demonstration farm, conservation practices implemented on this farm were observed and monitored as part of the project. A focus of this operation is maintenance of pastures (fescue/ orchardgrass/clover mix), which have been in place for over 30 years. Due to the high cost of over-seeding pastures, a single humane nose ring was used in each sow to minimize pasture destruction due to rooting. This allows for greater grazing flexibility since sows can be housed on established pastures without then needing costly pasture renovations. This producer documented that nose rings enabled him to maintain pasture cover above 87 percent in sow paddocks in both winter and summer months.

The high clay content of the soil requires careful management, especially when wet.

An improvised corral provided with bedding functions as sacrifice area when circumstances jeopardize a paddock's ground cover.

Humane nose ring are used at Wild Turkey Farms to maintain an adequate ground cover .

Partial removal of wet and dirty bedding material helps provide a healthy environment for sows and piglets.

Bailey Newton, Triple B Farm
Bullock, NC

I. Lessons Learned

1. This manager was able to maintain satisfactory ground cover through the use of rotational stocking and periodic use of a house where animals could be kept when soil and vegetation conditions were not suitable for hog occupation. Having sufficient acreage and the use of a building with an associated dry lot provided many options for animal movement to control the vegetation destruction and wallow management.
2. Pasture layout and soil slope was such that there was no runoff from the pastures even though there was a functional grass buffer on the downslope of the pastures. (This farm had about 88% of the area in grass, 4% in buffers downslope of the pastures and 9% of the pasture acreage in trees that provided shade on the upslope of the pastures).
3. The use of linear, rectangular paddocks with feed on one end and water on the other end of the paddock appeared to minimize the amount of damage to vegetation within the paddocks.
4. Sows appeared to root most actively immediately after entering a paddock; perhaps the use of large round bales of hay or some other "toy" can reduce the amount of rooting action, especially for the first few days of occupation of a new pasture.
5. Cattle and sheep were occasionally used to flash graze swine pastures to utilize forage not consumed by hogs and to help in taking nutrients off site.
6. Location and extent of wallow use can be managed through strategic placement of drinking water tanks relative to shade within a paddock.
   a. This farm created paddocks containing shade (trees) at the upslope end of paddocks which provided an opportunity for runoff to be filtered through the pasture prior to exiting the paddock into an ungrazed grass buffer.
   b. Drinking water locations were placed on the upslope end of pastures near the shade, and this appeared to encourage wallows around the drinking water tank.
   c. This farm made use of refurbished concrete "hog slats" beneath drinking water nipples to reduce the amount of wallow development near the drinking fountain.

Ground cover impacted by hog activities.

II. Farm Description

Mr. Bailey Newton owns and operates Triple B Farms in Bullock, NC (Granville County). Over the past 30 years Triple B Farms has transitioned from a confinement swine operation to a mixed species, pasture based operation. The farm currently produces pasture-raised pork, beef, lamb, chicken, turkey, and eggs, which is marketed through area farmers' markets and on-farm sales. Mr. Newton's 80 acre farm is primarily pasture, which is managed as forage for cattle and sheep, with approximately eight acres used for the swine operation.

Table VI.1. Overview of Triple B Farm

	2007	2010
Total acreage,	80	80
Acreage for hogs	15	4.58
Sows, mature hd	7	6
Boars, mature hd	2	2
Feeder, # sold/yr	62	66
Finished hogs, #	50	30

A small dirt lot (0.13 acres) was built beside one old confinement house that allows for use of some of the old hog pens inside, while still allowing the animals' access to the outdoors. These pens are mainly used for freshly weaned pigs until they are about 100 pounds and occasionally for farrowing sows in bad weather.

A small section of old cutover just to the west of the southernmost confinement house was briefly utilized as a pasture for sows. This area contained many small saplings with a limited amount of open space dominated by gypsum and ragweed.

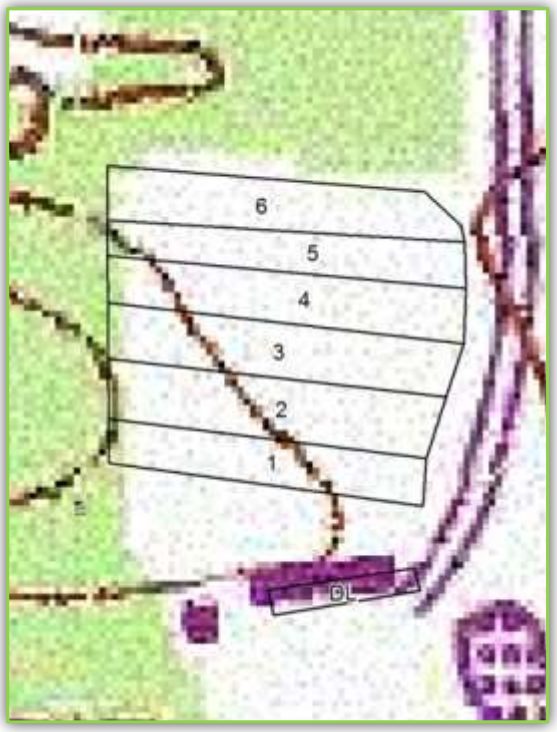
Pastures and Facilities Layout

Triple B Farms' swine operation consists of five grass pastures, a cutover timber area, and a portion of a former confinement hog feeding house with an adjacent dry lot (see Figures VI.1, VI.2).

Grass pastures are oriented in long narrow paddocks in a West to East direction. On the West (upslope) end of the pastures a small portion is covered by mature hardwoods that provide shade and shelter as well as a location for the watering tanks and wallows. Feeders are generally located on the East end (downslope)

Figure VI.1. Layout of grass pastures and old confinement feeding barn with associated dry lot. Note the shade on west end of pastures and buffer on east end (right side of photo).

Figure VI.2. Pasture location with respect to topography. Topo lines show 10 ft elevation differences.



Pasture Plant Species

Hog paddocks consist of a mixture of fescue, crabgrass, ryegrass, dallisgrass, orchardgrass, and clover with lesser amounts of other perennials and annuals mixed in. This species diversity helps ensure that forage is growing nearly year round.

A small section (0.5 acre) of old cutover just to the west of the southernmost confinement house was briefly utilized as a pasture for sows during breeding and gestation. The vegetation in this area was mainly young "woody" sapling species and a small (0.1 acre) open space dominated by a range of herbaceous species (brambles, ragweed, cypress weed, pigweed, and lambsquarter).

Lime was applied to the grass pastures, as required, based on annual soil testing recommendations. Tillage, including disking, cultivating, and conventionally drilling seed, was used to renovate selected pastures once or twice.

Buildings

An old confinement feeding house with a concrete floor is periodically used to raise weaningly pigs (up to 100 pounds) or for farrowing of sows during winter months. Adjacent to this house is a small dry lot (0.13 acres), which is available to weaned pigs but the sows do not have access to it.

Hog pastures with old confinement house in the back

Table VI. 2. Description of the areas used by hogs

Paddock ID	Acres				% of Total Acreage		% of Paddock
	Grass	Shade	Buffer	Total	Grass Paddock	Buffer, Outside paddock	Shade
1	0.54	0.05	0.02	0.61	88	4	9
2	0.75	0.09	0.03	0.87	86	3	12
3	0.72	0.09	0.03	0.83	87	3	12
4	0.68	0.07	0.03	0.78	87	4	10
5	0.55	0.04	0.03	0.62	88	5	7
6	0.65	0.03	0.05	0.73	89	7	4
Dry Lot		-	-	0.13			
Total or Avg	3.89	0.37	0.19	4.58	88	4	9

III. Recommended Conservation Practices

Triple B Farms was selected to participate as a CIG demonstration farm in 2007. As a project participant, CIG staff worked with Mr. Newton to identify agreed upon management changes designed to demonstrate practices that improve conservation management. At that time, Triple B Farms had 5 sows and 2 boars, down from a high of 8 sows and 1 boar in 2006. With demand for products appearing to be on the rise, Mr. Newton planned to expand to a 15 sow farrow-to-finish operation over the next 12-18 months. Management changes were discussed that would accommodate this increase in growth. In particular, Mr. Newton planned to convert 11.1 acres of cutover timber re-growth into pasture for the hog operation. The following describes the original changes that were agreed to:

Field 1- All paddocks will be divided into 2 paddocks of approximately equal size. A waterline will be installed to provide fresh drinking water and water for wallows to each paddock. These paddocks will be managed in a manner that facilitates the maintenance of perennial groundcover, however annual crops may be used as needed to provide groundcover and/or forage. By increasing the number of paddocks, Mr. Newton will be able to move animals more often and give each paddock a longer rest period following each use.

Cut-over timber area – The cutover area will be divided into paddocks as shown in Figure VI.3 and used to evaluate the rate of transition from cutover to pasture. Paddocks containing drainage flows will not be used for swine but will be planted to perennial grasses that can be periodically grazed by cattle and goats. These paddocks will be managed in order to transition the landscape from cutover timber land to perennial pastures. Fencing and water lines will be installed in hog paddocks. Nutrient build -up will also be monitored.

In 2008, Mr. Newton began to experience a decline in product demand. This coupled with record feed and fuel prices, halted Mr. Newton's expansion plans. Without sufficient swine numbers, CIG management changes had to be modified. The result was a decision to monitor groundcover in grass fields for the length of the project so that any observed correlations between stocking rate, groundcover, and pasture type could be assessed.

Notice the rectangular shape of the paddocks and the ground cover deterioration in the extreme where the feeder is located.

Natural shade is provided by the tree line.

Figure VI.3. Conservation plan map of the entire farm showing area being used for hogs near the old confinement finishing facilities.

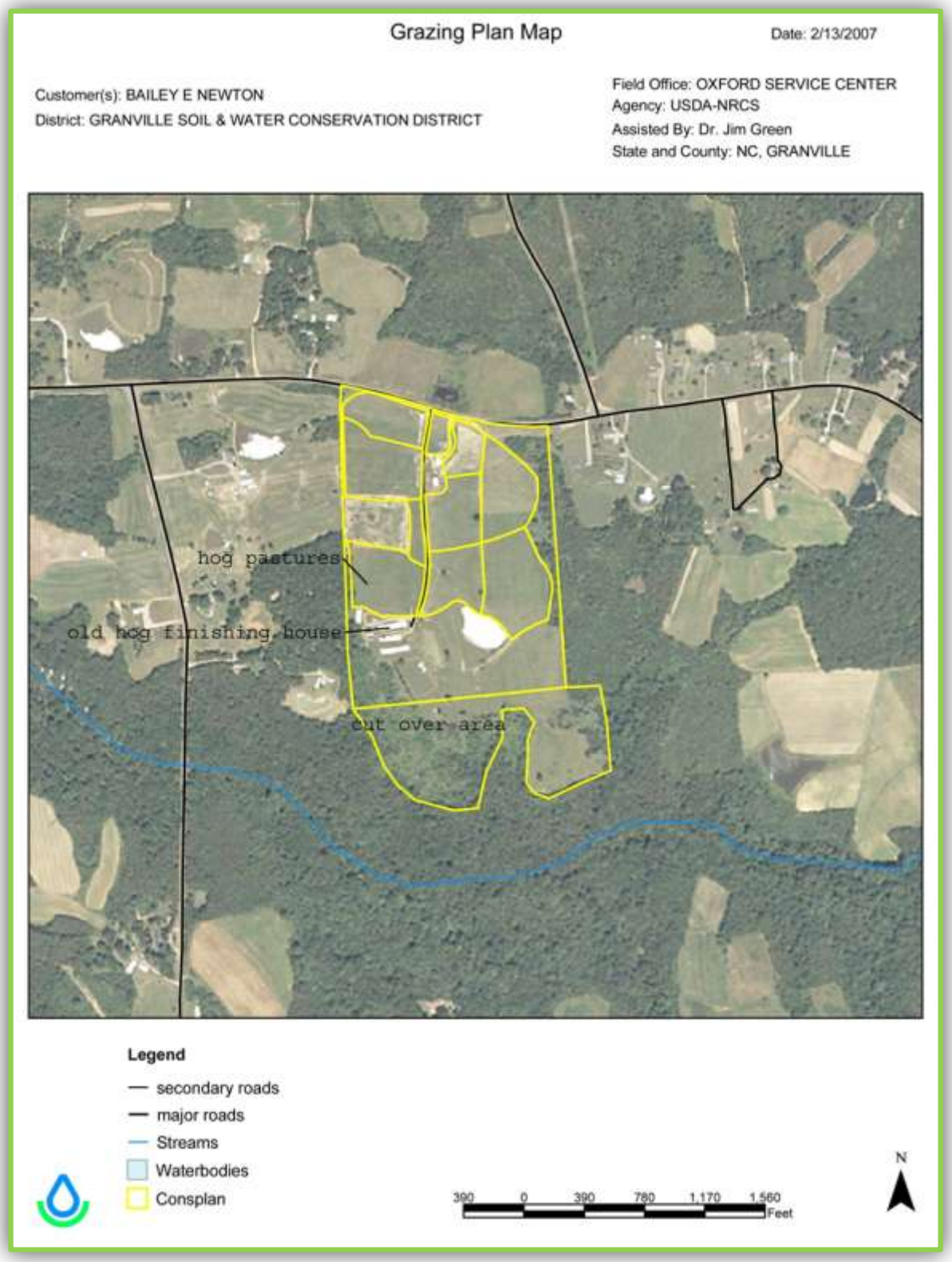
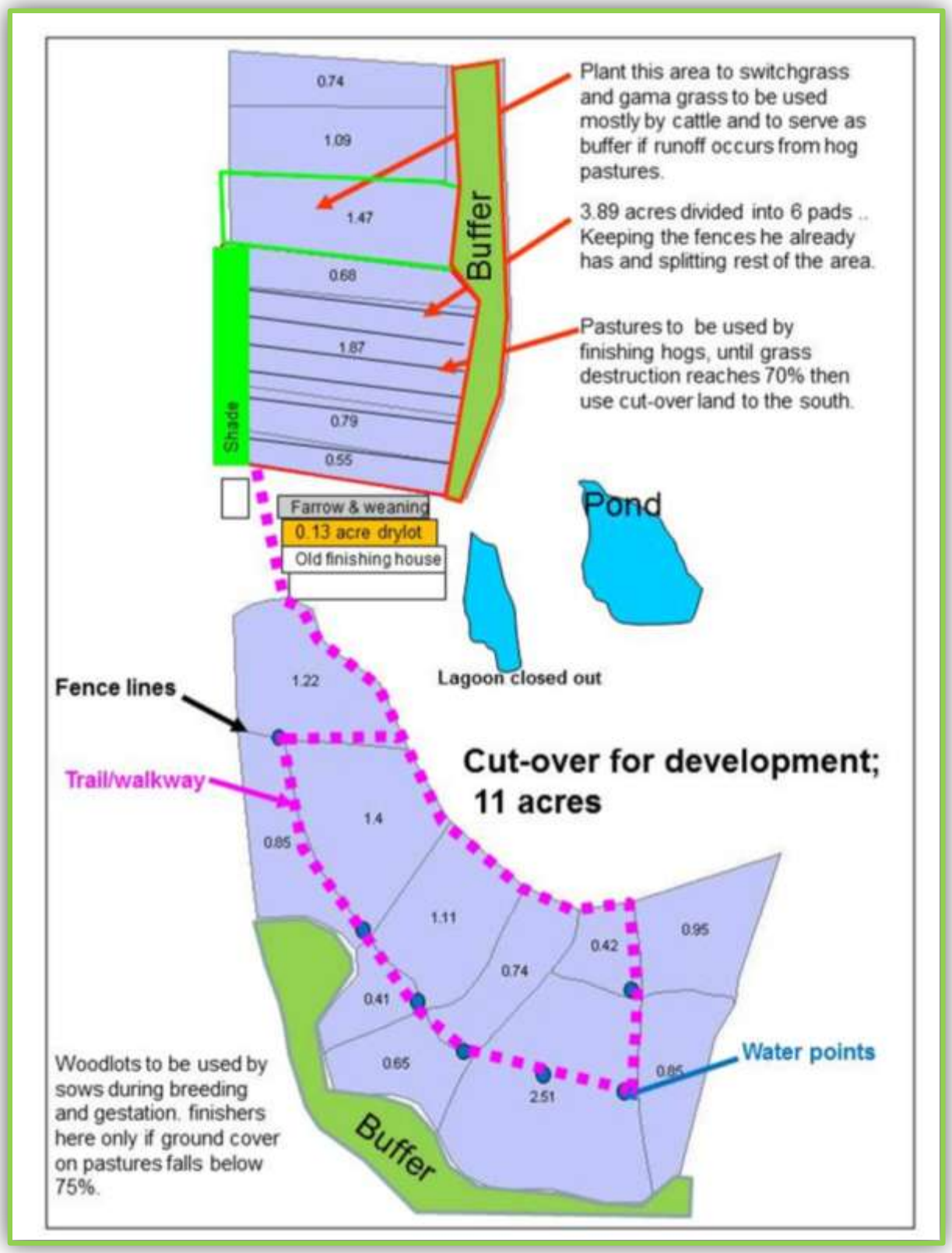


Figure VI.4. Map showing the areas to be developed for outdoor hogs with details for pipelines, fencing and stock trails.



IV. Data Collection Methods

The following data were collected to demonstrate the relationship between stocking density and management of vegetative ground cover. Bi-weekly farm walks provided an opportunity to collect data on the following aspects of the farm:

- Groundcover, including live vegetation and/or organic residue
- Vegetation canopy height
- Size of heavy use areas (sq ft) including the following:
    - feeder location
    - drinking water location
    - wallow location
    - trails from feed to water to lounging
- Animal numbers and size
- Location of the animals on the farm
- Field activities such as haying, renovation or grazing by other animals

The following methods were used to collect data:

Ground cover was monitored using a modified point-step method developed by NRCS to estimate groundcover in pastures. A zigzag pattern was walked across each field and a point on the boot of the evaluator was used to determine if the spot beneath the point was above "bare soil exposed" or "organic litter." Organic litter was defined as either living or dead vegetation. Species composition was determined through a visual estimation.

Heavy Use Areas (HUAs) were estimated by measuring and combining the totally denuded areas within each field boundary. Feeding and watering areas, wallows, portable shelters, and travel lanes were considered HUAs.

Stocking rate and stocking density estimates were developed using the NC NRCS 633 standard for Waste Utilization (see Table VI.3), which was used as a guide for grouping hogs into categories by growth phase. Using this categorical grouping based on "mean weight" for animals in various phases of production, a Steady State Live Weight (SSLW) was estimated throughout the monitoring period. The SSLW was expressed on a per acre basis to provide a better idea of stocking density for a pasture during various time periods. This provides an opportunity to compare stocking rates for different hog growth phases and numbers to each other on a weight/area basis.

Example: 1 sow with nine 5-lb pigs and three 150 lb gilts in one pasture would be assigned a SSLW of 838. The sow and 9 piglets are assigned a mean weight of 433 lbs and the three gilts are assigned a weight of 135 each. The total weight of this group of pigs will be summed as: (433x1) + (135x3) = 838 lbs of Steady State Live Weight. This number (838 lbs) would be assigned to a paddock during the period of time they were grazing it.

Table VI.3. Weight classes for determining Steady State Live Weight. Transposed from NRCS 633 Standards.

	Pounds		
Phase	Initial	Final	Mean
Wean - Feeder	10	50	30
Feeder – Finish	50	220	135
Gilt Developing	50	250	135
Boar Stud	250	550	400
Farrow – Wean	-	-	433
Farrow - Feeder	-	-	522
Farrow - Finish	-	-	1417

V. Results

The stocking rate on Triple B's hog pastures averaged approximately 0.4 farrow-to-finishers per acre or 4 wean-to-finishers per acre over the two-year period. However, during the pasture occupation periods, the stocking density averaged 1.4 farrow-to-finish per acre or about 15 wean-to-finishers per acre (see Table VI.4). While there was an attempt to estimate the stocking density using the Steady State Live Weight method, it is important to recognize that sows (during gestation) and boars do more damage to vegetation than growing pigs receiving a balanced feed ration free choice. The stocking density on this farm was relatively low and with the exception of paddock 4 was rarely heavily stocked.

The vegetative cover ranged from 63 to 98% depending on the amount of time hogs were in the paddock. Averaged over the 24-month project period, this is considered quite acceptable (see Table VI.5). That said, there were several months when ground cover was particularly low, especially on paddocks that had animals on them for extended periods (see Figures VI.6, VI.7). Ground cover estimates of the pastures excluded the areas considered part of the HUA because it is impossible to manage hogs on the ground without creating exposed soil in areas near feeders, drinkers, shade, and wallows. It is assumed that the HUA makes up a small percentage of the total pasture area thereby minimizing runoff into waterways or other off site areas. On this farm the HUA made up less than 10% of the pasture area with the exception of paddock 4 where animals spent prolonged periods during some seasons.

Buffer areas outside the pasture or around the HUAs can often be planned and maintained to mitigate the runoff potential from within pastures where vegetation may be destroyed. The buffers on Mr. Newton's farm were positioned down slope of the pastures and because they were always maintained at 90% or greater cover, they contributed significantly to improving overall farm cover estimates.

Table VI.4. Stocking rates expressed as live weight during the occupied months and averaged over the 24-month period.

Paddock ID	1	2	3	4	5	6	Average
Over 24 months							
Mean SSLW/ac	264	56	402	1290	647	624	547
Mean SSLW/ac, Expressed as Feeder to Finisher head (50-220 lbs)	2.0	0.4	3.0	9.6	4.8	4.6	4.1
Mean SSLW/ac , Expressed as Farrow to Finish, Head of sows	0.2	0.0	0.3	0.9	0.5	0.4	0.4
During occupied months							
Mean SSLW/ac	967	1229	2947	2027	2034	2746	1992
Mean SSLW/ac, Expressed as Feeder to Finisher head (50-220 lbs)	7.2	9.1	21.8	15.0	15.1	20.3	14.8
Mean SSLW/ac , Expressed as Farrow to Finish, Head of sows	0.7	0.9	2.1	1.4	1.4	1.9	1.4

SSLW/ac = Steady State Live Weight/acre (in lbs)

Table VI.5. Ground cover when considering the area that is considered HUA and buffer and the estimated amount of time the pastures were actually occupied by animals.

Paddock=	1	2	3	4	5	6	Average
Mean % GC w/o HUA	63	88	92	80	96	98	**86**
Mean % GC including HUA	63	88	92	78	95	98	**86**
Mean % GC including HUA and buffers	64	89	92	79	95	99	**86**
Avg. Annual % Time Vacant	40	52	47	20	37	42	**40**

GC=Avg. Ground Cover; HUA = Heavy Use Area; Buffers = Vegetative Buffer Areas outside of paddocks;*Sept. 2009-Dec. 2010

Figure VI.5 shows a sharp decline in vegetative cover during the period between December 2009 and March 2010. This also shows the introduction of pigs into this paddock in November, just prior to the vegetation decline, and their continued presence over 3 of the next 4 months. Likewise, upon the removal of the pigs, the percent of vegetative cover increases dramatically.

Figure VI.5. Ground cover, stocking density and heavy use area on paddock 1.

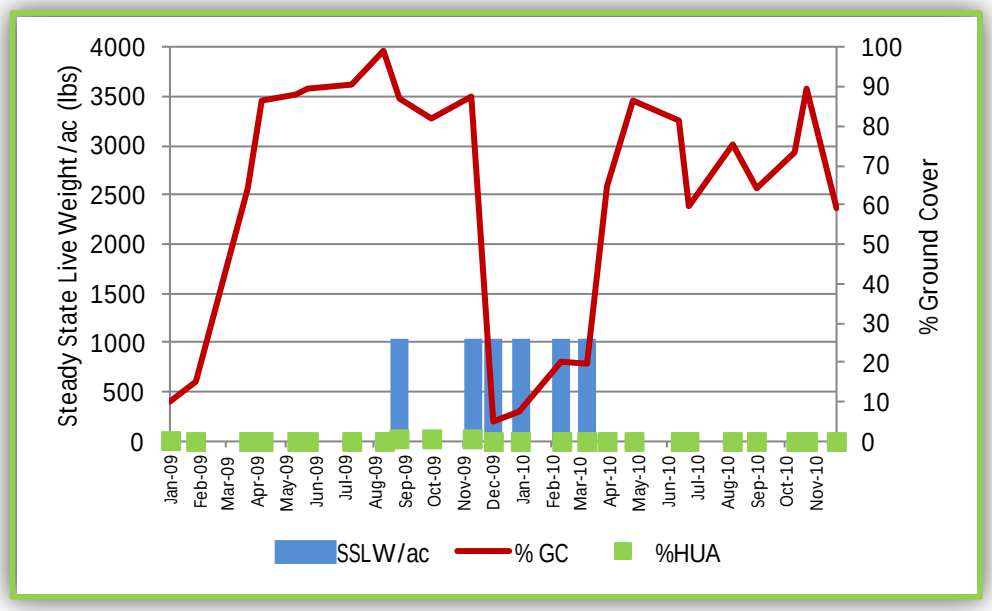
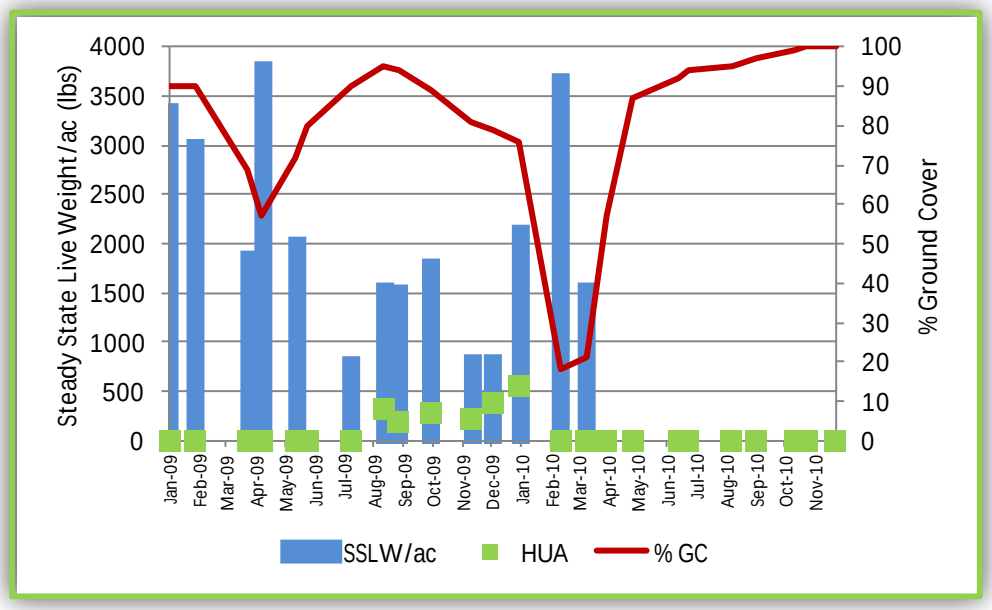
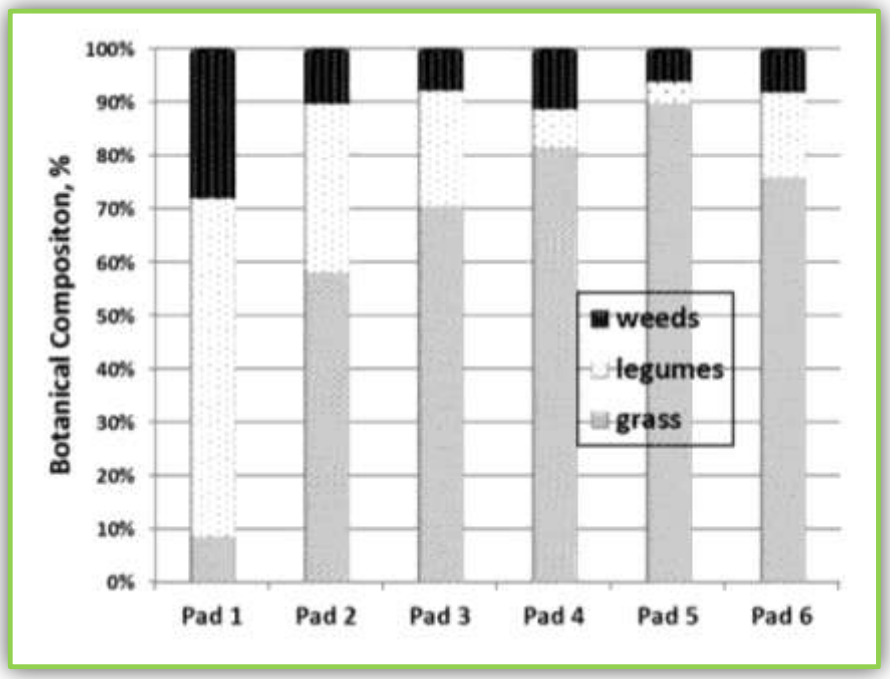


Figure VI.6. Ground cover, stocking density and Heavy Use Areas on Paddock 4



Botanical composition of the pastures (Figure VI.7) was mainly grass and the grass was predominately tall fescue and bermudagrass, but included bluegrass, crabgrass, yellow foxtail, goosegrass, orchardgrass. Legumes, mostly white clover, were also present. The weeds were mainly lambsquarter, pigweed and plantains.

Figure VI.7. Average botanical composition of pastures



Soil test data (see Table VI.6) indicate high to very high levels of primary nutrients with some significant increases, especially on pastures where the stocking density was highest during the observation period. Plant health was always good, with the exception of where plants were uprooted by hogs.

Table VI.6. Soil test results from pastures at two sampling

Characteristic	Year	Paddocks					
		1	2	3	4	5	6
pH	Dec 2008	-	6.6	6.7	6.7	6.8	6.8
	June 2010	7.1	6.7	6.9	6.8	7.0	-
PI	Dec 2008		50	119	135	148	30
	June 2010	75	66	122	291	373	-
KI	Dec 2008		172	170	110	94	112
	June2010	154	142	159	203	138	-
SI	Dec 2008		44	50	33	37	30
	June2010	29	32	32	42	39	-

Parker Farms
Hurdle Mills, NC

I. Lessons Learned

1. Successfully maintaining ground cover is strongly related to stocking density and the duration of hog occupation on a pasture. Indeed, extended periods of animal access to pastures make it virtually impossible for plants to survive unless the stocking density is extremely low.
2. On this farm, doubling the stocking rate over the 2 year period resulted in significant loss of ground cover and increased the potential for runoff of nutrients and soil particles.
3. The ability to plant forages during the optimal season and manage them appropriately during the establishment phase is critical to successful plant growth prior to exposure to hogs.
4. Maintaining vegetative ground cover with summer and winter annuals is strongly related to timely planting and early seedling grazing management practices.
5. Placing fences on the contour provides an excellent and practical way to reduce the slope length, which reduces runoff from pastures with limited vegetative cover.
6. Placement of fencing relative to slope direction has a significant impact on the development of small gullies and water flow along fence lines. Fences running up and down the slope create concentrated water flow along fence lines and initiates the beginning of gullies.
7. When drinking water is provided in every paddock, it is easier to control the location of wallows and drinking sites. Allowing wallows to develop without appropriate management can result in severe erosion.
8. Vegetation is best protected when grower-to-finishing hogs can be raised separately from hogs in the farrow-to-wean stage of development.
9. Providing "sacrifice areas" with housing and drinking water for animals when ground cover declines to 75% is a practical way to protect pastures. Deep bedded structure such as hoop houses can serve this purpose.

II. Farm Description

Randall and Renee Parker own and operate Parker Farms, a multi-generational family farm on 105 acres in the Hurdle Mills community of Orange County NC. The Parkers have been in the process of diversifying their enterprise and transitioning away from dependence on tobacco. With the help of their four children, the Parkers now raise hogs and laying hens in addition to tobacco and various row crops. Their hogs are raised on two separate farms, including approximately 13 acres at their home farm and 4 acres nearby on their "Brown Road" farm.

The Parkers began raising hogs outdoors for Niman Ranch in 2003 with the help of a Golden LEAF Foundation Grant sponsored by NCA&T University. When Niman Ranch stopped activities in North Carolina in 2006, the Parkers started selling hogs to Whole Foods Market. They now supply pasture-raised pork to a variety of other local wholesale buyers and in 2010 began direct marketing their pork and

eggs at farmers markets and through buying clubs.

Table VI.7. Summary of farm acreage and hog numbers during the 2008-2010 period

Characteristic	2008	2010
Farm acreage, acres	105	105
Acreage for hogs	13	16.6
Sows, mature hd	12	19
Boars, mature hd	2	2
Feeder, # sold/ yr	3	4
Finished hogs, #	22	189

Swine Pasture Management

Home Farm

The home farm consists of 16 pastures, 15 of which are used for swine production. Twelve of the pastures contained significant amounts of perennial grasses (tall fescue and limited amounts of common bermudagrass), and four fields were planted to annual forages each year, including ryegrass, small grains and millet. All pastures contained significant coverage from warm season annuals such as crabgrass and foxtails. This farm had a low stocking rate when the CIG project started and the pasture cover was greater than 75%, excluding the heavy use areas surrounding feeders, wallows and housing.

Brown Road Farm

The Brown Road farm includes 3 pastures where hogs were finished from approximately 50 lbs to 250 lbs. In the first year of use, these pastures contained mainly summer annuals, including crabgrass, foxtail, goosegrass and selected broadleaf plants. High stocking rates and the lack of rotation in these pastures resulted in ground cover of less than 20% by end of the finishing periods. Field B2 is well buffered but fields B1 and B3 had insufficient buffering between the hogs and the intermittent stream channel. CIG staff noted that buffering could have been improved by repositioning some of the fence lines.

Figure VI.8. Layout of Parker's "home" farm showing pasture numbers

Figure VI.9. Layout of Parker's "Brown Road" Farm, where finishing lots (B1, B2, and B3) were used for finishing hogs

III. CIG Plan & Implementation

At the outset of the demonstration, CIG staff discussed a range of management practices with the Parkers emphasizing those strategies that address environmental issues, are economically feasible, an can be adapted on other farms. These strategies included:

1. Placing fences along surveyed contours to reduce slope length and minimize gully formation along fences that run with the slope.
2. Installing waterlines to facilitate drinking water locations and wallow management.
3. Moving the finishing phase of the operation to another site that could easily be incorporated into the crop rotation on that farm.
4. Covering heavy use areas with straw, hay or woodchips to minimize rooting.
5. Better management of wallows to control their location and depth.
6. Incorporating crop rotations to remove nutrients from the farm.
7. Periodic renovation of pastures to maintain satisfactory soil cover.
8. Incorporating cattle into the operation as a way to utilize forages.
9. Installing nose rings to control rooting.

The Parkers decided to incorporate install waterlines, add additional farmland into their hog enterprise (e.g., Brown's Road area), to renovate selected pastures, to install waterlines, and to place fencing in a manner that and would help develop berms along the contour.

Excellent mixture of fescue and white clover

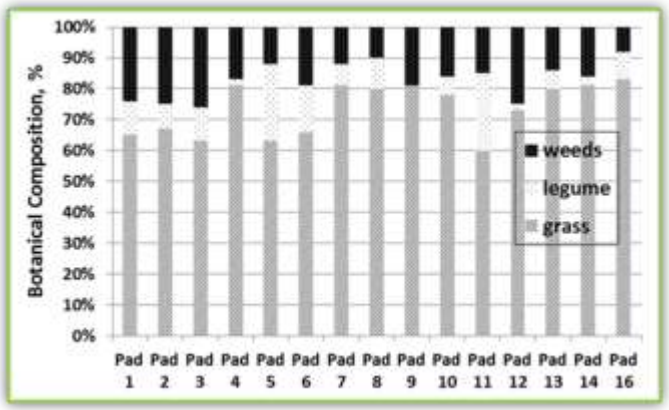
Waterlines

The Parkers installed waterlines and drinking water sites, which freed up time for other management duties, and it helped in relocating wallows and heavy use areas. Having drinking water in each pasture also provided opportunities to alter the paddock arrangement and allow for relocation of HUA's.

Botanical Composition of Pastures

The type of vegetation within a pasture can have a significant impact on survival in outdoor hog pastures. More than 60% (Figure VI.3) of the vegetation on this farm was grass and only a small percentage was legume. Most of the summer grasses were annuals such as crabgrass, foxtail, goosegrass and winter annuals included annual bluegrass and a little barley. Annuals also included small grains and ryegrass. Perennial grasses included tall fescue, bermuda and small amounts of Rescuegrass. Many of the plants classified as "weeds" were winter annuals such as henbit, chickweed, mustards, dock and lambsquarter.

Figure VI.10. Botanical composition of vegetation found in pastures during 2010.



Pasture Renovations

At the outset of the project, the Parker's stocking density was less than one sow (farrow-to-finish) per acre. Vegetative ground cover was exceptionally good and sufficient to minimize runoff and nutrient loss. However, as the sow herd expanded by about 50%, it was increasingly clear that ground cover was not sufficient to control runoff during many months of the year. Pasture renovation became more and more important with time. Annual crops like small grains, ryegrass, crabgrass and other summer annuals became the primary species used to provide cover and limited forage feed. Even though tall fescue was replanted in some pastures, the stocking density and duration of use of each pasture never really allowed sufficient time for satisfactory establishment.

Fencing

Hogs tend to explore the outer edges of their enclosures and to root around the perimeter; effectively resulting in the build-up of soil into a berm. The Parkers established some of the subdivision fencing on the contour; this created a berm on the contour, which changed the length of the slope and slowed the runoff of water and reduced sediment movement. In one instance, CIG staff noted at the beginning of the project that small rills (or gullies) were beginning to develop where hogs were wallowing along a slope of over 600 feet in length (in fields 1, 3, 4 and 5). Shortly after re-orienting the fencing to the contour, the fence line erosion slowed and eventually stabilized. Fencing on the contour appears to hold great promise as a widely adaptable, cost effective BMP for reducing erosion and nutrient runoff from outdoor hog operations.

Stocking Density

When the CIG project began in 2008, the Parkers were managing a herd of approximately 12 sows. As the project progressed, the number of sows expanded to its current herd of approximately 19 sows. The higher stocking density began putting pressure on the forage resources at the home farm and the Parkers decided to incorporate off site finishing of market hogs at their Brown Road farm where they established three fields. Hogs were brought in between 100-120lbs and remained on site until they reached a marketable weight of 250lbs. Usually one or two groups were raised on a field followed by a recovery period before adding more hogs. The forages in these three fields were mostly comprised of naturally occurring species of crabgrass, foxtail, and goosegrass mixed with some common bermudagrass.

Pastures were generally not renovated after each use though future plans are to incorporate vegetable production for direct market sales into the rotation to take advantage of the nutrients produced by the fast growing market hogs. This expansion kept the overall hog production land at approximately 1 sow per acre including the land that was temporarily out of production for forage resting and recovery.

IV. Data Collection methodology

The methodology for collecting each of the data points was as follows:

1. Ground cover was monitored using the "step/point method" on a biweekly farm walk. At each visit, staff walked a zigzag pattern across each field and used the point of his/her boot to estimate soil cover by recording whether the point intersected bare soil or organic material such as live or dead vegetation. Data were recorded only in areas that excluded heavy use areas (HUAs) associated with feeding, watering, and wallowing.
2. Species composition was determined grossly by estimating vegetation within the following groups: a) grass, b) legumes, and c) other species.
3. HUAs were estimated by measuring and then combining the areas determined to be totally denuded within each field boundary. Feeding and watering areas, wallows, portable shelters, and travel lanes were all considered HUAs.

V. Results

The overall objective of this demonstration was to observe the response of soil cover to management of hogs on pasture. Many factors effect vegetation survival but the number of animals and the duration of their presence on a pasture are two critical causes. An attempt was made to monitor animal numbers, animal size and movement from pasture to pasture and it was a challenge to keep daily records of each activity.

Understanding the impact of animals on soil and vegetation in pastures hinges on knowing the stocking rates or stocking density and duration of exposure to the resource. While it is customary to hear farmers and others discuss stocking capacity in terms of the number of hogs per acre in order to make meaningful comparisons, it was necessary to develop a standardized approach that takes into account animal size. We used a Steady State Live Weight (SSLW, lbs) method to standardize the stocking rate or density of animals on the farm.

We approached this by categorizing hogs into weight groups as explained by the Waste Utilization guidelines provide by the NC NRCS 633 standard (Table VI.8). The SSLW method allowed for the estimation of the live weight density on each pasture over the observation

Table VI.8. Weight classes for determining Steady State Live Weight

Production Phase	Initial	Final	Mean
	lbs		
Wean - Feeder	10	50	30
Feeder – Finish	50	220	135
Gild Developing	50	250	135
Boar Stud	250	550	400
Farrow to Wean	-	-	433
Farrow to Feeder	-	-	522
Farrow to Finish	-	-	1417

Stocking density based on SSLW (lbs)

The stocking rate on this farm was the equivalent of about 1.2 sows (farrow-to-finish) per acre during the 24 month observation period. The stocking density while on the specific pastures was slightly higher (Table VI.9). However, ground cover (Table VI.10 and Figure VI.11) was adversely effected by extremely long periods of exposure to animals with the average time that pastures were occupied ranging from 79 to 100 percent of the time (Table VI.9). The pastures that had the highest stocking density and longest occupancy rate generally had the lowest ground cover however a number of factors, including the season, vegetation type, and animal production

Figure VI.11. Ground cover for the farm over a 24-month period as compared to stocking density during occupancy

Table VI.9. Steady state live weight summarized for the 24 month period and for the months hogs were on specific pastures, 2009-2010

Characteristic	Paddock Number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	16
Mean SSLW, lbs/ac	1490	2846	876	1710	898	827	793	3971	1056	857	1791	775	5815	2828	1420
Mean SSLW, lbs/ac during occupied months	1788	3415	1001	2160	1437	1418	1360	5295	1152	857	2263	846	7345	2828	2269
Avg. time hogs on pasture, %	92	92	94	90	81	79	79	87	96	100	90	96	90	100	83

Production Phase	Stocking Density, based on SSLW, lbs/acre while on pasture														
Farrow to finish, sows+14 pigs	1.3	2.4	0.7	1.5	1.0	1.0	1.0	3.7	0.8	0.6	1.6	0.6	5.2	2.0	1.6
Feeder to Finish, each pig	13	25	7	16	11	11	10	39	9	6	17	6	54	21	17

Table VI. 10. Ground cover for pasture areas excluding the HUA for feeders, drinking water sites, wallows and housing and when averaged to include the area considered HUA (2010).

Area being evaluated	Paddock #														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	16
	Ground Cover, %														
Pasture excluding HUA	67	68	71	67	83	78	85	79	61	71	73	65	68	62	91
Pasture including HUA	60	66	71	67	78	72	81	72	62	67	64	59	64	59	85

HUA = Heavy Use Area

phase are all contributing factors. As a general rule, plants that are constantly grazed, trampled, or uprooted will not survive. Based on the stocking density for farrow to finish or finishing animals as illustrated in Table VI.9, it appears that this farm should be able to limit its impact on ground cover by combining groups of animals and providing more "rest" for pasture plants.

It is reasonable to expect that there is a strong relationship between stocking density and duration of occupation. However this was difficult to document on this farm. For example, paddock 10 had a relatively low SSLW/acre but it had hogs on it 100% of the time; and ground cover ended up being similar to paddock 13,

which had almost 10 times the stocking density (Figures VI.12, VI.13, VI.14). Paddock 16 had an intermediate stocking density and a high soil cover when occupied about 83% of the time.

B1 Finishing lot. Notice ground cover deterioration at the end of the production cycle, as a result of high stocking rates and an extended occupation period.

Paddock 16, maintained 73 % of ground cover while being managed with an average stocking rate of 2363 lb SSLW/ac

Figure VI.12. Ground cover and stocking density for paddock 10

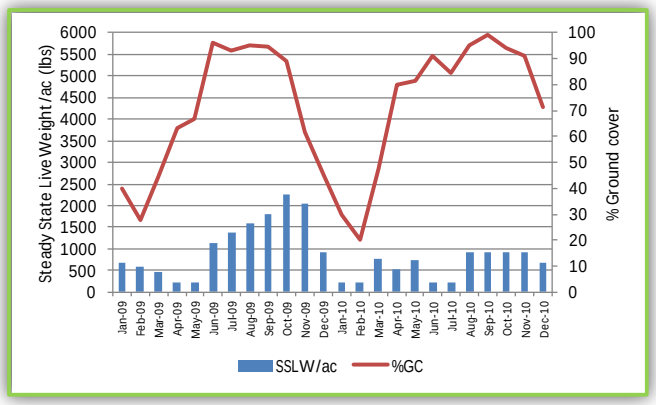


Figure VI.13. Ground cover and stocking density for paddock 13

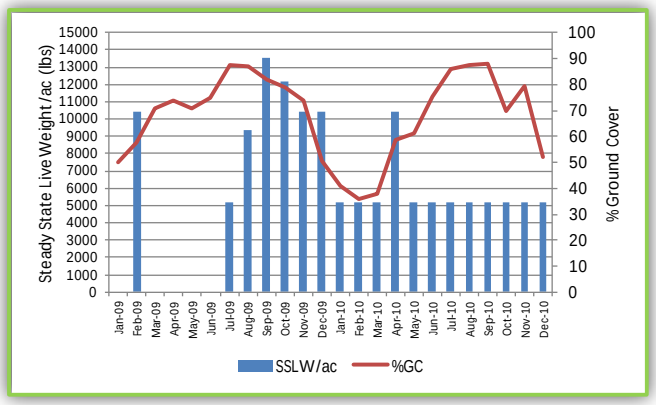
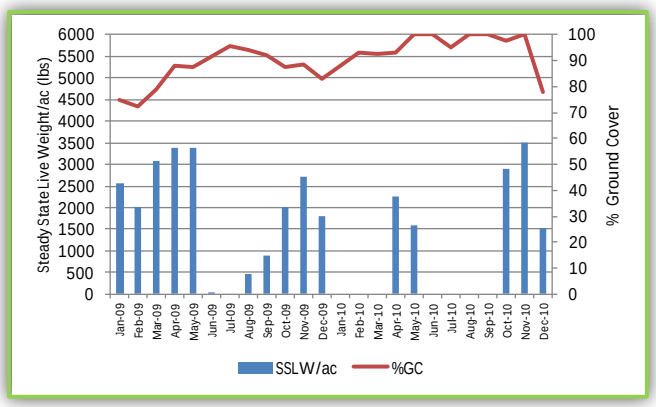


Figure VI.14. Ground cover and stocking density for paddock 16



Heavy Use Area Estimates

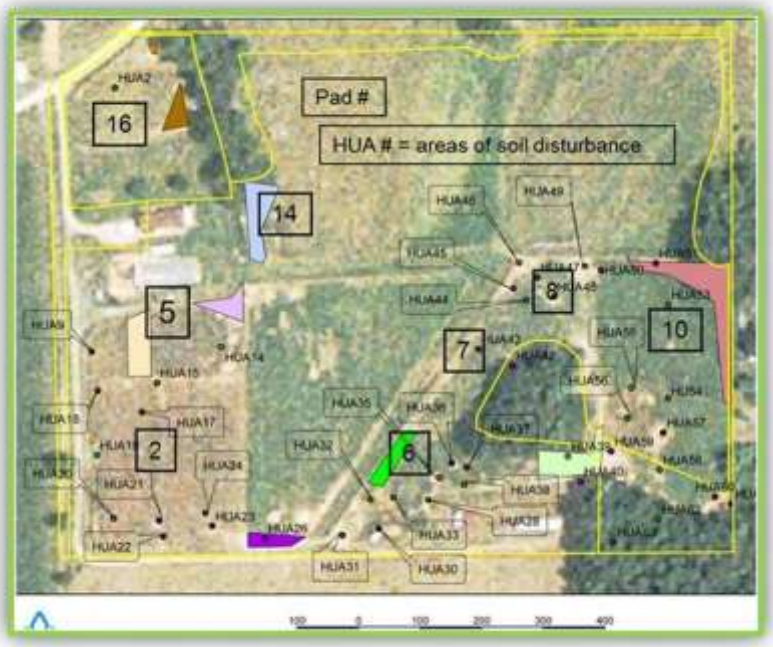
One of the major challenges on outdoor hog farms is the management of heavy use areas (HUAs), which are necessary for feeding, watering, wallows and housing. These necessary areas must be located so that they do not pose environmental damage through runoff or erosion beyond an acceptable level. There is debate over the proportion of the pasture or the farm that should be maintained as an HUA. This demonstration provided an opportunity to estimate the areas that can be considered HUA.

In March 2007 a very detailed evaluation of every pasture was made using GPS locations and measurements of the disturbed areas identifying the nature of the disturbance (Figure 8). The disturbed areas were compared to the paddock size to determine the proportion. The stocking rate at that time was about one sow (farrow-to-finish) on 1.5 acres. Areas attributed to feeding, watering, and wallowing and housing made up less than 5% (Table VI.11) of the land area, however uprooting of vegetation made up a much higher percentage of the area (ranging from 3 to 33% of the land area). Even when considering the total disturbance portion of the pasture, it was about 18% of the land area. The feeding area was about 4% and wallows and housing were less than 1%.

Table VI.11. Estimates of bare soil within pastures as a result of animal activity around feeders, drinking waterers, housing, wallows and uprooted vegetation.

		Bare soil associated with the following				
Paddock #	acres	Rooting behavior	Feeder	Housing	Wallow	Total
		% of area within each paddock				
1	0.6	15	7.2	0.7	0.4	**23**
2	1.7	3			0.1	**3**
6	0.7	32	4.1	0.5	1.2	**37**
7	0.3	3			0.8	**4**
8	0.6	7	4.7		0.7	**12**
10	1.8	14	2.6	2.3	1.3	**20**
14	0.3	33			1.1	**34**
16	0.6	5	1.7		0.2	**7**
average		**14**	**4.0**	**1.2**	**0.7**	**18**

Figure VI.15. Parker farm map showing the location of the many disturbed areas as a result of rooting, feeders, housing location and wallows. March 2007. Estimated stocking rate on the farm was one sow (farrow to finish) per 1.1 acre.



During the 24 month observation period, the stocking rate increased to about one sow per 1.1 acre and the HUA portion of the pasture was generally less than 10% (Figure 9). There was no consistent relationship between stocking density and the HUA portion of the pastures. But it seems reasonable to expect that density and duration of occupation would have an impact on the portion of the pasture considered HUA.

Summary

The Parker farm was chosen as a participant in this project because their pastures were considered in excellent condition. It was understood that they were stocked at about one sow per 1.5 acres. The farm was relatively new to outdoor hogs at the time and the vegetation was predominately tall fescue and bermudagrass mixed with various summer and winter annuals.

This farm installed waterlines, considered improved wallow management, renovated several pastures, placed selected fences on the contour, and incorporated additional farmland into the hog production operation. These practices certainly contributed to improvements in ground cover management. Particularly important may have been the addition of land for their hog operation, which ultimately reduced stocking rates and allowed for periodic resting periods for some pastures.

On this farm it was observed that paddocks which had periodic resting periods (recovery) also maintained a higher level of ground cover.

The relationship between HUA and stocking density is not clear based on the data collected but it appears that less than 15 % of the land area on similarly stocked farms would be considered as HUA.

Figure VI.16. Relationship between stocking density and portion of the pasture affected by HUA.

VII. Summary and Future Research Needs

If not properly managed, outdoor swine production can pose environmental risks.

This project explored different strategies that can be adopted to reduce the environmental impacts of outdoor hog production systems, with a main focus on maintaining vegetative ground cover as a means to limit soil nutrient losses. The following summarize our primary findings:

- Stocking rates need to be established according to on farm circumstances, including soil, forage, weather, animals, management system and skills.
- Annual forages appear to be more sensitive to natural pig behaviors, including rooting, grazing and trampling. We suggest stocking rates of 15 pigs/ac (wean-finish) on annual forages.
- Perennial forages are less sensitive to pigs' natural behaviors and stocking rates can maintained in the range of 15 to 30 pigs/ac and 4 to 6 sows/ac.
- Soil nutrient deposition and soil compaction increase as stocking rates increase. Removal of excess nutrients deposited to the system using hay crops is effective and highly recommended.
- Rotational management is effective and has many advantages including that it provides a rest period for forages, better distribution of soil nutrients, and a potential reduction in parasite loads.

This project identified several key practices that address conservation issues in outdoor hog production systems. Additional research is needed to further refine existing practices and explore potential new strategies. Future research should focus on evaluating an integrated approach to minimizing the environmental impacts of outdoor hog production systems, with a particular emphasis on best nutrient management practices to be implemented in grass/legume mixtures. Two main strategies should be evaluated:

Animal management strategies

Animal management strategies can be explored to minimize vegetative ground cover damage, reduce soil nutrient build-up, and improve the spatial distribution of nutrients. A partial list of potential activities to evaluate includes:

a. Stocking density.

b. Management system (Continuous vs. rotational).

c. Periodic harvest of forage (hay, straw) to remove excess of nutrients.

d. Design of a mobile shelter prototype.

e. Design and location of wallows.

f. Inclusion of "deep bedded structures" during a phase of the outdoor swine production system.

g. Implement "a potty training" strategy.

h. Evaluation of composting and vermicomposting processes and products of swine bedding.

i. Multi-species grazing.

Nutritional and feeding strategies

Nutritional and feeding strategies can be evaluated with the intent to reduce the amount of nutrients imported into the system. A partial listing of potential research activities includes:

a. Multiphase feeding

b. Concentrate restriction.

c. Modification of diet composition (e.g., reduction in dietary protein and utilization of phytase).

d. Evaluation of alternative feedstuffs.

Dependent variables include:

On the environment: ground cover percent, soil damaged area, botanical composition, soil biodiversity, Soil physical and chemical charactheristics (soil compaction, pH, soil nutrients up load (N (NO3 and NH4), C, P, K, Zn, Cu, Ca, Mg, Bo)), N and P leaching.

On the animal: growth and reproductive performance, carcass and pork quality (technical and sensorial), parasite load.

Legumes have an important role to play in a concentrate restriction program.

Providing good quality forage is the first step to reducing nutrients imported into the system.

IX. Appendices

Appendix A. Student contributions

Graduated Student Theses

Bordeaux, Christopher. 2010. Optimizing Nutrient Management and Vegetative Ground Cover on Pasture Raised Pig Operations. 77 p. Master Science thesis. Soil Science Department. North Carolina State University. Raleigh, North Carolina.

Renner, Bart. 2011. The Effect of Stocking Rate History on Soil Nutrient Levels and Forage Nutrient Uptake in Pasture Hog Production Systems. 92 p. Master Science thesis. Crop Science Department. North Carolina State University. Raleigh, North Carolina.

Undergraduate Student Theses

Cardona Hernández, Jorge. O. 2009. Evaluación de la carga animal porcina sobre la cobertura vegetal en un pastizal de Bermuda (*Cynodon dactylon*). 45 p. Tesis Ingenieria Agronomica. Universidad Nacional de Agricultura. Catacamas, Olancho. Honduras.

Maradiaga Rodriguez, Walter D. 2009. Efecto de la carga animal sobre la ganancia de peso y el comportamiento de cerdos manejados en pastoreo. 55 p. Tesis Ingenieria Agronomica. Universidad Nacional de Agricultura. Catacamas, Olancho. Honduras.

Lobo Medina, Arlin D. 2009. Efecto de la movilización de los equipos sobre la cobertura vegetal usando el pasto sudán con porcinos en pastoreo. 46 p. Tesis Ingenieria Agronomica. Universidad Nacional de Agricultura. Catacamas, Olancho. Honduras.

Guevara González, Juan C. 2011. Efecto de la movilizacion de las estructuras de sombra y bebederos sobre la cobertura vegetal de centeno (*Secale cereale*) y ryegrass (*Lolium multiflorum*) en pastoreo con cerdos de engorde. Tesis Ingenieria Agronomica. Zamorano, Honduras.

Guifarro Castro, Ingrid V. 2012. Efecto de la carga animal con cerdas bajo pastoreo sobre la cobertura vegetal de un pastizal bermuda (*Cynodon dactylon*). Tesis Ingenieria Agronomica. Universidad Nacional de Agricultura. Catacamas, Olancho. Honduras.

Zelaya Andino, Ariel S. 2012. Evaluación de sistemas de pastoreo continuo y rotativo con cerdos en etapa de crecimeinto utilizando pasto Bermuda (Cynodon dactylon). Tesis Ingenieria Agronomica. Universidad Nacional de Agricultura. Catacamas, Olancho. Honduras.

Appendix B. Papers and Peer Reviewed Abstracts

Papers

Bordeaux, Christopher. Effects of Rotational Infrastructure within pasture-raised pig operations on ground cover, soil nutrient distribution and bulk density. (Submitted for publication to the Journal of Soil and Water Conservation).

Renner, Bart. The Effect of Stocking Rate History on Soil Nutrient Levels and Forage Nutrient Uptake in Pasture Hog Production Systems. In elaboration phase. (Under development with intent to publish).

Extended Peer Reviewed Abstract.

Pietrosemoli, S. and Green, J. 2009. Effects of stocking rate of mature sows on bermudagrass (*Cynodon dactylon*) ground cover during winter. MEMORIAS ALPA. Volumen 17. Suplemento I. 447-450. XXI Reunión Bienal. San Juan, Puerto Rico. 18-23 de Octubre de 2009.

Peer Reviewed Abstracts

Pietrosemoli, S., Green, J. and Vibart, R. 2009. Effects of stocking rate of weaned to finishing pigs on Bermudagrass ground cover. J. Anim. Sci. Vol. 87, E-Suppl. 2/J. Dairy Sci. Vol.92, E-Suppl. 1: 449.

S. Pietrosemoli, J. C. Guevara, J. Cardona, W. Maradiaga, A. Lobo, J. T. Green. 2010. Animal weight gain in a pastured hog production system. J. Anim. Sci. Vol. 88 , E-Suppl. 2/J. Dairy Sci. Vol. 93 , E-Suppl. 1: 127.

S. Pietrosemoli, J.C. Guevara, A. Lobo, J. Cardona, W. Maradiaga, J. T. Green; 2010. Weight gain of Duroc pigs managed in a Sudangrass (*Sorghum bicolor*) pasture. J. Anim. Sci. Vol. 88, E-Suppl. 2/J. Dairy Sci. Vol. 93, E-Suppl. 1: 128.

S. Pietrosemoli, J.C. Guevara, A. Lobo, J. Cardona, W. Maradiaga, J. T. Green; 2010. Behavior of Duroc pigs on sudangrass (*Sorghum bicolor*) pastures. J. Anim. Sci. Vol. 88, E-Suppl. 2/J. Dairy Sci. Vol. 93, E-Suppl. 1: 307.

S. Pietrosemoli, J. C. Guevara, J. T. Green; 2011. Effects of sow stocking rates on soil nutrients in a bermudagrass (*Cynodon dactylon*) pasture. J. Anim. Sci. Vol. 89, E-Suppl. 3: 25.

S. Pietrosemoli, J. C. Guevara, J. T. Green; 2011. Effects of sow stocking rate and season on bermudagrass ((Cynodon dactylon() ground cover. J. Anim. Sci. Vol. 89, E-Suppl. 1/J. Dairy Sci. Vol. 94 , E-Suppl. 1:289.

B. Renner, S. Pietrosemoli, J-M. Luginbuhl, C. Raczkowski, J. T. Green, J. Grossman. 2011. Effect of stocking rate on forage production, soil compaction and root numbers in a swine pasture system. Anim. Sci. Vol. 89, E-Suppl. 1/J. Dairy Sci. Vol. 94, E-Suppl. 1:315.

S. Pietrosemoli and J. T. Green; 2012. Soil nutrients in tall fescue (*Festuca arundinacea* L.) paddocks managed under different outdoor hog systems. Anim. Sci. Vol. 90, E-Suppl. 3/J. Dairy Sci. Vol. 95, E-Suppl. 2: 32.

S. Pietrosemoli and J. T. Green; 2012. Effect of outdoor swine management systems on tall fescue (*Festuca arundinacea* L.) ground cover and animal performance. Anim. Sci. Vol. 90, E-Suppl. 3/J. Dairy Sci. Vol. 95, E-Suppl. 2: 33.

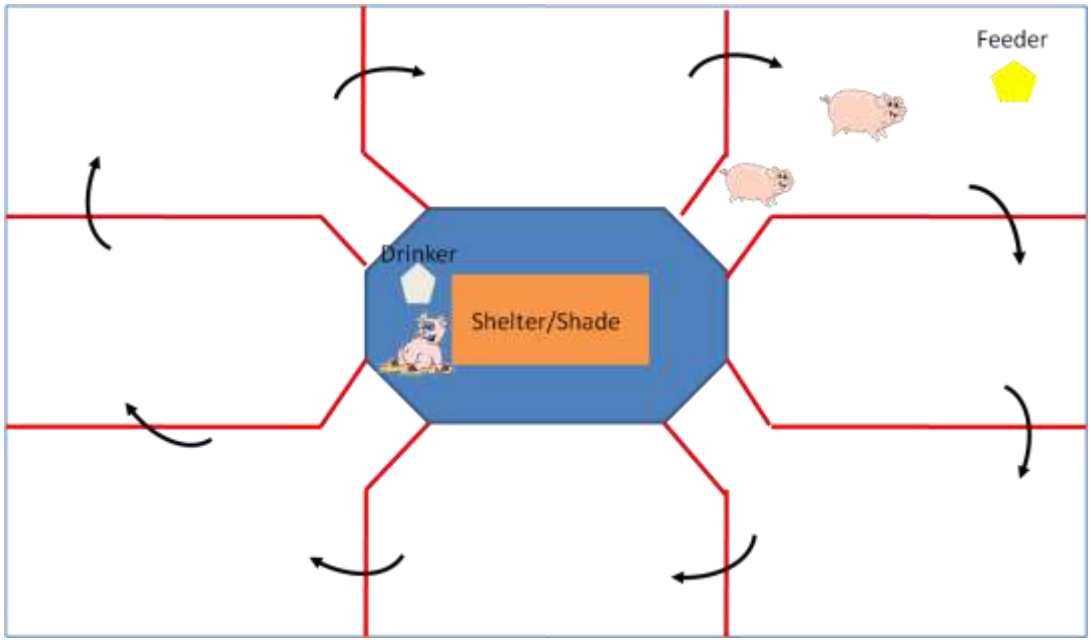
S. Pietrosemoli, J-M. Luginbuhl, and J. T. Green; 2012. Effect of outdoor swine management systems on the botanical composition of tall fescue (*Festuca arundinacea*) paddocks. Anim. Sci. Vol. 90, E-Suppl. 3/J. Dairy Sci. Vol. 95, E-Suppl. 2: 33.

Appendix C. Crop Species and Their Primary Season of Growth and Use By Hogs

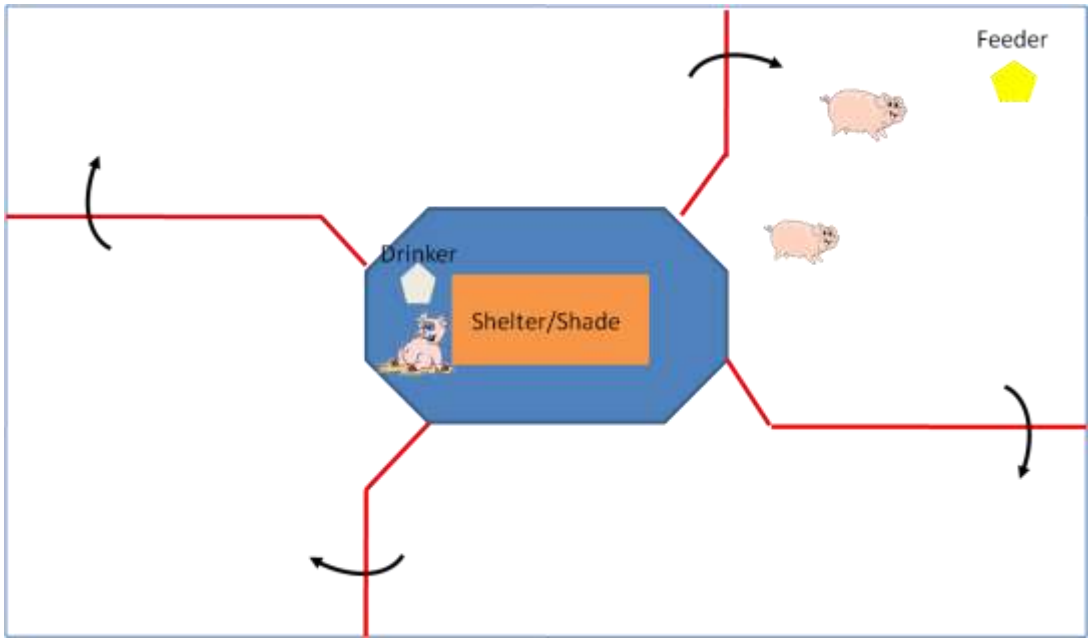
Crop Type	Primary Season of Growth and Use				
	Dec-Jan-Feb	Mar-April	May-June	July-Aug	Sep-Oct-Nov
Crop Residues (Corn, Sorghum, Smallgrains)	Not likely to have significant residue for soil cover.		Smallgrain stubble and straw could be used as soil cover following grain harvest.		Corn stubble could be used following grain harvest
Alfalfa & Red Clover	Do not graze during this period	May start grazing when alfalfa reaches the bud stage of growth in April	Graze on monthly basis through September; these plants will not survive uprooting, so they are best used as forage and frequent rotational stocking is necessary for plant survival.		Allow plants to reach 12" height prior to first frost and limited use just before leaf drop from frequent frosts.
Bermudagrass (Hybrids and Seeded cultivars)	Makes good soil cover during the dormant seasons if significant top growth is accumulated during the growing season.	Use cautiously in March-April during spring "green-up"	Bermuda would be used most anytime of the year. It has potential to survive uprooting because of its rhizome and stolon growth.		
Summer annuals (Crabgrass, Millets, Sudangrass, Sorghum, Corn, Soybeans, Cow Peas, Teff, Buckwheat	Will not be available, unless the autumn growth was accumulated	Plant during this period.		Use through September- October or accumulate the growth to be used as dormant soil cover during the winter.	
Tall Fescue	Graze Stockpiled growth	Use through May or early June if growth is adequate		Do not use	Could use in this period or growth could be stockpiled for later use.
White Clover (Ladino) mostly in mixture with perennial grasses	Very limited use during this period	Base the grazing management on what will favor the associated grass in the mixture. Realize that hogs relish white clover leaves and stolons, therefore rooting of this plant may be more extensive and controlling the stocking density and frequency of animal movement will be paramount for the plant's survival.			
Winter Annuals (Smallgrains, ryegrass, crimson clover, vetch, forage turnips, rape)	Very limited use during this period because root system will be small. However in favorable years grazing will be available if planting was early.	Use during this period		Would not be available unless the mature spring growth was accumulated and not used previously.	Plant during this period.
	In systems where winter annual forages are planted in the fall and grazed out in the spring followed by the planting of summer annual forages one could expect limited early winter grazing (less than 30 days) and 60-90 days in March-May, followed by 45-90 days in July-September. Assuming everything is favorable, the potential days of grazing could range from 180-210.				
Dry lot or Sacrifice Lot	Dry lots or sacrifice lots may be used if properly buffered and subsequently cropped to maintain nutrient balance, especially for Phosphorus and Nitrogen. These lots are effectively used in combination with pastures to provide recovery periods for grazed or uprooted plants.				
Woodlots	Woodlots may be used for shade, but one cannot expect timber growth or even tree survival unless the stocking density is extremely low and/or the time of contact is extremely short. For example, animals may have access to a specific area for maximum of a few days once or twice per year. Consider keeping animals away from the "drip-line" of trees to minimize root and trunk damage.				

Plant Considerations	
Grasses that will be most tolerant of rooting, traffic and abusive grazing. However, nothing survives complete and continuous leaf removal or uprooting.	Tall fescue Ky bluegrass Bermudagrass Bahiagrass
Plants that offer the highest quality feed value and are preferred by grazing hogs.	White and red clover Alfalfa Smallgrains Ryegrass Brassicas Sudangrass Millets Crabgrass

Appendix D. Schematic for Rotational Management System



This system relies on the use of electrical fencing that can be easily installed or removed. An area is divided in nine sections and animals have permanent access to the central area, which functions as an HUA. Animals are then rotated weekly from one section to the next. Shelter/shade and drinking water is provided in the HUA, while the feeder is moved with the animals. This system can be used with sows, and wean-to-finishing hogs during their first eight weeks.



During the last four weeks of the finishing period, reduce the number of sections to four. Move animals weekly through these sections and maintain permanent access to the central area.