RESEARCH & DEVELOPMENT

A Study to Determine if the Biofuel Crop Camelina is a Wildlife Attractant
(Phase I and Phase II)

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16. Abstract

Airport managers have significant annual operating costs tied to maintaining airport green space that can often exceed hundreds of acres and often face challenges with high fuels costs to operate ground vehicles. This project was initiated to explore modifying the land use around airports to support the production of oilseeds and other biomass crops that could be used either as a fuel resource or generate revenue for airport operations. One crop of particular interest was camelina. Camelina is a flowering oilseed that in its native growth regions requires relatively few crop inputs (fertilizer, pesticides, etc.). It is unique in that its oil can be used to support the production of either biodiesel for ground vehicles or used in a process to make a renewable aviation fuel. The overall goal of the project was to assess the feasibility of growing camelina on marginal, underutilized spaces in the southeast and scientifically monitor and document animal attractiveness to the crop. Specific objectives of the project to establish effective production methods, quantify costs in adopting camelina, identify key land selection criteria, and survey wildlife were completed in two phases, Phase I and Phase II. Our crop production efforts showed promise in identifying land characteristics needed for a good crop stand of camelina. The project has exposed some of the environmental sensitivities of camelina in our warmer, humid southeastern climate. Key challenges for camelina production are weed competition, susceptibility to fungal pathogens and excessive moisture. These experiences informed our cultural management decisions and research related efforts to improve production practices and identify most promising site selection conditions at select NC airports. Wildlife surveys did show increases in birds and mammals with the introduction of camelina production practices relative to control turf plots. Overall, useful data were generated and will be available if and when a time arises for camelina to be a part of future conversations.

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EXECUTIVE SUMMARY

Airport managers have significant annual operating costs tied to maintaining airport green space that can often exceed hundreds of acres. Typically, turf grass mowing operations generate several recurring costs including labor, fuel, and capital expenditures. In addition to this specific maintenance cost, airport operators can intermittently experience the challenge of higher fuel costs to operate the various ground vehicles required to keep the airport operational. To alleviate these financial concerns, one option this project investigated was modifying the land use around the airport to support the production of oilseeds and other biomass crops that could be used as a fuel resource. One crop of particular interest was camelina. Camelina is a flowering oilseed that in its native growth regions requires relatively few crop inputs (fertilizer, pesticides, etc.). Camelina is unique in that its oil can be used to support the production of either biodiesel for ground vehicles or used in a process to make a renewable aviation fuel. The United States Navy has recently accepted contracts from fuel suppliers that will provide camelina-derived renewable aviation fuel. However, with the possibility of bird strikes and other animals entering runway space, it was equally important to assess the wildlife intrusion implications of modifying airport land use.

This project is similar to the previously funded NCDOT project led by Dr. Matthew Veal that successfully demonstrated the production of flowering oilseeds along North Carolina highways. This program used canola and sunflowers in rotation to meet aesthetic goals similar to the wildflower beautification program while achieving the maintenance goals of contract mowing operations. In addition to meeting these management goals, the pilot program indicated each mile of roadside enrolled in the program would generate in excess of $200/mile. One advantage of the airports over the right-of-way is the confined nature of the landing holdings allows for easier contracting with local farmers to complete the operations. Additionally, there are fewer safety concerns with regards to carrying out agricultural operations in close proximity to motorists. However, the feasibility of growing camelina on marginal, underutilized spaces in the southeast has not been fully established and animal attractiveness to the crop has not been scientifically monitored and documented.

The overall goal of the project was to assess the feasibility of producing camelina as a bioenergy crop at airport facilities in North Carolina, and address the unknowns of required crop production practices and observable wildlife attractiveness. Specific objectives of the project to establish effective production methods, quantify differences in costs between adopting camelina and current turf management practices, identify key land selection criteria, and monitor wildlife were completed in two phases, Phase I and Phase II. Phase I of the project offered several learned lessons from camelina crop production and wildlife survey efforts over two growing seasons and presented several questions and concerns raised by aviation stakeholders regarding the potential for alternative crop production at an airport facility. Our crop production efforts showed promise in identifying land characteristics needed for a good crop stand of camelina. The project has exposed some of the environmental sensitivities of camelina in our warmer, humid southeastern climate. Key challenges for camelina production are weed competition, susceptibility to fungal pathogens and excessive moisture. These experiences informed our camelina cultural management decisions and research related efforts to improve production practices and identify the most promising site selection conditions.

The successful camelina/sorghum crop rotation in 2015-16 (end of phase I) supported the need for additional observations to make reasonable assessments regarding wildlife attractiveness as part of Phase II. The second phase allowed further examination of 1) crop production management, including crop rotations, tillage/land preparation practices, and planting time, to determine the costs and feasibility associated with transforming fallow grassland into productive cropland and; 2) wildlife interactions with aviation vehicles and impact from crop production operations/activities. Safety was always at the heart of the inception of this research project. Wildlife surveys did show increases in birds and mammals with the introduction of camelina production practices. Through discussions with NC DOT Aviation, any additional wildlife presence as a result of these practices was deemed enough to advise against using camelina cropping systems to support airport operations. Overall, useful data were generated and will be available if and when a time arises for camelina to be a part of future conversations.

TABLE OF CONTENTS

APPENDIX E: SITE SELECTION INFORMATION STUDIED AIRPORTS E1

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

In the face of rising global fuel demand and decreasing production, non-food crop derived biofuels present a more environmentally friendly alternative than fossil fuels (Shonnard et al., 2010). *Camelina sativa*, an oilseed similar to canola, is one such non-food crop with applications in renewable fuels. A unique characteristic of camelina is that its oil can be refined into jet fuel; in fact, in early 2009 Japan Airlines completed the first successful test flight using an 84% camelina, 16% jatropha and less than 1% of algae fuel mixture (Shonnard et al., 2010; Lane, 2012). The big question facing plant based biofuel production is "Where should we grow the feedstock?" Taking agricultural land from food production to fuel production causes a moral dilemma as well as threatens food markets, while clearing forest lands affects soil carbon reserves and atmospheric interactions (Campbell et al., 2008).

Many airports in the United States lease out portions of their land for crop production, usually for corn and wheat (DeVault et al., 2012). Depending on yields, associated costs and demand, producing biofuel feedstock could become a lucrative endeavor for some airports (DeVault et al., 2012). Growing camelina in particular on airport turf fields presents a unique opportunity as its oil can be refined into jet fuel. By producing their own camelina on site individual airports could gain supplemental income by selling the seeds to biodiesel manufacturers, universities, or even farmers. The airports could also fuel their ground fleets with biodiesel made on-site which would make the airports more self-sustaining and could possibly save them money on fuel.

According to airnav.com, there are 110 airports in North Carolina however not all are suitable for crop production programs. This search considered only publicly owned airports under the assumption that any initiative to instill a crop production program could be publicly funded. Major airports, primarily involving ticketed passengers were also excluded. The other criterion for the search was that the airport be located within five miles of existing agricultural land. The benefit of having these lands nearby is that the farmers could form a cooperative with the airports to rent their equipment. This initial investigation yielded 57 airports across North Carolina that could possibly host an agricultural production program. Table 1 below lists the airports according to the county in which they are located. Highlighted airports are candidate locations where we have initiated camelina crop production and wildlife attraction studies. Not included in the analysis (based on set criteria), but included as a viable site for our studies is the ***Kinston Regional Jetport***. The researchers are very appreciative of the willingness of the airport cooperators to support this research effort, making space and resources available and accommodating our schedule of activities.

Table 1. Prospective North Carolina Airports by County

County	Airport Name	Grassland and Pasture Acreage	Cropland in 2006 (Acres)
Alamance	Burlington-Alamance Regional	113.4	0
Anson	Anson County	58.9	0
Ashe	Ashe County	63.6	0
Avery	Avery County (Morrison Field)	13.6	0
Beaufort	Warren Field	12.4	32.9
Bladen	Elizabethtown (Curtis L. Brown Jr. Field Airport)	0.4	66.7
Brunswick	Brunswick County (Cape Fear Regional Jetport)	9.3	1.6
Cabarrus	Concord Regional	217.0	0
Caldwell	Foothills Regional Airport	64.0	0
Carteret	Michael J. Smith Field	0.7	24.4
Chatham	Siler City Municipal	72.2	0
Cherokee	Western Carolina Regional Airport	76.7	43.3
Chowan	Northeastern Regional	0.4	12.7

Cleveland	Shelby Municipal	101.4	0
Columbus	Columbus County Municipal	38.9	20.5
Currituck	Currituck County	98.3	112.3
Dare	Billy Mitchell*	107.6	0
	First Flight*	1.8	0
	Dare County Regional	7.1	0.7
Davidson	Davidson County	39.1	0
Duplin	***Duplin County***	***5.8***	***38.9***
Edgecombe	Tarboro-Edgecombe	28.7	10.2
Franklin	Franklin County	76.7	0
Gaston	Gastonia Municipal	12.0	0
Granville	Henderson-Oxford	65.6	0.4
Halifax	Halifax County	65.6	32.9
Harnett	Harnett County	53.4	28.0
Hyde	Hyde County	0	282.1
	Ocracoke Island	64.0	36.5
Iredell	Statesville Municipal	45.1	0
Jackson	Jackson County	31.6	0
Johnston	***Johnston County***	***212.1***	***124.5***
Lee	Sanford-Lee County Regional	48.9	0
Lincoln	Lincoln County	73.4	0
Macon	Macon County	72.5	0.7
Martin	Martin County	12.7	29.8
Montgomery	Montgomery County	8.9	0
Orange	Horace-Williams	67.8	0
Pender	Henderson Field	7.6	64.0
Person	***Person County***	***104.5***	***0***
Randolph	Asheboro Municipal	117.4	0
Richmond	Richmond County	85.8	34.2
Robeson	Lumberton Municipal	6.0	44.9
Rockingham	Rockingham County	42.2	0
Rowan	Rowan County	108.0	0
Rutherford	Rutherford County	90.0	0
Sampson	Sampson County	0.9	39.3
Scotland	Laurinburg-Maxton	57.4	217.4
Stanly	Stanly County	62.9	0
Surry	Elkin Municipal	46.0	0
	Mount Airy/ Surry County	61.8	0
Union	Monroe	61.8	0
Washington	Plymouth Municipal	6.9	152.9
Wayne	Goldsboro Wayne Municipal (Wayne Executive Jetport Airport)	4.2	11.3
	Mount Olive Municipal	0	86.2
Wilkes	Wilkes County	210.7	0
Wilson	Wilson Industrial Air Center	142.9	20.9
	Sum	3258.6	1570.2
		Total	4828.8

*Owned by National Park Service

The total amount of acres potentially available for planting is approximately 4,829 acres across the 57 airports found to meet the selection criteria. The average acreage is 84.7 acres per airport. Johnston

County Airport has the highest available acreage of 336.6 acres. Since beginning the study and exposing some of the research findings and potential impact at an invited field day and outreach activity held at our Person County Airport site in June 2016, other airport managers have indicated interest in the opportunities.

Project Purpose and Scope

As the debate over the use of lands for the production of food, fiber, feed, and energy intensifies, identifying new land areas that could be placed into agricultural production would provide several benefits addressing long-term production sustainability and improve revenue streams for land managers. Currently there are numerous privately managed and municipal lands that could be used to support agricultural production, while meeting or exceeding current aesthetic, economic, and environmental standards in place with current land maintenance programs. Introducing crop production is simply a new, revenue generating form of land management that can replace ongoing maintenance operations such as mowing, wildflower beautification, or erosion control programs. Additionally, crop rotations can be custom selected to meet the needs and requirements of a particular industry, trade, or individual situation. Crop rotations can enhance aesthetics with the use of flowering crops, meet sustainability goals by supporting biofuels development or providing a mechanism for carbon sequestration, or provide a significant source of revenue through the sale of grain, fiber, and biomass products.

A pilot program (2009-2011) led by Dr. Matthew Veal in cooperation with the North Carolina Department of Transportation successfully demonstrated the
Carolina highways to meet aesthetic goals similar to the wildf
achieving the maintenance goals of contract mowing operatio
source of vegetable oil that could be used in the production of
for the agencies fleet. Airports represent a unique opportunity
land traditionally not included in crop production. Many airp
recurring maintenance cost that supports safety, security, and
airport land holdings from turf grass to a row crop would mee
an economic return and support renewable biofuel production
in Roxboro, NC covers nearly 400 acres of land (Figure 1). W
considerable portion of the Person County Airport, the majori
Identifying areas within the airport that could support crop pr
could provide a rural, low-volume airport with a critical supplemental revenue stream. Additionally, the aerial photo indicates potential agricultural cultivation sites in lands adjoining the airport. This suggests the incorporation of agricultural production at the airport could be supported by the local community; preventing the airport from investing in expensive mechanized equipment. Our initial research at the Person County Airport site has shown promise producing nearly 700 lbs/acre (8.6% moisture content wet-basis) of camelina as a winter cover crop. Our operations on this site have also allowed us to demonstrate some of the benefits with respect to engaging the local community.

Figure 1. The 394 acre Person County Airport in Roxboro, NC

In addition to revenue and aesthetic improvements, there is a growing demand from the general public and regulators to move towards a greener society. Aviation is not immune to this push as the European Union is pushing U.S. air fleet operators to move towards renewable jet fuels to avoid carbon taxes. Camelina is one crop that would be visible and well-received at many aviation facilities. Camelina is an oilseed in the Brassica family that has a very short growing season, is drought tolerant, and has a relatively low nitrogen requirement. Perhaps the most beneficial aspect of camelina is its oil is one of the few plant derived compounds that can be converted into a renewable jet fuel. Growing camelina at airports that can then be used in the production of jet fuel would show to the public and other aviation stakeholders the commitment from the U.S. aviation industry to become more green.

The major concern or disadvantage of crop production at an aviation facility is this activity can encourage wildlife activity that would affect flight operations. Avoiding aircraft encounters with wildlife is critical for the proposed program adoption. Crops selected have been and will continue to be closely and routinely monitored at all airport field sites to determine any threats this activity may introduce. Both bird and mammal activity will be studied. The wildlife impact assessment will continue to be conducted by personnel from USDA. Site selection and crop production activities are planned in conjunction with USDA-APHIS to support data collection suitable to make sound recommendations as it relates to possible wildlife hazards. All crop production activity has been and will continue to be completed with the understanding that if a crop is deemed a hazard to flight operations, it will be immediately destroyed and plowed into the ground. We did not encounter this issue with a camelina, grain sorghum rotation or a camelina, cover crop mix rotation. Additional cropping seasons with successful site repetitions will improve data required for more meaningful assessment of wildlife impact of the crop and possible rotations.

Research Objectives

The overall goal of the research project was to examine the feasibility of producing camelina as a bioenergy crop at airport facilities in North Carolina, addressing crop production practices and wildlife attractiveness. Specific objectives were to:

1. Determine practices that support growth of camelina as a winter cover crop, focusing specifically on site preparation, standability, yields, enterprise budgets, and impact on airport operations;
2. Generate enterprise budgets for camelina production and crop rotations and make comparisons to current turf grass management maintenance operations at airport facilities;
3. Develop criteria to select land available for crop production at airports in North Carolina and use GIS to visually map these lands within the state;
4. Catalog and quantify the impact of these production operations on the wildlife populations at the airport and assess the hazards they may create for both airport ground and air vehicles.

General Research Approach and Methodology

Airport Locations

This study investigated the production of agricultural crops on airports across North Carolina. The plan involved selecting a minimum of two airports in North Carolina. Person County Airport, Johnston County Airport, and Kinston Regional Jetport were studied as part of Phase I. Duplin County Airport was adopted using space that was recently converted from forest to open field space. These airports would be used to evaluate the economic and management potential of growing a combination of traditional row crops and energy crops. At each airport location, two approximately 10 acre plots were designated as the study plots. The 10 acre plot size was suggested as the optimal plot size to conduct the wildlife studies. One of the 10 acre plots served as a control and was maintained under the current turf grass management plan. The second 10 acre plot was managed under agronomic practices pertaining to the crop rotation selected for the airport. All crop production was completed by NCSU personnel with some assistance from host airport operations to maintain space (e.g. intermittent mowing). The airports were selected to minimize travel time between airports and still offer some geoclimatic diversity.

Crop Rotations

While camelina was the focus of the project, year-round production of this plant is not feasible so it was necessary to rotate it with other row crops to protect the land resource for erosion, minimize weed populations, and maximize the return. As such bird-resistant grain sorghum or forage sorghum crop rotation was targeted to make use of existing agricultural infrastructure and markets in the region. All sites had a common camelina crop grown in the first rotational cycle to provide a common link across all sites. Camelina is a flowering oilseed that produces a plant oil that can be converted into a renewable jet fuel. Camelina meal can also be a valuable animal feed ingredient as it is high in protein. Grain and forage sorghums are summer annuals with a ~100 day production cycle. Sorghum crops are drought tolerant, have moderate nutrient requirements, and produce 6 – 9 dry tons of biomass per season. The biomass can be used in the production of cellulosic ethanol or is valuable grain/forage for cattle.

Data Collection

The data collected during the field activities was used to determine the land available at airports for crop production as well as the economics of the activity. Ultimately, this information should allow airport managers to determine if they have sufficient available lands to support crop production and which crops provide the greatest advantages over their current land management practices.

Field Operations – input (fertilizer, herbicides, pesticides, seed, etc.) costs, tillage, time required for operations, fuel consumption, and labor requirements.

Crop Products – market value (i.e. grain price at elevator/feed mill), value-added market opportunities/costs (i.e. cost if oil was expressed on site with oil and meal products marketed separately) , transportation and storage considerations, costs to produce renewable fuels, and impacts on soils (i.e. nutrient recovery/depletion).

Airport Data – information required to make GIS assessment of land availability at the airport.

Wildlife Assessment

USDA APHIS WS used an Integrated Wildlife Damage Management (IWDM) approach (sometimes referred to as IPM or "Integrated Pest Management") in which a series of methods may be used or recommended to reduce wildlife damage. To determine the best methods for the research we agreed that the best compromise between cost-efficiency and statistically-sound science would be to do a study in one geographic region of North Carolina. Due to local environmental variations within the region, NCDOT-DA, NCSU, and APHIS WS selected three candidate airports to establish bird and mammalian surveys. Data collected from these surveys was analyzed following the survey period of the project. To further generate a statistically valid sample of bird usage of camelina, the study design consisted of three airports with three survey days of bird observations per month at each airport. To estimate mammalian attraction to camelina, APHIS WS conducted one night-time survey per month at each airport using infrared night vision equipment.

Organization of the report

LITERATURE REVIEW

Volatility in crude oil markets has driven demand for bioenergy, bioproduct, and industrial chemicals that are supported by sustainable feedstock supply chains. Biofuels are alternative fuels made from renewable sources that emit lower amounts of greenhouse gases (Agarwal et al., 2010; An et al., 2011; Blackshaw et al., 2011). Several countries have implemented legislation in order to promote the use of biofuels including the European Union, Canada and the United States. The European Union set a goal to have 5% of transport fuels made from renewable sources by 2005 (Bernardo et al., 2003); similarly, Canada set a goal of having diesel and heating oil have a 2% renewable content by 2010 (Blackshaw et al., 2011). In 2007, the United States Congress passed the US Energy Independence and Security Act (EISA) which establishes the Renewable Fuel Standard that requires the use 136 billion liters of biofuel annually by 2022 (Blackshaw et al., 2011). Reduction of carbon emissions has also been the objective of several legislations, including the Low Carbon Fuel Standard (LCFS) passed by the California Air Resources Board in 2009 (Shonnard et al., 2010). The LCFS requires the state's transportation system to reduce its carbon emissions by 10% by the year 2020 (Shonnard et al., 2010).

Expanding renewable fuel production to offset petroleum use in transportation can make a significant impact on fuel cost and supply issues, environmental factors and national security concerns. A segment of those fuel alternatives that can positively impact our industrial, agricultural, construction, military and transportation infrastructure include biodiesel and alternative aviation fuels. Aside from benefits in power and energy performance, fuel efficiency and safety, diesel made up 22% of petroleum-based fuels consumed by ground vehicles (US EIA, 2016a), while jet-fuel made up an additional 11% in 2014 (US DOT, 2016;US EIA, 2016b). U.S. oil-based fuel consumption is expected to decline as the use of alternative fuels increases. Increased commercial-scale production of economically viable biodiesel and alternative jet-fuels will improve fuel source diversification, benefit air quality and assist with fuel market stability (FAA, 2014; AJF-IWG, 2016) with oilseeds best suited for biodiesel, alternative jet fuel and related fuel additive conversion processes. In particular, camelina as an annual crop high in omega-3 fatty acid content (>35%) is highly amenable to conversion into advanced biofuels. The aromatics and phenolics present in the oil also support fuel biorefining. The remaining protein-rich meal has been FDA-approved for livestock feed and has benefits over other meals (Moriel, 2011; Dangol, 2015). The meal has been described to contain 10-12% oil with approximately 5% being omega-3 fatty acids, is 40% protein, and is low in glucosinate (Pilgeram, et al., 2007). Life cycle analysis of camelina-based jet fuel and diesel concluded that they can reduce CO_2 emissions by 75% and 80%, respectively compared to petroleum-based fuels (NRCS, 2011; Shonnard et al., 2010).

Camelina can be considered new to U.S. crop production, with most recent research taking place in the Great Plains and Pacific Northwest as those climates are best suited to native varieties (cool, arid climates). Limited research has been conducted to date in the Northeast and upper Midwest (Obour et al., 2015; McVay and Lamb, 2008; Hunter and Roth, 2010; Grady and Nleya, 2010). Seed yields published in these regions over the last 10 years range between 200 to 2000 lbs/ac (Obour et al., 2015; McVay and Lamb, 2008; Hunter and Roth, 2010; Gesch, 2014; Ehrensing, 2008, NDSU, 2009). With the development of a new crop and motives to expand production acreage to benefit energy markets, agribusiness and security drivers, significant efforts are needed to establish a sound foundation that informs producers on viable and effective cropping practices.

With a 75-90 day maturity window and cold weather tolerance, our team has successfully produced camelina in NC starting late fall or late winter/early spring, which allows growers an additional rotational crop and one whose price is not tied to the traditional grain market. Growing camelina on non-agricultural lands such as airport turf fields presents an innovative solution to producing fuel feedstocks with low carbon emissions (Shonnard et al., 2010; Reijnders, 2009; Debolt et al., 2009; Campbell et al., 2008). Our own trials with some of the same varieties of camelina used in other US regions fall within the range of seed yields observed, even for poor production years and challenging weather conditions (150-970 lbs/ac).

Since camelina is a cool season crop with a relatively short growing period much of the ideal growing season for other crops in the southeast U.S. remains after camelina is harvested. This provides a camelina producer the opportunity to explore warm season rotational crops that enhance their overall cropping system. With an estimated harvest window for camelina lying between late-May and mid-June one rotational crop option is grain sorghum (*Sorghum bicolor*). Grain sorghum is a globally relevant crop primarily used for livestock feed. The grain also has applications as a feedstock in ethanol production and is becoming more popular within the consumer food industry (United Sorghum Checkoff Program, 2016). Grain sorghum is typically planted between the months of April and June, and planting date in combination with the row widths used for planting have been shown to influence grain yields. Grain yields can be optimized with nitrogen applications between 80 and 125 lbs of N per acre (Heinger et al., 2009). Approximately 8,000 acres of grain sorghum were harvested in North Carolina in 2018 with an average yield of 60 bu/acre and average price of $6.60/CWT (~$3.69/bu). This provides an estimated $1,774,000 value to the agriculture in NC (USDA/NASS, 2018).

Crop rotational practices that include grain sorghum have shown promise for increasing subsequent crop yields while showing yield stabilization over time (Coulter et al., 2011; Sindelar et al., 2016). This yield increase and stabilization can be partially attributed to the diversified crop rotation, and the decrease in disease and pest pressure through an integrated pest management (IPM) approach (Holtzer et al., 1996). Grain sorghum can be an attractive rotational crop for farmers in the southeast with benefits in reducing nematode issues (Rodriguez-Kabana et al., 1991; Kirkpatrick and Thomas, 2011) and recruitment of arbuscular mycorrihizal fungi which have been shown to improve soil and plant health, disease and pest resistance, and water use efficiencies within an agroecosystem (Gosling et al., 2006). With the current potential value of grain sorghum as part of multi-season rotational cropping system for NC farmers, investigating and integrating the crop into the camelina production system can add value to airport operations.

Further diversification of cropping systems through the introduction of cover crops have shown promise for improving soil health, water use and retention, minimizing erosion, reducing compaction, and increasing subsequent crop yields while providing yield stabilization (Blanco-Canqui, et al, 2012; Raper et al., 2009; Williams and Weil, 2004; Yang et al., 2019; Sindelar et al., 2016). Similarly, cover crops grown prior to traditional grain crops have shown the ability to control weed competition and promote reduced tillage practices (Boquet et al., 2004; Buchi et al., 2019). Since there are no currently EPA approved post-emergence broadleaf herbicides labeled for camelina, and given the sensitivity of the crop to marginal soil characteristics, the positive effects of cover crops on weed suppression, organic matter and fertility can help restore underutilized land to functional crop production spaces at NC airports.

Wildlife and Crop Production on Airports

Wildlife strikes involving birds (96.8% of all strikes) and mammals (3.1% of all strikes) with aircraft cost US civil aviation approximately $382 million every year with 71% of the strikes occurring below 500 feet above ground level and often within airport property (Dolbeer et al. 2016). Habitat management on airports has been effective at reducing wildlife strikes (Dolbeer et al. 2016). However, in the generally weak worldwide economy airports need to create further revenue in order to maintain economic viability. The maintenance of standard airport grasslands through mowing programs can cost airports a minimum of $10 per hectare for each mowing session (Washburn and Seamans 2007), therefore airports are examining alternative land use programs that can generate some revenue without increasing risk associated with wildlife strikes. One possible land use is alternative energy production via solar, wind or biofuel. DeVault et al. (2012) points out that airports may provide an adequate location for such energy production if safety is not compromised.

Another revenue program is the leasing of airport land for agricultural activities (DeVault et al. 2013). The Federal Aviation Administration (FAA) recommends against using airport property for any agricultural production. However, the FAA does recognize that at times, due to financial difficulties, airports may have to proceed with agricultural activities and if so they are to follow recommended minimum distances between crops and certain airport features (Federal Aviation Administration 2007). However, with the exception of avoiding grain crops, the selection of crops that minimize the risk of wildlife strikes is open to speculation. Sterner et al. (1984) provided a literature review concerning the attraction of crops to bird species and Blackwell et al. (2009) provide a summary of agriculture as a potential land-cover type at airfields and surmise that there may be opportunities to use revenue-producing crops that will present minimal wildlife hazards at airports. Iglay et al. (2017) did examine bird use of corn, wheat, and soybean on fields in Ohio and found that large flocks of birds occurred corn and wheat fields while soybean fields also attracted birds but not to the same extent as corn and wheat.

The combination of agricultural activities and biofuel production may be achieved by growing crops such as camelina (*Camelina sativa*) or safflower (*Carthamus tinctorius*), members of the mustard family (Dajue and Mündel 1996, Francis and Warwick 2009). Seeds of these plants may be crushed with the subsequent oil being used for biodiesel or aviation biofuel. The remaining plant product may be used as a protein-rich feed source for livestock (Dajue and Mündel 1996, Moloney et al. 1998, Berglund et al. 2007, Smith and Makkar 2012). In Switzerland, camelina seeds placed on or near the ground in preparation for planting were heavily fed upon by slugs but had limited bird damage (Kollmann and Bassin 2001). However, camelina has been added to bird seed mixes and included in wildflower strips for the purpose of attracting wildlife to distinct areas (Pywell and Nowakowski 2008). Crowley and Fröhlich (1998) indicate that small seed eating birds will use camelina; however, Pavlista et al. (2011) found that camelina production was not affected by birds found in the Nebraska Panhandle.

Camelina must be rotated with some other crop during the course of a year. Potential rotational crops include grain sorghum (*Sorghum* spp.), soybeans (*Glycine max*), and other small grain crops. Soybeans generally do not provide adequate structure and cover for hazardous bird species (Husak and Grado 2001), and have been shown to be a low quality food for waterfowl (Jarvis 1976, Krapu et al. 2004).

Sorghum is fed on by white-tailed deer (*Odocoileus virginianus*) (Matschke et al. 1984) and are a significant hazard to aircraft (Dolbeer et al. 2000, DeVault et al. 2011). There are grain sorghums (*Sorghum bicolor*) that are bird resistant (Niehaus and Schmidt 1970, Tipton et al. 1970, McMillian et al. 1972) and may be available for use in airport settings. However, care must be taken in variety selection as well as in harvest strategy as sorghum stubble has been shown to be attractive to birds (Flickinger and Pendleton 1994). A lack of peer reviewed studies of bird and small mammal use of camelina fields throughout a production year prevents determining if the crop will compromise aircraft safety at or near airports.

REPORT BODY

Crop Production

Airport Sites

Initial narrowing of airports to engage considered public ownership, non-commercial flights, proximity to agricultural land in production (~within 5 miles) to align the project with the potential to gain support from a local cooperative and/or reduce the need to invest in mechanized equipment, and a significant land base that was either maintained as grass/pasture and/or in previous crop production.

Fall 2014- Fall 2015 Initial Crop Rotation Season- Research participants with NCSU, USDA-APHIS, NCDOT and airport cooperators/personnel considered areas that best suited combined needs for reasonable agronomic conditions, statistically sound wildlife surveying, and safe management with airport operations at 1)Person County Airport; 2) Johnston County Airport; and 3) Kinston Regional Airport (Figure 2). Initial agronomic considerations included ease of field access, soil quality, drainage, previous land use, region, and climate. Two plots, one test plot (planted) and one control plot (unplanted), that were at least one km apart and 4 ha in size were required to meet minimum study standards for wildlife surveys. It was also important that the crops grown in rotation with camelina were consistent between airport sites. Proximity to our equipment and resources was important to feasibility of completion for personnel and budget constraints. Field sites (~10 acres each) were established for crop production and controls (common management) and borders of the layouts were physically marked. Soil samples were collected at multiple spots and compiled for different zones marked across the field sites. In addition, soil resistance measurements were taken at various locations across each test plot to quantify potential soil compaction challenges. Sample analyses for macronutrient, micronutrient and pH /lime adjustment recommendations were obtained from NCDA Soil Testing Laboratory. Herbicide was applied using a third party licensed applicator to achieve an initial foliage (grass and broadleaf) kill prior to planting. Based on soil analysis results, lime and fertilizer (N, P, K, S) were applied to test plots using third party licensed applicators. Camelina (Blaine Creek variety) was planted between November 19th and December 2nd, 2014 by no-till drill on 7.5" rows at a seeding rate of 9 lbs/ac. Limited plant emergence led to a replant of the camelina at all sites in March 2015. Camelina emergence and establishment was monitored over time. Poast was applied as a post-emergent herbicide to help manage grass weeds.

Figure 2. Airport Camelina Production and Control Sites. Person County Airport (Top Left); Johnston County Airport (Top right); Kinston Regional Airport (Bottom Left); Duplin County Airport (Bottom Right).

A bird feeding resistant sorghum (Southern States, SS655) was selected to fit within the June to September window as a rotation crop between camelina growing seasons, offer some form of potential value-added profit for airports, and because it would require relatively minimal crop management and meet wildlife attraction expectations at the airport. In preparation of the sorghum crop to be planted no-till (drilled; 15" rows; 5.3lbs/ac, 80,000 seed/ac), plots were mowed and sprayed with a contact herbicide. Additional fertilizer was not applied for the sorghum crop as it was assumed that the limited camelina emergence resulted in residual soil nutrients being available. Sorghum was planted between mid-June and mid-July 2015 at the airports and two of the research stations (Central Crops and Williamsdale Field Lab) for comparative data collection from conventional tilled spaces (same planting methods). Emergence and growth progression of the grain sorghum planted at Person County, Johnston County and Kinston Regional was continuously monitored. Weed pressure and other issues (pests, diseases) were also noted. A grain moisture meter was set up to take moisture measurements in September and into October (weekly as possible) to assess maturity and harvest timing (~13-16% moisture). Working around wet conditions, grain was harvested with a small plot combine and grain weights were measured using truck scales at a local ag facility.

<u>Camelina Cropping Seasons: 2016 and 2017</u>- In preparation for a second camelina crop production year at Person County, Kinston Regional, and Johnston County Airports, soil samples were collected across the field sites (Figure 3) and submitted to Waypoint Analytical for nutrient analysis. The locations of soil samples for each airport are shown below, the blue pins marking where samples were taken in each field, scale 1:2000 (red pins are locations where penetrometer readings were taken in Fall 2014). Recommendations on nutrient levels for canola were requested based on determined nutrient levels after the sorghum crop. The field at Kinston and Johnston County were fairly uniform, while several areas in

the field at Person County showed higher variability, especially in pH. Based on the soil analysis, decisions were made on the levels of lime, N, P, K and S applications need for the three field locations. Applications at Person County were split into three different zones for lime application. In addition, manganese was determined to be a micronutrient that was needed to help with soil fertility at Kinston Regional.

Challenges faced with the marginality (and fallow status) of the spaces selected at the airports for camelina production, particularly weed pressure, drainage and soil uniformity of the field sites, required a change in management beyond no-till practices and fertility. Decisions were made to support the best chances for a successful camelina crop, which included 1) conventional tillage at the Person County and the Kinston regional Airports; and 2) more frequent mowing and a heavy herbicide kill of the grasses at the Johnston County Airport, minimizing erosion issues with tillage and >5% slope at the plot. Herbicide was applied at the time of conventional tillage prior to the last disc pass to address grasses, standing weeds and winter annual weeds. The wet Fall 2015, resulted in planting the 2016 camelina crop as a late winter, early spring option (rather than an early fall option). The crop has proven to still germinate and perform well under these conditions in other regions and this delayed date can help alleviate some of the challenges with excessive soil moisture at the airports and rainfall within our region. For 2016, SO-50 camelina was planted at the airport sites and linked research station control plots (Johnston County and Central Crops, Kinston Regional and Caswell Research Farm, and Person County) within the month of March. Just prior to planting at Kinston Regional and Person County, fertilizer (N, P, K, S) and lime were applied based on soil analysis results and a pass with a cultipacker was completed. The seed drill was calibrated at a seeding rate of 15 lbs/ac (7.5" rows, ⅛" to ¼" depth) to help ensure decent emergence for a late Winter/Spring planting.

Figure 3. Soil Sample Locations at the Airport Camelina sites. Kinston Regional (Top); Johnston County (Middle); Person County

Camelina emergence, weed pressure, and general field conditions were monitored over the growing season. Poast was applied as a post-emergent herbicide to help with management of grass weeds. Camelina harvest with a small plot combine was completed at Person County Airport, Kinston Regional Jetport, and Caswell Research Farm in June 2016. As a result of excessively high weed and volunteer crop pressure Johnston County Airport and Central Crops Research Station were omitted from harvesting activities.

A crop was not rotated behind camelina in 2016. Standing vegetation post-harvest was mowed and plots were mowed intermittently during remaining surveying and until camelina crop production was initiated in late winter/early spring 2017. In 2017, SO-50 camelina was planted in March at just Person County Airport after conventional tillage using the same crop production practices (soil sampling, herbicide, fertility) described in 2016 (Figure 4). Emergence, plant development soil moisture, weed pressure. and fungal disease was monitored over time. Plant counts were made using a 1 m x 1 m square boundary randomly placed throughout the test plot.

<u>Sorghum Rotation Crop 2017-</u> After mowing in late May a residue dry-down, burndown herbicide (Dual Magnum and Roundup) was sprayed to minimize regrowth of smartweed that emerged heavy at Person

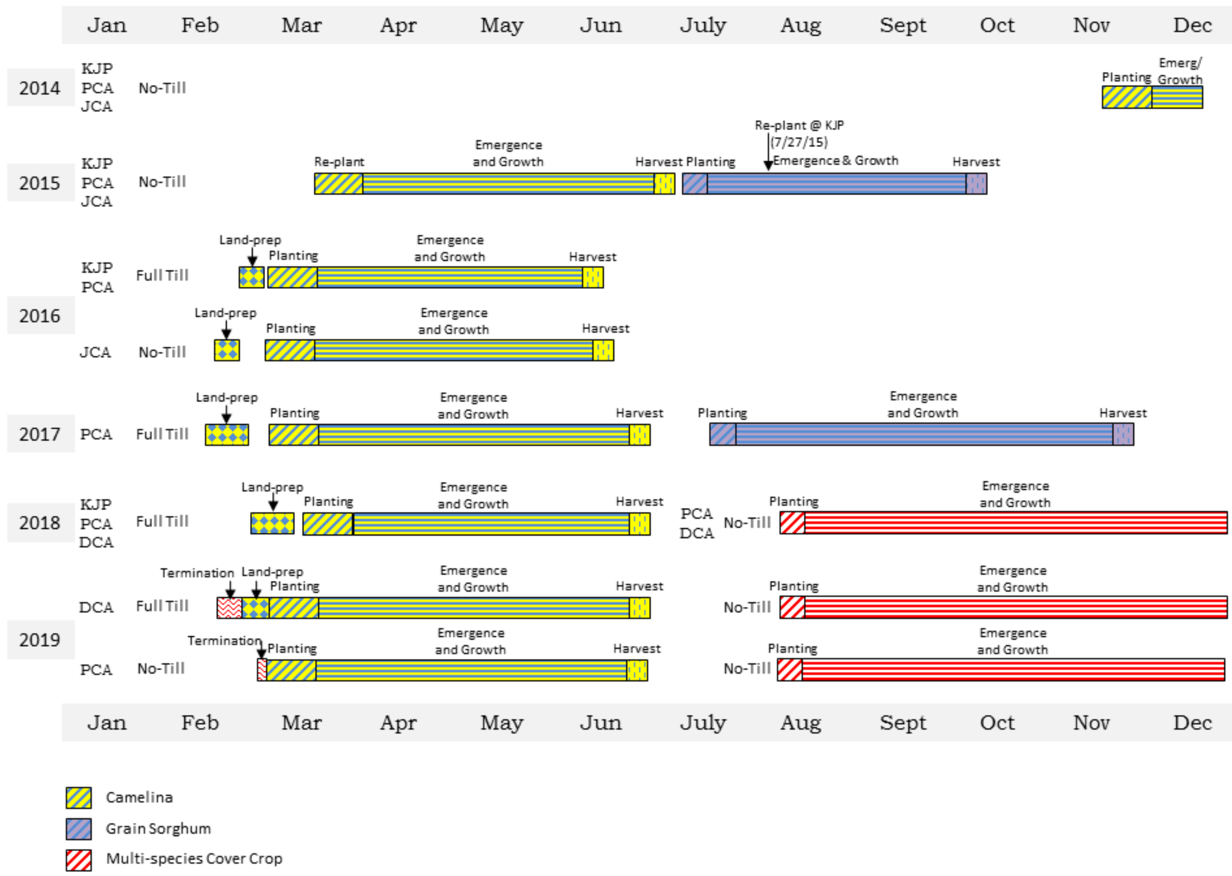
County Airport using a third party licensed applicator in July. It is likely that not having the summer cover crop in 2016 and leaving tilled field space fallow lead to some of the weed challenges observed in 2017. The bird-resistant sorghum seed variety (Southern States, SS655) was planted no-till (no-till drill, 5.3 lbs/ac, 15" rows). Post emergent granular nitrogen fertilizer (100 lbs/ac) was applied a month after planting. Plant counts, weed pressure and other issues (sugarcane aphids; disease) were noted. Grain samples were collected for moisture estimates to assess maturity and harvest timing (~13-16% moisture target). Sorghum was harvested using a small plot combine in November 2017.
Camelina-Multi-Species Cover Crop Rotation 2018 and 2019- In 2018 Duplin County Airport was added as a study location (Johnston County Airport was removed after 2016). The site is close to 24 acres supporting two 10 acre study plots and some additional acreage for full crop coverage as well as the control plot (10 acres). Soil samples were taken at all airports (Kinston Regional, Person County, Duplin County) and research station (Williamsdale Field Labs, Caswell Research Station) test locations. Samples were sent out for analysis and fertility recommendations. Conventional tillage (disking and field cultivating) in combination with a pre-plant incorporated (PPI) herbicide were completed at each airport in an attempt to address broadleaf weed emergence challenges. Although the sorghum crop from 2017 was planted no-till, tillage was important to renew the space at Kinston Regional (out of production since 2016) and assist with drainage and uniform seed bed at Person County. Tillage was not necessary at Duplin County as the space acquired was recently cleared of trees and land planed. Lime and fertilizer (N, P, K, S) applications were completed based on soil analyses prior to planting in March and early April 2018. Camelina SO-50 was planted using a no-till drill calibrated at a seeding rate of 14.5 lbs/ac (7.5" rows). The large seed box was used to plant at Kinston Regional and 8 acres at Duplin County. The small seed box was used to plant Person County and 8 acres at Duplin County. An additional 8 acres at Duplin County was planted with a seed spreader (17.2 lbs/ac). Poast herbicide applications were not applied this year. Sites resulting in reasonable crop development were harvested with a small plot combine in June 2018. A multi-species cover crop mix was configured and included: *Cereal Rye (70%)***:** provides lasting residue for weed suppression due to relatively high carbon to nitrogen ratio (C:N). Root system is good at scavenging phosphorus. Both above and below ground biomass is effective at tying up nutrients to minimize loss through leaching or runoff. Specifically for Duplin Co. Airport it would provide erosion control through the end of summer until termination in the spring. *Hairy Vetch (15%) and Crimson Clover (15%):* both species are legumes capable of high nitrogen fixation. Some of this nitrogen would be held in the system for subsequent crops by the cereal rye. Two legumes were selected to allow each ecosystem to select which worked best at that site. Herbicide was applied and the cover crop was planted with a no-till drill at a seeding rate of 58-62 lb/ac at Duplin County and Person County Airport mid to late August 2018 to accommodate the typical season appropriate for the mix. Weather and wet field conditions prevented planting at Kinston Regional within the planting window, most significantly Hurricane Florence. Development of the cover crop and field conditions were monitored at planted sites (Person and Duplin County) and included any biological activity and weed development.

Airport supported hurricane relief efforts at Kinston Regional Airport and placement of FEMA personnel and facilities forced the project team to abandon further study at this site. Surveys at Kinston Regional Jetport concluded on October 24th, 2018 because FEMA trailers were stationed on the control plot. These trailers were designated to be on site for up to 2 years. The project team recognized the significance of the surveys and the control plots to study findings and conclusions. Without the ability to continue surveys the decision was made to also stop planting on the camelina test plot at Kinston as to not waste project funding and resources.

Part of the rationale for planting the cover crop was to assist with weed pressure, capture soil nutrients, and provide opportunity for no-till management. Considering weed emergence, cover crop development, and soil accessibility the cover crop was chemically terminated and camelina (Blaine Creek variety, 14 lb/ac, 7.5" rows) was planted no-till direct into the standing crop at Person County Airport and planted following a single field cultivator pass at Duplin County Airport in March 2019. Soil samples for fertility recommendations were sent for analysis as previously described and fertilizer applied close to

Figure 4. Airport Crop Production Operations and Timing 2014 50 2019

planting time. Monitoring of emergence and field conditions continued as previously described. Plots



Despite the presence of plants in the field and many reaching maturity, the emergence was low in the 2014-2015 cropping season. Issues with seed spacing and distribution across the fields were also observed. With this season most issues with seed emergence were attributed to soil saturation issues at all the airport sites. Some plants showed stunted growth (Person County Airport) while plants on well-drained soil (*Research Studies*-Caswell Research Farm; higher ground; tiered areas) showed high germination rates with plants reaching full maturity. Weed pressure and the variety of different weeds at the airport locations was also a concern post-emergence.

Soil temperatures and rainfall during the 2014-2015 camelina growth window were reviewed to paint a better picture of the field conditions. Rainfall data for Johnston County, Person County and Kinston Regional airports were determined from values presented for the towns of Smithfield, Roxboro, and Kinston, respectively (Table 2). Rainfall totals for Johnston County and Kinston Regional airports indicate that during the 'critical germination and growth zone' for Camelina rainfall was abnormally high. Johnston County and Kinston Regional airports had rainfall amounts of 2.52 and 2.77 inches above normal, respectively. Person County airport had a combined rainfall and snow-melt amount near normal values. During the camelina growing season (fall planting), from October 2014 to April 2015, both Kinston Regional and Johnston County airports received rainfall above normal amounts, while Person County airport was below average. Above average rainfall could lead to seed failing to germinate and rotting in the soil. Wetter than normal conditions could also result in plant death after germination given that camelina is a crop that prefers well drained soils and drier growing conditions. Saturated soil conditions likely played a part in the crop failure observed with camelina in the 2014-2015 growing season, and had an impact in future seasons.

	Johnston Co. Airport (Smithfield)				Person Co. Airport (Roxboro)				Kinston Jetport (Kinston)				
Date	Rainfall	Snow	Normal Rainfall	Rainfall Difference	Rainfall	Snow	Normal Rainfall	Rainfall Difference	Rainfall	Snow	Normal Rainfall	Rainfall-Normal Rainfall Difference	
	inches				inches				inches				
Oct-14	3.81		3.03		3.45		3.7		1.44		3.07		
Nov-14	4.03		3.07	0.96	3.72		3.46	0.26	2.93		3.07	-0.14	Critical Zone
Dec-14	4.76		2.95	1.81	4.18		3.7	0.48	3.91		3.07	0.84	
Jan-15	4.83		3.62	1.21	2.88		3.82	-0.94	4.7		3.74	0.96	
Feb-15	1.89		3.35	-1.46	2.62	9.76	3.35	-0.73	4.3	2.52	3.19	1.11	
Mar-15	3.77		4.29		3.73	0.39	4.45		3.94		3.9		
Apr-15	1.96		3.31		2.78		3.35		4.14		3.15		
Total	25.05		23.62	2.52	23.36	10.15	25.83	-0.93	25.36	2.52	23.19	2.77	

Table 2. Precipitation Data at areas in proximity to Airport sites from Oct 2014 to Apr 2015

Data is from usclimatedata.com; 10inches of snow is equivalent to 1 inch of snowmelt (www.erh.noaa.gov/box/tables/snowfall-meltwater.html)

Soil temperatures can also affect plant germination. It is recommended that temperatures be above 50°F to ensure germination before a frost if camelina is planted in the fall and temperatures be at or above 38°F for germination if camelina is planted in the spring. Review of some of the soil temperature data at the time of planting through the NC Cronos System at areas near the airport sites revealed that the average soil temperatures were above 50°F. While these temperatures are factors considered, the timing of planting was not likely a factor in the lack of emergence issues observed with the camelina in 2014-2015. A soil penetrometer was used to measure soil resistance across the fields at the three airport sites to assess compaction limits on root formation (Figure 5). The optimal soil resistance limits for camelina have not been demonstrated however, in general most crops perform well under 250 psi. The largest soil resistance values were observed at the Johnston County airport with upwards of 100 psi being observed at 2 inch depths below the surface and in some case 350 psi at 4 inches at multiple locations across the terraced field site. The Person County Airport site had been previously stripped of the top soil for use at another location. While the soil resistance levels were less than those observed at Johnston County overall, the soil resistance was between 100 and 300 psi within the first 6 inches below the soil. Rocky soil conditions were also observed at both Person and Johnston County airport sites. The Kinston Regional site was previously in crop production prior to becoming unmanaged and covered with native weed species. As such the soil resistance levels were relatively low and uniform at depths up to 10 inches below the surface with a maximum resistance of approximately 200 psi. Root development of camelina is relatively shallow compared to many row crops and although soil resistance levels are high in multiple locations at the different sites, they were likely not large enough to inhibit growth of camelina as we observed in 2014-2015. Aside from soil resistance impacting root formation, an improved seed bed that can be achieved with tillage, similar to the conditions used in the research station studies, may help germination and emergence.

The Person County plot was able to support the growth of sorghum in 2015 with minimal issues and no obvious soil fertility, soil saturation, pest, or disease problems and produced a reasonable crop (Table 3). 2015 rainfall delayed in-field drying of the grain as well as created saturated soil conditions in the field, limiting access by equipment—including our small grain combine and loading trucks. While the grain had matured (moisture content ~30%), the decision was made to harvest the grain at a higher moisture content rather than waiting for the appropriate field moisture (~18-20%) to be reached as an attempt to meet conditions for a late fall planting of the camelina crop. Field conditions were still wet in many spots, but with several rain free days the team took the opportunity to get in the field. 17,380 lbs of wet grain sorghum at an average field moisture content of 28% (wet-basis) and adjusted test weight of 67.3 lbs/bushel of grain (13.5% MC) was harvested for 7.9 acres. The yield for this harvest was approximately 14,467 lbs of grain at 13.5% standard moisture resulting in 1831 lbs/ac and 32.7 dry bushels/ac at standard test weight (Table 3).

Sorghum emergence at the Kinston Regional site was slowed similar to what was observed at Person County. Slow emergence may have been an unexpected characteristic of the variety planted. At Kinston, there were also early signs of weed pressure and this pressure became much more obvious later in the season. However, the problem was not able to be addressed based on crop maturity/height with additional herbicide application without harming the crop. The crop at Kinston also began to fail due to other agronomic issues as evidenced by the crop damage (e.g. stunted growth, leaf discoloration, leaf dieback). Soil and plant samples were taken at multiple locations in the field to assess where plant stress could be attributed. It was determined that the micronutrients in the soil were lacking. In the case of Kinston, Mg was determined to be deficient for sorghum and likely an issue in combination with the lime (Mg and Ca competition for binding sites interactions—affecting CEC and nutrient availability) we had applied to get the soil pH of this fallow area back to that suitable for crop production. With the micronutrient stress, the crop was also more susceptible to sugarcane aphids, which the leaves of many of the plants showed evidence of such an infestation. As a result, this sorghum crop failed and we were not able to harvest.

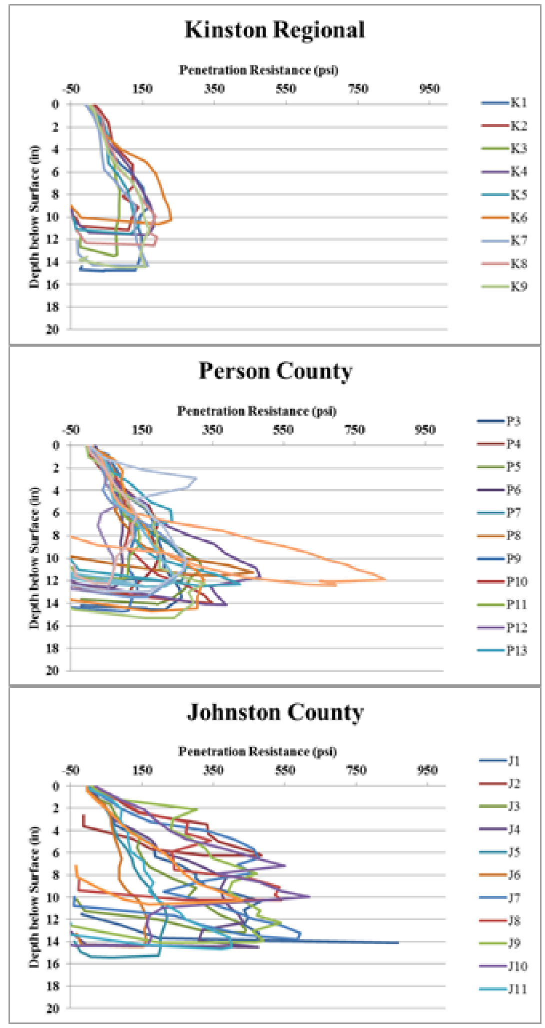


Figure 5.Soil penetrometer resistance measurements taken at various locations across airport sites

While the sorghum at the Johnston County Airport was able to emerge in some places, the overall success of emergence across the site, was minimal to none. Despite heavy herbicide applications at Johnston County, our inability to provide the intensive weed management needed for that site (e.g. consistent mowing and spray applications) limited the potential for a successful crop. Grasses and broadleaf weeds out-competed the sorghum crop and we did not observe a successful crop at that location. It was discussed among project personnel the possibility of abandoning that site as to not "waste" resources on an area that we may not be able to successfully manage for crop production with a limited budget (in labor/time and inputs). Regardless, the Johnston County site offered feedback in terms of suitable site selection and management needs for airport locations with limited field equipment and operational budgets. Since the slope of this Johnston County site would also not allow for additional management with tillage, this site was removed from the study in 2017 and the Duplin County site was added in 2018.

Table 3. Camelina Yields at Airport Sites 2014-2019

Comparison of airport Camelina yields						
	Camelina			Sorghum		
		Grain			Grain	
	Plant Counts	Wet Yield	Moisture Content	Plant Counts	Wet Yield	Moisture Content
Airport	*K-seed/ac*	*lb/ac*	M_w	*K-seed/ac*	*lb/ac*	M_w
2014-2015						
Person Co.	—	—	—	—	1998	28%
Johnston Co.	—	—	—	—	—	—
Kinston Jetport	—	—	—	—	—	—
2016						
Person Co.	—	672	12%			
Johnston Co.	—	—	—			
Kinston Jetport	—	970	24%			
2017						
Person Co.	441	—	—	86	1179	16%
2018						
Person Co.	1011	—	—			
Duplin Co.	1141	43.25	15%			
Kinston Jetport	673	—	—			
2019						
Person Co.	—	—	—			
Duplin Co.	283	49.87	9%			

The grain sorghum crop grown at the research stations in 2015 (Central Crops and Williamsdale Field Lab) under conventional tillage conditions showed variable results. Interestingly the Central Crops site performed very well while Williamsdale Field Lab showed similar performance to what was observed at Kinston Regional. While the quality of the areas selected at the airports may be considered marginal for different reasons, there may also be some issues related to this variety of sorghum variety and susceptibility to sugarcane aphids in the eastern part of the NC. The crop at the Williamsdale Field Lab died and degraded to nothing which is what we have previously observed when a crop becomes infested with sugarcane aphids. It should also be noted that sweet and forage sorghums that we planted next to the plot at Williamsdale produced a crop without issues.

In 2016, with conventional tillage incorporated at two airports, camelina emergence was noticed at all sites within 10 days of planting. The most uniform germination was observed at the Person County Airport site. There was also noticeable variability in time of emergence at all sites. Variations were most likely related to differences in planting depth (e.g. with use of a no-till drill and tilled soils; terraced surfaces with hillside planting) and soil moisture differences in the fields as some areas were not as well drained as others at all sites. Crop damage was noticed in some plants either from soil saturation or several overnight freezing days in March. Weeds were also starting to compete with the emerging camelina crop as temperatures started to warm, especially at Johnston County Airport having issues with both broadleaf weeds and grasses. As a result, early growth was stunted and the camelina crop was later deemed non-viable for meaningful harvest and yield determination at Johnston County. Crop injury in low lying areas was observed as a result of high soil moisture in April and May at all sites. Aside from Johnston County, weed pressure from grasses was moderate at all sites benefiting from the post-emergent herbicide. Broadleaf weed pressure increased substantially in late April and May at Person County Airport and Kinston Regional Jetport. There was evidence of fungal disease (powdery or downy mildew) and lodging at Person County Airport in late May 2016. Signs of mildew were also observed at time of harvest for the Caswell Research Farm. Humidity, soils and plant genetics contribute to proliferation of fungal pathogens in camelina. The severity of disease can influence seed development and yields after flowering. Camelina wet yields in 2016 from Person County and Kinston Regionals were similar to those previously reported, yet below 1000 lbs/ac (Table 3). Harvest losses, field uniformity and inconsistent seed development likely contributed to lower yield values.

In 2017 camelina that emerged at Person County Airport was not uniform in some areas as a result of seeding depth challenges and water saturation issues. Plant emergence and development was decent, averaging 497,764 plants/acre. Crop damage was noticed in some plants with early emergence as well as on plants that had developed for more nearly 60 days. There was variability in the maturation of the emerged plants. Weed pressure started to become heavy in the field with the relatively constant rainfall that season, especially in the lower, poorly drained areas (noted mid-May). The primary weed was a broadleaf, smartweed, that is known to be a species that thrives in high soil moisture environments (unlike camelina). The height and fill of the weeds continued to increase in and around the developed camelina crop (noted in mid to late May). Mildew also started to develop around the seedheads in May. Despite an initial healthy crop of camelina, with the extreme weed pressure, consideration of machine harvest had to be abandoned and hand-harvest of a small section was completed. Prevalence and height of smartweed was extreme at Person County within weeks of harvest time. To prevent seed head formation and minimize such weed carryover in future seasons the field site was mowed. Sorghum (16% moisture w.b, 11,646 wet lb) was harvested from 9.87 acres and the grain was offered to an end-user. Grain yields were approximately 19.42 dry bushels/ac, 59lbs/bushel @13.5% moisture (Table 3). These yields are relatively low compared to other grain sorghum varieties produced in North Carolina.

In 2018, the project switched to a camelina-multi-species cover crop rotation to offer soil health benefits and reduce input and overall management costs of a double crop system. Emergence in some areas was not uniform as a result seeding depth differences and soil saturation. Plant counts for the different planting methods used at Duplin County Airport were on average 1,000,429 plants/acre (range 246,858 to 1,566,135 plants/acre and 1,282,553 plants/acre (range 764,857 to 2,452,397 plants/acre) for broadcast and drilled, respectively. Kinston Regional Airport had plant count averages of 708,201 plants/acre (range 756,763 to 1,137,168 plants/acre) in the large field and 639,404 plants/acre (range 32,375 to 918,637 plants/acre) in the small field. Person Co. Airport had plants up to 6" tall and some were starting to flower by May. Pant counts for that airport were on average 1,011,715 plants/acre (range 732,482 to 1,234,292 plants/acre). Overall average counts for the fields are presented in Table 4. Pre-plant incorporated herbicide seemed to reduce overall emergence of broadleaf weeds and in the case of Person County, stunt the development of smartweed. Weed development at Duplin County was quite minimal and did not seem to negatively impact crop development or ability to harvest. Smartweed among other broadleafs still emerged and created competition at Person County Airport. Similarly, broadleaf weeds presented competition issues at Kinston regional Airport. The crop matured well at Duplin County Airport and seemed to be doing well at Kinston Regional aside from continued challenges with weeds. Early plant death was observed at the Person County Airport and eventually plants died at the Kinston Regional Airport. Poor crop maturation and early death of plants at Person County and Kinston Regional, limited harvests to Duplin County Airport. Harvested yields were considerably lower this year, possibly a result of the late planting date (worked around rainfall and field access). The later planting contributed to early flowering and altered maturation of the crop and seed development in the warmer weather and longer daylight hours. There were also shatter losses prior to and during harvest as well as general seed loss as we approached the harvest date at Duplin County. Overall yield from Duplin County Airport is presented in Table 4 for 2018. The drilled plot yielded 33.4 dry lbs/ac (field moisture was 14.4%) and the broadcast plot yielded 57.7 dry lbs/ac (field moisture was 9.7 %). In comparison to drainage challenges often experienced at the other airport locations, Duplin County Airport was very sandy and did not hold much water for the plant to draw from during the cropping season. Yield comparisons for this year can be made to those achieved at the research stations (Table 15).

After the camelina season in 2018, weather presented challenges to cover crop emergence, particularly with Hurricane Florence which made landfall on September 14th, 2018 and rains prior to and continuing through September 17th, 2018. 20 to 30+ inches of rain for south east and south central NC were recorded and the rainfall drowned or eroded most of the emerging crop at Duplin County Airport.

Table 4. 2018 Camelina Stand and Yield Summary

2018 Airport Camelina Yield Summary

Location	Field	Plot ID	Stands (plant/acre)	Seeding Rate (lb/ac) Planted	Seeding Rate (lb/ac) Emerged	Germination Rate (%)	Dry Yield (lbs/ac)	Moisture Content (Mw)
Duplin Co. Airport	Drilled	Drilled	1,285,553	13.0	3.21	24.7%	33.4	14.4%
	Broadcast	Broadcast	1,000,249	15.5	2.50	16.2%	57.7	9.7%
Person Co. Airport	All	All	1,011,715	13.8	2.53	18.3%	-	-
Kinston Jetport	Small	Small	708,201	19.5	1.77	9.1%	-	-
	Large	Large	639,404	19.5	1.60	8.2%	-	-

In addition to Hurricane Florence, Tropical Storm Michael hit North Carolina October 11, 2018. Michael added an additional 3 to 4 inches of rainfall in the Person county area and wetter conditions to the Duplin County and Research Station sites. This rain compounded the negative effects of wet weather conditions on crop development and establishment in the already water logged soils following Hurricane Florence. The cover crop seed planted did not effectively recover at Duplin County Airport. However, by February of 2019 cereal rye, crimson clover and hairy vetch began to emerge non-uniformly across the Person County site, particularly in areas with decent drainage or higher ground. The late emergence overlapped planting timing for camelina, so the benefit of the cover crop species will likely not be fully realized.

Early emergence of camelina was observed at both Person and Duplin County airports, but the stand at Duplin was much better than that at Person County. Plants did not survive the extensive rainfall endured at the Person County airport and poor soil drainage. For 2019, a reasonable stand was not achieved at Person County. Camelin plant counts at Duplin County ranged from 72,843 to 283,280 plants/acre. Pre-emergent herbicides were effective in minimizing grass and broadleaf weed development in 2019 and post-emergent herbicides were not needed as of mid-May. Camelina was harvested in June and while seed was effectively collected, yield values were considerably low (Table 3).

Wildlife Assessment

To determine the best methods for researching the production of camelina at airports in North Carolina, it was agreed that the best compromise between cost-efficiency and quantification of avian hazards would be to do a study at three candidate airports. These airports were selected based upon site visits and soil samples conducted by USDA APHIS Wildlife Services and NCSU. The airports selected for this study included Johnston Regional Airport (KJNX), Kinston Regional Jetport (KISO) and Person County Airport (KTDF). At each of the airports 2 ≥4-ha plots were established (Figure 6). One plot served as a control area whereby no agricultural activity occurred. The second plot was established to serve as a test area in which camelina and a rotational crop (e.g. grain sorghum) were planted and subsequently harvested. Each plot was monitored from October 2014 to July 2016. The plots were designed to maintain at least 1km of separation between plots, although plots on the same airport are not necessarily statistically independent. In the event that bird use posed a significant threat to aircraft, a protocol was in place that the experimental crop fields would be plowed under and the experiment terminated.

Biologists from the USDA Wildlife Services North Carolina program conducted 3 bird transect surveys (1 survey includes an AM and PM count) per month for 22 months. Start time of transect surveys was randomly selected for each AM and PM count with the condition that at least 4 hours separate counts.

Weather conditions were recorded at the beginning of each transect. Transects were surveyed in the same direction each time and followed the same path. Observers scanned ahead and to the sides while walking slowly and quietly along the transect line. All observations occurred in the direction that the observer was heading and never behind or more than 90° left or right. The distance to the bird when it was first detected as well as the angle to the bird from the observation line was recorded. Distances was measured with laser rangefinders. Also documented were the species and the plot cover type at the time of observation. All birds were identified to the lowest possible taxonomic level. Perpendicular distance between the bird(s) and transect were calculated using the angle and the sighting distance. If birds were flocked, distance to the center of the flock and angle to center of the flock was recorded along with the number of birds in the flock. A bird flock was defined as a relatively tight aggregation of birds, as opposed to a loosely clumped spatial distribution of birds (Buckland et al. 2001).

Figure 6. Plot design and layout (Person County Airport, Camelina Plot on left and Control Plot on right)

Surveys were conducted for white-tailed deer and other mammal use of control and test plots one time each month starting approximately 30 minutes after sundown. A Forward Looking Infrared (FLIR) camera was used from a vantage point that allows the observer to view the entire area. The observer quietly moved into position and to view the area taking enough time to slowly scan the 4-ha area and record the presence of any wildlife observed.

During the initial phase I surveys, several variables were encountered that affected the dataset of the wildlife surveys. These variables included limited sample size, competition with weed growth in treatment plots, rotation crops that were attractive to birds, wet conditions leading to degraded treatment plots, and geographical limitations. Phase II was initiated to expand and improve the results of the dataset for both wildlife and agriculture. Aligning with crop production efforts, Duplin County airport was added to provide an additional region and land use habitat a different rotational crop (the multi-species cover crop previously described) was used to assist with soil improvements and in controlling weed prevalence on the treatment plots. As a result of excessive slope and other variables encountered during the initial study Johnston County Airport was removed from Phase II surveys.

Surveys from April 2018 to October 2019 (Phase II) were completed at three airports, Kinston Regional Jetport (6 months, April-Oct 2018), Person County Airport and Duplin County Airport. The approach to conducting surveys did not change between project phases, maintaining three bird surveys and one mammal survey monthly at each airport. The eighteen month survey period of Phase II provided an opportunity to survey two seasons of camelina growth and one rotation cover crops.

<u>Kinston Regional Jetport</u>-As part of Phase I transect survey data was collected from October 2014 through July 2016. A total of 132 surveys were conducted at both the control and treatment plots (Table 5). During these surveys, a total of 24 bird species were observed using the treatment plot when it was in the camelina growth phase and 8 species were observed while it was in the sorghum phase of growth. A total of 26 bird species were observed in the control plot. We also documented surveys in which no birds

were observed. A total of 100 surveys were conducted at the treatment plot in which no species were recorded and a total of 81 surveys recorded no species in the control plot.

Observations were also recorded at both the treatment and control plot to determine bird usage during each month over the entire survey period. Data was recorded at the treatment plot based on current phase of crop growth (Figure 1). Total birds observed monthly remained relatively similar throughout most months. An increase in the number of mourning doves was recorded during the December survey period using the treatment plot. A total of 258 mourning doves were observed during this period with a mean of 13.6 birds per observation. Similarly, in the June survey period, an increase in mourning doves and red-winged blackbirds resulted in more birds being observed in the treatment plot than the control. During the March time period, higher bird numbers were observed in the control plot due to an increase in Eastern meadowlark and fish crows. Likewise, higher numbers of birds were observed in April due to higher numbers of Eastern meadowlarks and purple martin observations.

Table 5. Bird Observations at Kinston Regional Jetport, October 2014 to July 2016

	Camelina (99 surveys)	Control (132 surveys)	Sorghum (33 surveys)
# of Species	24	26	8
Total # observed	726	529	96
Mean # observed	2.3	1.4	1.6
# surveys no species	86	81	14

Observations were also recorded at both the treatment and control plot to determine bird usage during each month over the entire survey period. Data was recorded at the treatment plot based on current phase of crop growth (Figure 7). Total birds observed monthly remained relatively similar throughout most months. An increase in the number of mourning doves was recorded during the December survey period using the treatment plot. A total of 258 mourning doves were observed during this period with a mean of 13.6 birds per observation. Similarly, in the June survey period, an increase in mourning doves and red-winged blackbirds resulted in more birds being observed in the treatment plot than the control. During the March time period, higher bird numbers were observed in the control plot due to an increase in Eastern meadowlark and fish crows. Likewise, higher numbers of birds were observed in April due to higher numbers of Eastern meadowlarks and purple martin observations.

As part of Phase II, transect survey data was collected from April 2018 through October 2018. As a result of hurricane Florence data collection was canceled at Kinston on 10/24/2018 due to long-term storage of FEMA facilities at the airport. A total of 132 surveys was conducted at both the control and treatment plots (Table 6). During these surveys, a total of 16 bird species were observed using the treatment (Camelina) plot, whereas a total of 9 bird species were observed in the control plot. Surveys were also documented in which no birds were observed. A total of 20 surveys were conducted at the treatment plot in which no species were recorded and a total of 11 surveys recorded no species in the control plot.

Table 6. Bird Observations at Kinston Regional Jetport, April 2018 to October 2018

	Camelina (66 surveys)	Control (66 surveys)
# of Species	16	9
Total # observed	207	197
Mean # observed	3.1	3.0
# surveys no species	20	11

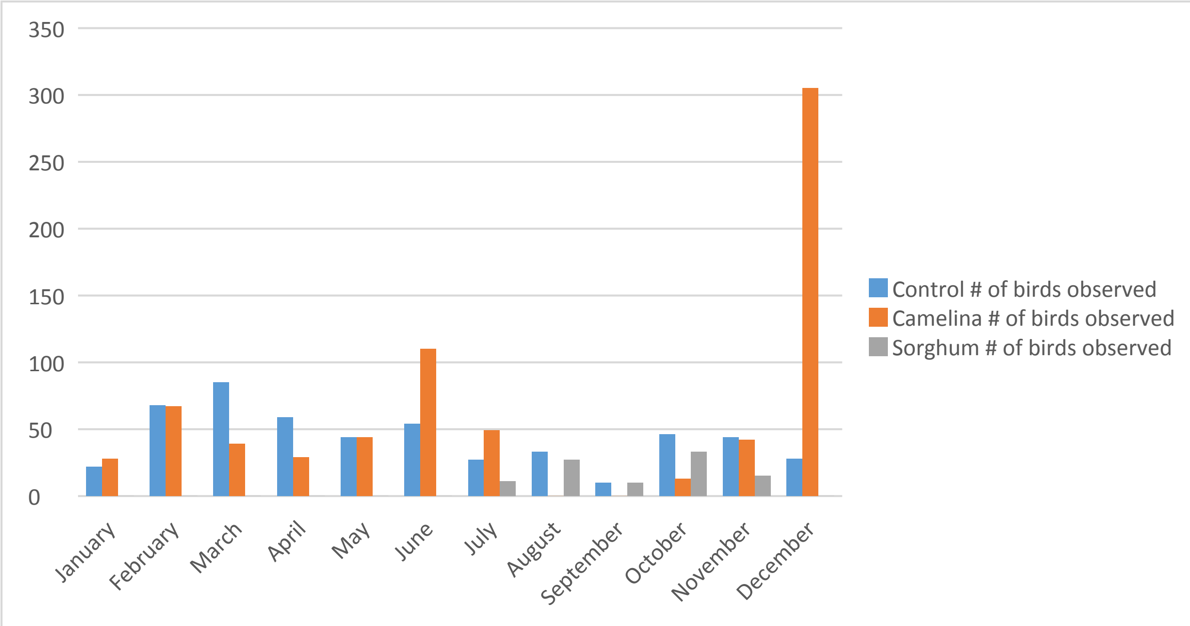


Figure 7. Total number of birds per month at Kinston Regional Jetport, NC (Oct 2014 - July 2016)

Observations were also recorded at both the treatment and control plot to determine bird usage during each month over the entire survey period (Figure 8). The highest levels of bird use at the treatment plot occurred in July and August. Eastern meadowlarks, indigo buntings, and tree sparrows were the species most frequently present in the treatment plot during this time period. Bird use of the control plot was highest during the months of May, June, and July. Eastern meadowlarks and purple martins were the most commonly observed bird species in the control plot during this time period.

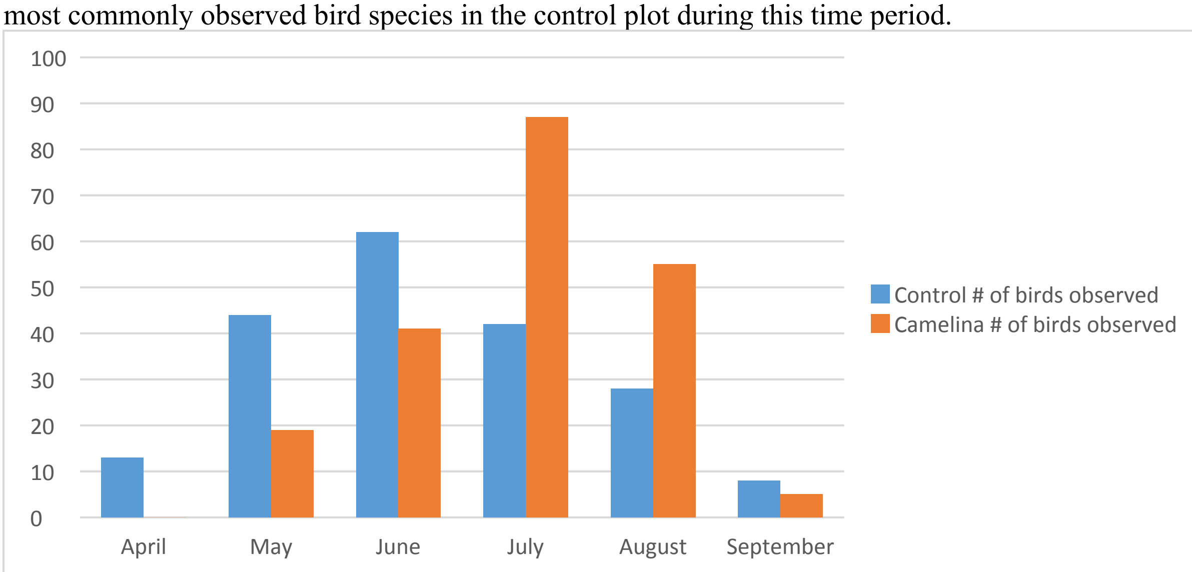


Figure 8. Total number of birds observed per month at Kinston Regional Jetport, NC (April 2018 – October2018)

<u>Johnston County Airport</u>-During Phase I, transect survey data was collected from October 2014 through July 2016. A total of 132 surveys were conducted at both the control and treatment plots (Table 7). During these surveys, a total of 24 bird species were observed using the treatment plot when it was in the camelina growth phase and 6 species were observed while it was in the sorghum phase of growth. A total of 21 birds species were observed in the control plot. We also documented surveys in which no birds

were observed. A total of 98 surveys were conducted at the treatment plot in which no species were recorded and a total of 154 surveys recorded no species in the control plot.

Table 7. Bird Observations at Johnston County Airport, October 2014 to July 2016

	Camelina (104 surveys)	Control (130 surveys)	Sorghum (26 surveys)
# of Species	24	21	6
Total # observed	799	351	78
Mean # observed	2.4	1.2	1.1
# surveys no species	74	154	24

Bird observations at Johnston County Regional Airport resulted in more birds being observed at the treatment plot during 10 of the monthly survey periods (Figure 9). During March, a significant increase in bird observations occurred at the treatment plot. This was a result of an increase in observations of American crow, Eastern meadowlark, European starlings and mourning doves. Likewise, high observations of Eastern meadowlark, brown-headed cowbirds, and red-winged blackbirds resulted in more birds being observed at the treatment plot during the June survey period. During the October period, a noticeable increase at the control plot resulted from higher numbers of Eastern meadowlarks and American crow observations.

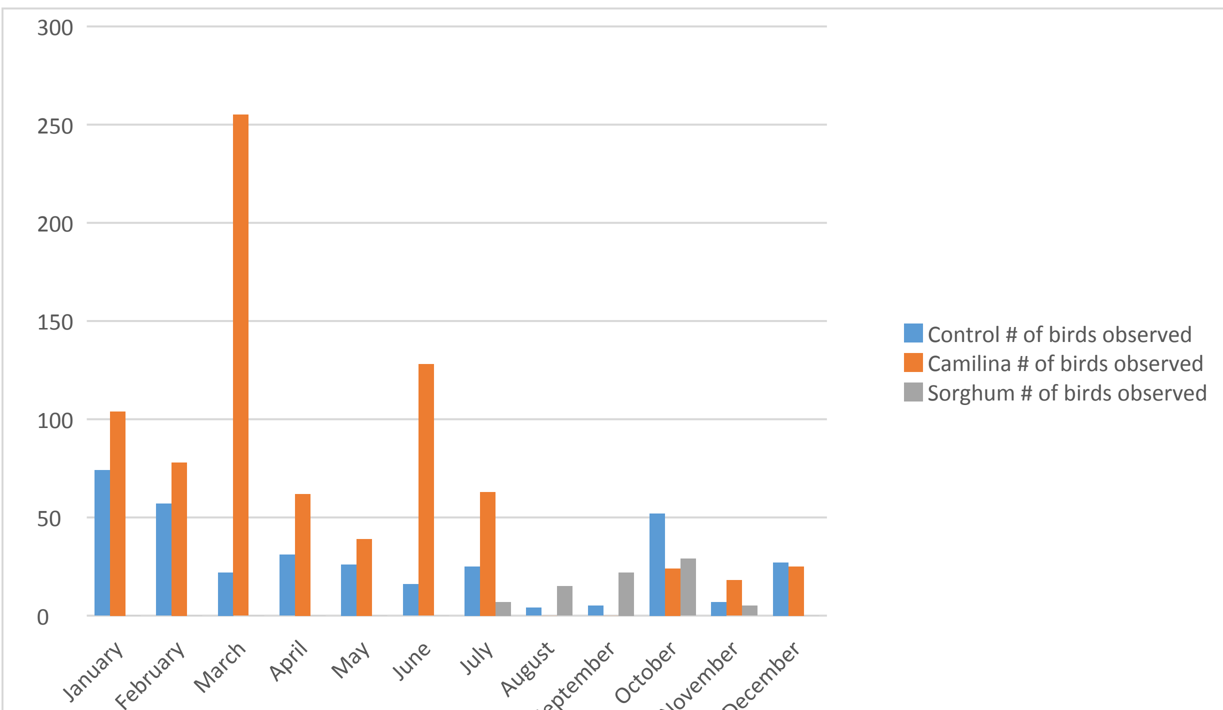


Figure 9. Total number of birds per month at Johnston County Airport, NC (Oct 2014 - July 2016)

Person County Airport-Transect survey data was collected from October 2014 through July 2016 as part of Phase I. A total of 125 surveys were conducted at both the control and treatment plots (Table 8). During these surveys, a total of 30 bird species were observed using the treatment plot when it was in the camelina growth phase and 15 species were observed while it was in the sorghum phase of growth. A total of 20 birds species were observed in the control plot. We also documented surveys in which no birds were observed. A total of 97 surveys were conducted at the treatment plot in which no species were recorded and a total of 121 surveys recorded no species in the control plot.

Table 8. Bird Observations at Person County Airport, October 2014 to July 2016

	Camelina (102 s		urveys)
# of Species	30	20	15
Total # observed	1003	494	1206
Mean # observed	3.6	1.6	14.5
# surveys no species	88	121	9

	Camelina (200 surveys)	Control (200 surveys)
# of Species	32	15
Total # observed	1,669	184
Mean # observed	8.3	0.9
# surveys no species	33	138

Bird observations at Person County Airport resulted in more birds being observed at the treatment plot during 11 of the monthly survey periods (Figure 10). Most notably large flocks of brown-headed cowbirds and red-winged black birds were observed when the treatment plot was in the sorghum phase of growth in September and October. During these months, a total of 442 brown-headed cowbirds were observed with a mean flock size of 14.4 birds in September and 54.5 in October. At total of 587 red-winged black birds were observed with a mean flock size of 23 birds in September and 141 in October. Higher numbers of American goldfinches also were recorded during these months in the treatment plot. During the November period, brown-headed cowbirds were still being recorded in large numbers at the treatment plot. A total of 182 birds with a mean flock size of 36.4 were recorded. A higher number of bird observations in the treatment plot during the March period were a result of increased American robin observations. A total of 123 birds were observed with a mean flock size of 30.8.

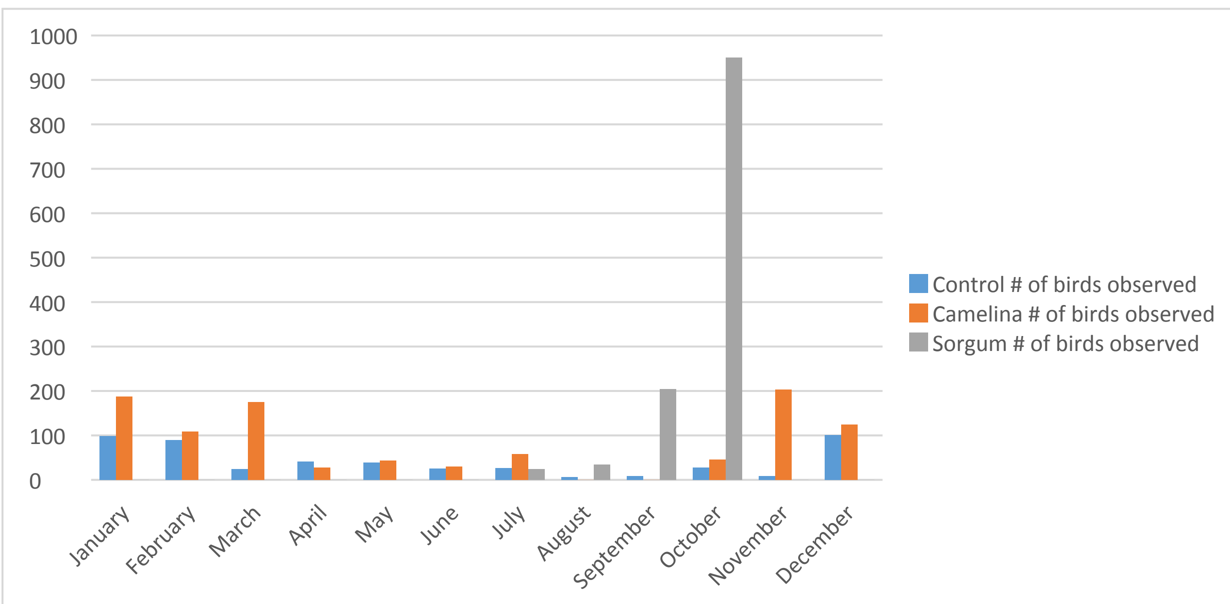


Figure 10. Total number of birds per month at Person County Airport, NC (Oct 2014 - July 2016)

As part of Phase II, transect survey data was collected from April 2018 to October 2019 at the Person County Airport. A total of 400 surveys were conducted at both the control and treatment plots (Table 9). During these surveys, a total of 32 bird species were observed in the treatment plot, whereas a total of 15 bird species were observed in the control plot. Similar to other airports locations there were surveys documented in which no birds were observed. A total of 33 surveys were conducted at the treatment plot in which no species were recorded and a total of 138 surveys recorded no species in the control plot.

Table 9. Bird Observations at Person County Airport, April 2018 - October 2019

Bird observations at Person County Airport resulted in more birds being observed at the treatment plot during all monthly survey periods (Figure 11). During the February, March, and April survey periods, Eastern bluebirds, killdeer, and savannah sparrows were recorded in large numbers in the treatment plot. During the month of September, mourning doves, Eastern meadowlarks, and European starlings were present in the treatment plot in large numbers. Overall, bird use of the control plot was relatively low. Eastern bluebirds and Eastern meadowlarks were the most frequently observed birds in the control plot.

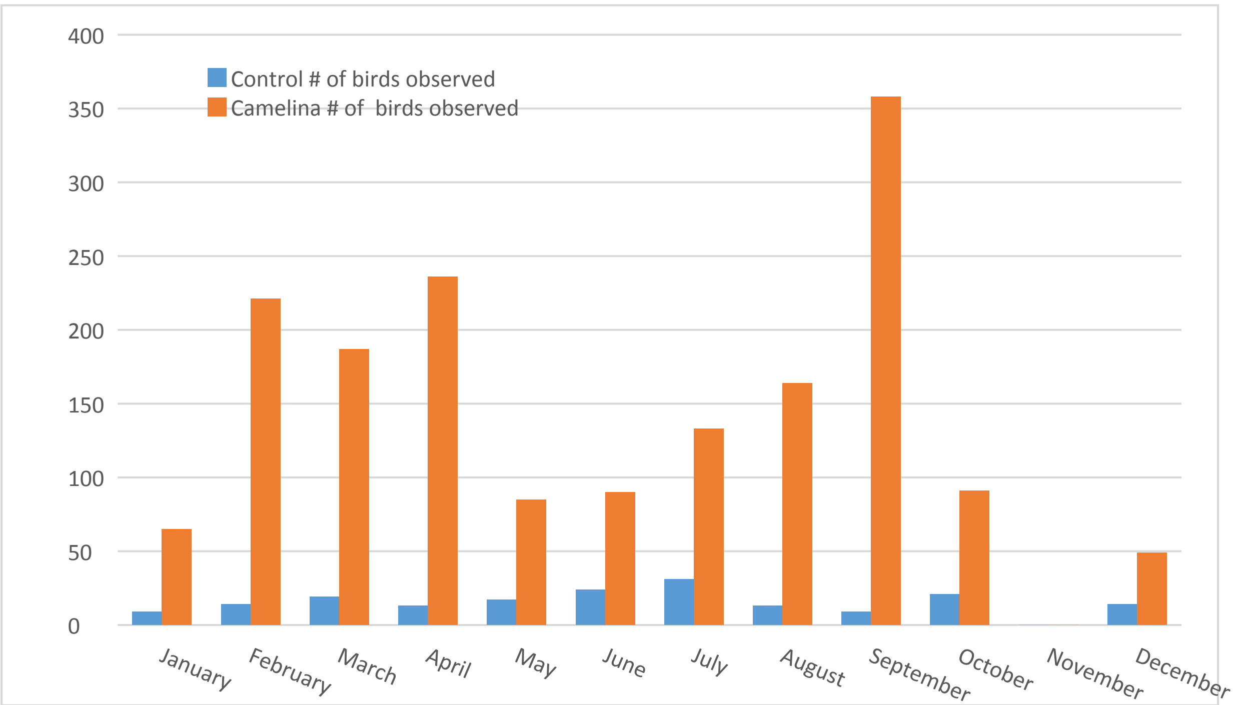


Figure 11. Total number of birds observed per month at Person County Airport, NC (April 2018 - October 2019)


Figure 12. Duplin County Airport treatment and control plots (April 2018 – October 2019)

Duplin County Airport-Transect survey data at this airport, initiated in Phase II, was collected from April 2018 through October 2019. Two treatment plots were established at Duplin County Airport as a result of the availability of space with the recently cleared area and the decision to keep survey plots close to the same acreage. Plot 1 (which included transects DPL1 and DPL2) was approximately 10.2 acres in size. Plot 2 (which included transects DPL3 and DPL4) was approximately 7.2 acres (Figure 12).

A total of 638 surveys were conducted at both the control and treatment plots (Table 10). During these surveys, a total of 30 bird species were observed using the treatment plots, whereas a total of 26 bird species were observed in the control plot. Surveys were also documented at Duplin County Airport where no birds were observed. A total of 153 surveys were conducted at the treatment plots in which no species were recorded and a total of 38 surveys recorded no species in the control plot.

Table 10. Bird Observation at Duplin County Airport, April 2018 - October 2019

	Camelina (432 surveys)	Control (216 surveys)
# of Species	30	26
Total # observed	754	969
Mean # observed	1.7	4.5
# surveys no species	153	38

Bird observations at Duplin County Airport found more birds being observed in the treatment plots during the August survey period (Figure 13). During the June, July, and August survey months, a significant increase in bird observations occurred in the treatment plot. This was a result of an increase in observations of barn swallows, red-winged blackbirds, and savannah sparrows. In contrast, a high number of killdeer were observed in the control plot during March. During the October and November periods, a noticeable increase in the control plot resulted from higher numbers of Eastern meadowlark observations.

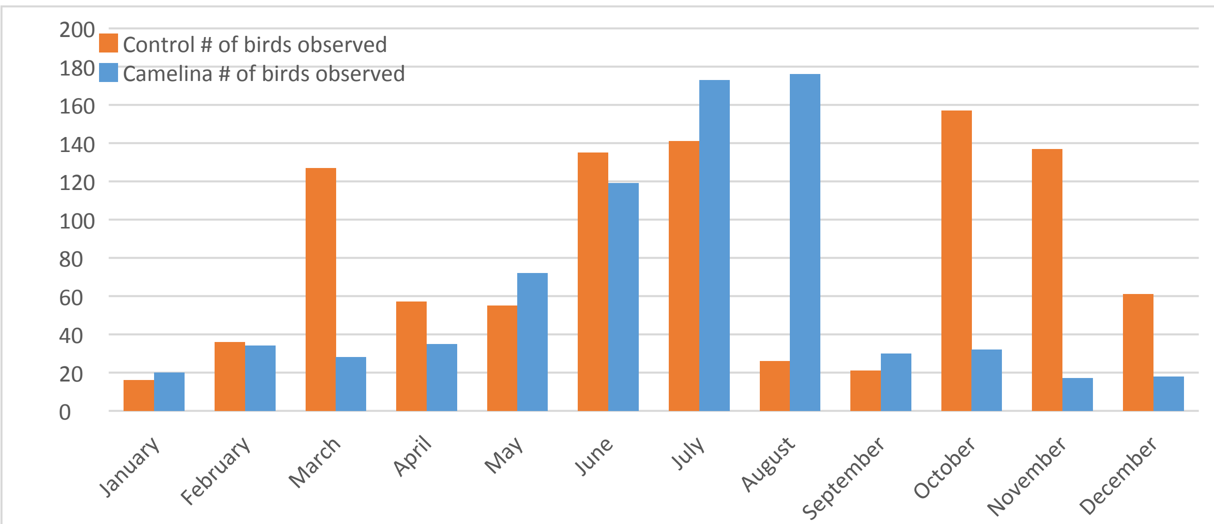


Figure 13.Total number of birds observed per month at Duplin County Airport, NC (April 2018 - October 2019)

<u>Airports Combined Phase I</u>-Observation results were recorded at the control plots and at the treatment plots based on the current crop and phase of production, camellia or sorghum (Figure 14). A total of 305 surveys were conducted at the treatment plots while it was in the camelina growth phase and 82 surveys were completed during the sorghum phase of growth. A total of 387 surveys were conducted at the control plots. A total of 44 different species of birds were recorded using the treatment plots while it was in the camelina phase and 19 species were recorded during the sorghum phase of growth. A total of 37 different species were recorded at the control plots. Treatment plots recorded higher total numbers of birds observed during both phases of growth than the control plots. A total of 2,528 birds were observed in the treatment plots during the camelina phase and 1,380 during the sorghum phase. Combined, the treatment plots resulted in a total of 3,908 birds observed and a total of 1,374 birds for the control plots. A number of surveys were made that no birds were recorded. A total of 124 surveys resulted in no birds observed at the treatment plots during the camelina phase of growth and 26 surveys during the sorghum phase. A total of 150 surveys resulted in no birds being observed total at the treatment plots. A total of 178 surveys resulted in no birds observed at the control plots.

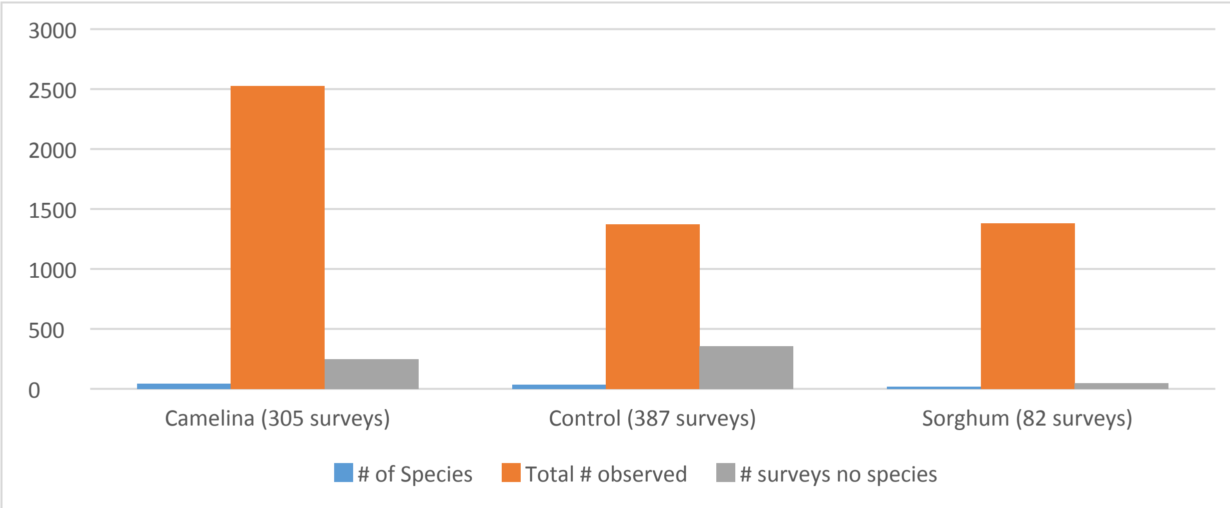


Figure 14. Plot observation results at all airports combined (October 2014 - July 2016)

A total of 44 species were recorded using the treatment plots during the camelina phase of growth. A list of species was developed based upon the most common species observed (Table 11). The most notable species hazardous to aviation included Eastern meadowlarks, European starlings, American robins, mourning doves and brown-headed cowbirds. The highest number of birds observed by species was the Eastern meadowlark with a total of 660 being observed. Mourning doves were recorded on 89 occasions and a total of 474 were documented. Brown-headed cowbirds were recorded with a mean flock size of 26.7 birds per observation.

A total of 19 species were recorded using the treatment plots during the sorghum phase of growth and a list of species was developed based upon the most common species observed with management of that crop (Table 12). The most notable species hazardous to aviation included red-winged blackbirds and brown-headed cowbirds. Red-winged blackbirds were recorded on 6 occasions with a mean of 100.3 birds per observation. A total of 602 red-winged blackbirds were recorded. Brown-headed cowbirds were recorded on 14 occasions with a mean of 31.6 birds per observation.

Table 11. List of common bird species recorded during 305 surveys at the treatment plots during the camelina phase of growth (October 2014 –July 2016)

	Number of times observed	Total number observed	Mean number per observation	Maximum observed at one time
Eastern meadowlark	208	660	3.2	30
mourning dove	89	474	5.3	40
northern mockingbird	41	42	1	2
American crow	28	76	2.7	11
European starling	25	203	8.1	30
Eastern bluebird	19	47	2.5	8
American robin	16	206	12.9	80
savannah sparrow	15	27	1.8	3
killdeer	12	32	2.7	12
brown-headed cowbird	17	454	26.7	79
Other		307	N/A	N/A

Table 12. List of common bird species recorded during 82 surveys at the treatment plots during the sorghum phase of growth (October 2014 –July 2016)

	Number of times observed	Total number observed	Mean number per observation	Maximum observed at one time
Eastern meadowlark	52	94	1.8	6
mourning dove	32	74	2.3	11
brown-headed cowbird	14	442	31.6	80
American goldfinch	12	83	6.9	24
Northern mockingbird	10	13	1.3	3
red-winged blackbird	6	602	100.3	280
American crow	7	23	3.3	5
European starling	1	1	1	1
Other	N/A	48	N/A	N/A

A total of 37 species were recorded using the control plots. A list of species was developed based upon the most common species observed (Table 13). The most notable species hazardous to aviation included Eastern meadowlark, Northern harriers and turkey vultures. Eastern meadowlarks were observed on 235 occasions and a total of 600 were observed. Northern harriers were observed on 20 occasions. Turkey vultures were documented at the control plots on 17 occasions and a total of 23 were observed.

Table 13. List of common bird species recorded during 387 surveys at the control plots (October 2014 –July 2016)

	Number of times observed	Total number observed	Mean number per observation	Maximum observed at one time
Eastern meadowlark	235	600	2.6	28
savannah sparrow	45	86	1.9	6
Wilsons snipe	38	79	2.1	9
Northern harrier	20	22	1.1	3
song sparrow	32	47	1.5	4
turkey vulture	17	23	1.4	3
unknown sparrow	17	19	1.1	2
Brown-headed cowbird	1	2	2	2
European starling	6	34	5.7	16
Other	N/A	462	N/A	N/A

<u>Mammals Phase I</u>-We conducted surveys for white-tailed deer and other mammal use of control and test plots one time each month starting approximately 30 minutes after sundown during Phase I. A total of 58 surveys were conducted at the treatment plots during the camelina phase of growth and 10 surveys were conducted during the sorghum phase. A total of 67 surveys were conducted at the control plots. A total of 69 deer were observed using the treatment plots and 12 were observed using the control plots.

<u>Airports Combined Phase II-</u> Observation results for phase II were recorded at the control plots and at the treatment plots (Figure 15). A total of 698 surveys were conducted for treatment plots, whereas a total of 482 surveys were conducted for control plots. A total of 41 different species of birds were recorded using the treatment plots, whereas a total of 34 different species was recorded at the control plots. The treatment plots resulted in higher total numbers of birds observed than the control plots. A total of 2,630 birds were observed in the treatment plots and a total of 1,350 birds were recorded in the control plots. For surveys where no birds were recorded, a total of 206 surveys resulted in no birds observed for treatment plots and a total of 187 surveys resulted in no birds observed in the control plots.

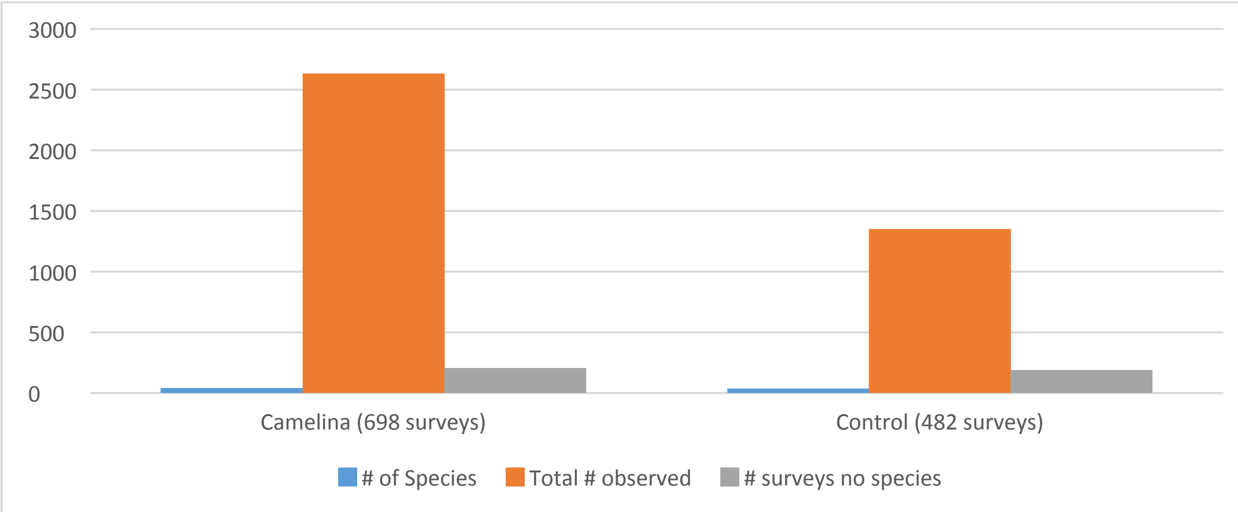


Figure 15. Plot observation results at all airports combined (April 2018 - October 2019)

Forty-one total species was recorded using the treatment plots. The most common species observed during Phase II in the treatment and control plots are listed in Table 14 and 15, respectively. The most notable species hazardous to aviation included mourning doves, European starlings, and Eastern meadowlarks in treatment plots, with the mourning dove recording the highest number of birds observed by these species (347 total observations). European starlings were recorded on 24 occasions (157 individual birds) and Eastern meadowlarks were recorded on 58 occasions (138 individual birds). A total of 34 species were recorded in the control plots. The most notable species hazardous to aviation was the Eastern meadowlark. Eastern meadowlarks were observed on 408 occasions with 711 total birds.

Table 14. List of common bird species recorded during 698 surveys in treatment plots (April 2018 – October 2019)

	Number of times observed	Total number observed	Mean number per observation	Maximum observed at one time
savannah sparrow	109	630	5.8	40
mourning dove	73	347	4.8	76
killdeer	80	243	3.0	14
European starling	24	157	6.5	33
red-winged blackbird	95	150	1.6	10
Eastern meadowlark	58	138	2.4	19
horned lark	48	103	2.1	12
barn swallow	32	103	3.2	27
American crow	50	97	1.9	6
Other		662	N/A	N/A

Table 15. List of common bird species recorded during 482 surveys in control plots (April 2018 – October 2019)

	Number of times observed	Total number observed	Mean number per observation	Maximum observed at one time
Eastern meadowlark	408	711	1.7	38
killdeer	36	145	4.0	88
savannah sparrow	64	93	1.5	6
purple martin	35	87	2.5	8
barn swallow	33	73	2.2	25
Eastern bluebird	24	56	2.3	10
American crow	15	53	3.5	11
Other		132	N/A	N/A

Mammals Phase II-We conducted surveys for white-tailed deer and other mammal use of control and test plots one time each month starting approximately 30 minutes after sundown. A total of 69 mammalian surveys were conducted at the treatment plots. A total of 50 surveys were conducted for the control plots. A total of 21 deer were observed in treatment plots, whereas 5 were observed in the control plots.

Enterprise Budgets

The following crop enterprise budgets have been developed to estimate the expected costs and potential revenue associated with the production of camelina or grain sorghum on marginal spaces including regional airports. Production methods investigated and presented represent typical field activities for crop production in the southeast U.S. but specifically North Carolina. However, actual production values will vary due to management preferences, and production output due to climatic conditions. These budgets represent cost and return comparisons as a decision making tool related to the production of camelina and grain sorghum and should be regarded only as a guide or starting point for individual airports and other stakeholders for developing budgets that better represent their production practices and capabilities, soils, and specific

Table 16. Budget Summary of Single Crop Tilled and No-till Camelina Production

Camelina - Single Cropped, Tilled

		Expenses			Gross		Net Profit	
		Implement	Tractor	Total	Revenue	Expenses		
Acres	Tractor Hours Req'd	$/ac	$/ac	$/ac	$	$	$	$/ac
5	9	$ 375.00	$ 119.71	$494.71	$ 1,515.80	$ 3,148.82	$ (1,633.01)	$ (326.60)
10	17	$ 187.80	$ 67.56	$255.36	$ 3,031.60	$ 3,896.67	$ (865.07)	$ (86.51)
15	25	$ 125.60	$ 50.50	$176.10	$ 4,547.40	$ 4,656.13	$ (108.72)	$ (7.25)
20	33	$ 94.45	$ 41.97	$136.42	$ 6,063.20	$ 5,414.59	$ 648.62	$ 32.43
25	42	$ 75.88	$ 36.85	$112.73	$ 7,579.01	$ 6,176.04	$ 1,402.96	$ 56.12
30	50	$ 63.50	$ 33.44	$ 96.94	$ 9,094.81	$ 6,937.50	$ 2,157.30	$ 71.91
35	58	$ 54.66	$ 31.00	$ 85.66	$ 10,610.61	$ 7,698.96	$ 2,911.65	$ 83.19
40	67	$ 48.08	$ 29.18	$ 77.25	$ 12,126.41	$ 8,462.42	$ 3,663.99	$ 91.60
45	75	$ 43.36	$ 27.75	$ 71.11	$ 13,642.21	$ 9,243.88	$ 4,398.33	$ 97.74
50	83	$ 38.88	$ 26.62	$ 65.50	$ 15,158.01	$ 9,990.34	$ 5,167.67	$ 103.35
55	92	$ 35.55	$ 25.69	$ 61.23	$ 16,673.81	$10,754.80	$ 5,919.01	$ 107.62
60	100	$ 32.78	$ 24.91	$ 57.69	$ 18,189.61	$11,520.26	$ 6,669.36	$ 111.16
65	108	$ 30.48	$ 24.25	$ 54.73	$ 19,705.41	$12,287.71	$ 7,417.70	$ 114.12
70	117	$ 28.50	$ 23.69	$ 52.19	$ 21,221.21	$13,055.17	$ 8,166.04	$ 116.66
75	125	$ 26.81	$ 23.21	$ 50.02	$ 22,737.02	$13,824.63	$ 8,912.38	$ 118.83
80	133	$ 25.31	$ 22.78	$ 48.09	$ 24,252.82	$14,592.09	$ 9,660.73	$ 120.76
85	142	$ 24.02	$ 22.40	$ 46.43	$ 25,768.62	$15,362.55	$10,406.07	$ 122.42
90	150	$ 22.87	$ 22.07	$ 44.93	$ 27,284.42	$16,132.01	$11,152.41	$ 123.92
95	158	$ 21.85	$ 21.77	$ 43.62	$ 28,800.22	$16,903.47	$11,896.75	$ 125.23
100	167	$ 20.93	$ 21.50	$ 42.43	$ 30,316.02	$17,673.93	$12,642.10	$ 126.42
105	175	$ 20.10	$ 21.26	$ 41.36	$ 31,831.82	$18,445.38	$13,386.44	$ 127.49
110	183	$ 19.37	$ 21.03	$ 40.41	$ 33,347.62	$19,218.84	$14,128.78	$ 128.44
115	192	$ 18.71	$ 20.83	$ 39.54	$ 34,863.42	$19,993.30	$14,870.12	$ 129.31
120	200	$ 18.09	$ 20.65	$ 38.74	$ 36,379.22	$20,765.76	$15,613.46	$ 130.11
125	208	$ 17.54	$ 20.48	$ 38.01	$ 37,895.03	$21,540.22	$16,354.81	$ 130.84
130	217	$ 17.03	$ 20.32	$ 37.35	$ 39,410.83	$22,315.68	$17,095.15	$ 131.50
135	225	$ 16.56	$ 20.17	$ 36.74	$ 40,926.63	$23,091.14	$17,835.49	$ 132.11
140	233	$ 16.15	$ 20.04	$ 36.19	$ 42,442.43	$23,869.60	$18,572.83	$ 132.66
145	242	$ 15.75	$ 19.91	$ 35.66	$ 43,958.23	$24,646.05	$19,312.18	$ 133.19
150	250	$ 15.39	$ 19.79	$ 35.19	$ 45,474.03	$25,424.51	$20,049.52	$ 133.66

Camelina, No-Till		**10 ac**		
Estimated Yield		*2500 lbs/ac*		
	Unit	Cost/Unit	Quantity	Total Cost
Fixed and Variable Costs				
Seed	LBS	$ 2.28	12	$ 273.60
Herbicides				
Glyphosate	OZ	$ 0.25	42	$ 105.00
Poast	OZ	$ 0.86	20	$ 172.00
Fertilizer				
17-17-17-5	LBS	$ 0.21	150	$ 312.00
Lime	TON	$ 35.00	0.15	$ 52.50
Machinery				
Tractor (75hp)	Acre	$ 57.07	1	$ 570.70
No-Till Seed Drill (8')	Acre	$ 58.50	1	$ 585.00
Pull Type Fertilizer Spreader	Acre	$ 19.50	1	$ 195.00
3pt. Sprayer	Acre	$ 47.30	1	$ 473.00
Labor				
All operations	HRS	$ 7.50	7	$ 52.50
Custom Harvesting (10' grain header)	LBS	$ 0.012	2500	$ 300.00
Total Costs				$ 3,091.30
Gross Receipts				
Camelina				
Seed	LBS/Acre	$ 0.12	2500	$ 3,031.60
Oil	LBS/Acre	$ 0.22	875	$ 1,950.39
Meal	LBS/Acre	$ 0.08	1625	$ 1,312.42
Total Receipts (Seed Only)				$ 3,031.60
Total Receipts (Oil and Meal Only)				$ 3,262.81
Net Profit (Seed Only)				**$ (59.70)**
Net Profit (Oil and Meal Only)				**$ 171.51**

Methods employed in developing these enterprise budgets include actual input prices that were directly available from suppliers, vendors, and other sources during the production of camelina and sorghum on NC regional airports from 2014-2019, and for cover crop production from 2018-2019. Similarly, equipment costs, including ownership, repair and maintenance, were estimated from engineering formulas developed by the American Society of Agricultural and Biological Engineers for new equipment (ASABE, 2005; ASABE, 2006; ASABE, 2011; Edwards, 2015; Givan, 1991; Lazarus and Selley, 2002). Cost of equipment ownership is determined by method of capital recovery which estimates the amount of money that should be set aside annually to replace the value of the machinery (Kay and Edwards, 1999). Repair and maintenance for machinery in these crop enterprise budgets are represented as value estimates for full service repairs on new equipment. Estimating custom hire rates and labor wages were developed from industry contacts and current extension fact sheets (Edwards, 2015; Jansen and Wilson, 2016). Labor costs associated with wages from hired labor within these crop enterprise budgets represent time only devoted to the completion of field activities associated with the production of said crop. Equipment purchase prices are estimated based on prices referenced from online equipment brokers (e.g. tractorhouse and fastline equipment). Crop revenue is estimated based upon the expected yields for each crop under optimal growing conditions utilizing current commodity prices. Camelina commodity prices were separated into two possible revenue streams; seed only, and oil and meal. Camelina seed value is estimated at 2/3rd of current Canola prices as provided by the Canola Council of Canada and adjusted for any applicable currency exchange rates. Camelina oil yield is assumed to be between 30-35% of initial seed yield by weight with the remaining 65% representing camelina seed meal (Pilgeram et al., 2007; George et al., 2017). Grain sorghum commodity prices were established based upon actual current market prices realized by cash grain bids in the Raleigh, NC area. Seed cost for planting, and fertilizer and lime costs are all derived from actual invoices received during the 2014-2017 production of camelina and sorghum at regional airports. Fertilizer and lime rates are representative of soil requirements after year one of seed production. Remedial fertilizer and lime requirements prior to year one will vary depending on location and soil condition. All enterprise budgets assume that grain harvesting operations for each crop will be contracted at $0.60/bu. Cost of herbicides were estimated based on purchase prices realized during the 2014-2017 cropping seasons in conjunction with the University of Nebraska – Lincoln fact sheet EC130 (University of Nebraska – Lincoln, 2017).

Enterprise budgets (Appendix A, Table 16) summaries include two tillage systems (e.g. conventional tillage, and no-tillage), and two cropping systems (e.g. single crop, and double crop). For single crop systems both camelina and grain sorghum were evaluated independently. For double crop systems a camelina into sorghum, and camelina into cover crop practice were evaluated. Individual unit operations for all tillage/cropping systems are outlined below (Table 17). Enterprise budgets have been generated illustrating the cost of production and potential profit for custom hiring all production tasks for both grain sorghum and camelina (Appendix A). Fixed costs in all enterprise budgets assume a ten acre operation resulting in a seemingly high cost per acre for each piece of machinery. These costs would decrease as total acres in production increased as shown in Table 16. Remaining global assumptions for each simulation (Appendices A) are outlined in the enterprise budget and simulation assumptions table (Table 18) and output for all simulations are shown in Figure 16.

Table 17. Unit Operations of tillage and cropping systems

Tillage and Cropping System Practices
Single Crop Tilled Operations Passes: 2 disk, 1 F/C, 2 fert. spreader, 1 drill, 2 herbicide
Double Crop Tilled Operations Passes: 4 disk, 2 F/C, 2 fert. spreader, 2 drill, 4 herbicide
Single Crop No-Till Operations Passes: 2 fert. spreader, 1 drill, 3 herbicide
Double Crop No-Till Operations Passes: 2 fert. spreader, 2 drill, 5 herbicide
Camelina/Cover No-Till Operations Passes: 1 fert. spreader, 2 drill, 2 herbicide

Table 18. Budget and Simulation Assumptions

Enterprise Budget and Simulation Assumptions	
Camelina	
Camelina Test weight (lb/bu)	50
Camelina Seeding Rate (lb/ac)	12
Camelina Seed Cost ($/lb)	$ 2.28
Camelina Germination Rate (%)	92%
Camelina Seed Yield (bu/ac)	50
Camelina Seed Sale Price ($/bu)	$ 6.06
Camelina Oil Yield (lb/ac)	875
Camelina Oil Sale Price ($)	$ 0.22
Camelina Meal Yield (lb/ac)	1625
Camelina Meal Sale Price ($)	$ 0.08
Fertilizer Rate (lb/ac)	150
Fertilizer Cost ($/lb)	$ 0.21
Lime Rate (lb/ac)	300
Lime Cost ($/lb)	$0.0175
Sorghum	
Sorghum Seeding Rate (lb/ac)	9
Sorghum Seed Cost ($/lb)	$ 2.04
Sorghum Germination Rate (%)	0.85
Sorghum Yield (bu/ac)	80
Sorghum Sale Price ($/bu)	3.86
Fertilizer Rate (lb/ac)	150
Fertilizer Cost ($/lb)	$ 0.21
Lime Rate (lb/ac)	300
Lime Cost ($/lb)	$0.0175
Cover Crop	
5 way mix ($/ac)	$ 30.00
Other	
Labor ($/hr)	$ 7.50
Exchange Rate (09/07/2019): 1 CAD = 0.76 USD	
Tractor	
Tractor Remaining Value (RV) set for 400 ac/yr usage	0.2
Current Hours	0
Interest Rate	0%
Fuel Cost	2.59
Capital Recovery Factor	0.08
End of Life Repair %	0.11
***Machinery** - Make, Model (Purchase Price, Lifespan, Rate)*	
NewHolland, T4.75 ($44,500, 20yrs)	
Great Plains, 3P806NT No-Till Seed Drill ($18000, 20yrs, 5ac/hr)	
Adams, Fert. Spreader ($5995, 20yrs, 10ac/hr)	
Cropcare, 3pt Sprayer ($14500, 20yrs, 10ac/hr)	
Athens, Tandem Disk ($10,500, 20yrs, 3ac/hr)	
Unverferth, Field Cultivator (F/C) ($3350, 20yrs, 5ac/hr)	
Holescher, Roller ($3500, 20yrs, 5ac/hr)	

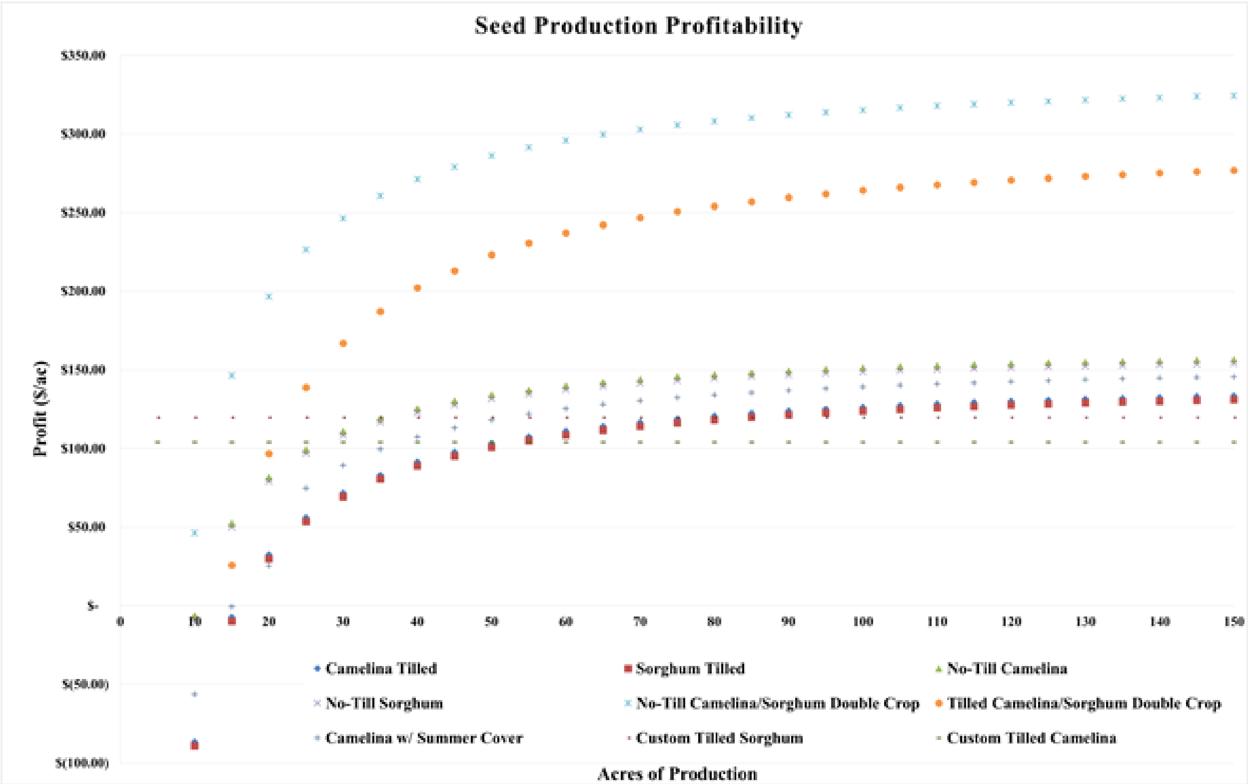


Figure 16. Summary of profits and breakeven points for different cropping systems and tillage practice scenarios considered for camelina and sorghum grown on airports

Given these assumptions break-even acreage for camelina and grain sorghum utilizing a single cropped conventionally tilled operation is approximately 20 acres. No-till break-even acreage for both single cropped camelina and grain sorghum, conventionally tilled double cropped camelina into grain sorghum, and no-till camelina with cover crop can be achieved at approximately 15 acres of production. At 10 acres of production no-till double cropped camelina into grain sorghum is profitable.

Potential Markets

Crops produced on airport space can potentially be sold into conventional markets or used for biofuel production to offset fuel used by the airport. In all cases, the economics are improved, versus conventional producers, by the fact that the land used for crop production does not otherwise generate revenue, and, in fact, incurs maintenance costs that would be at least partially replaced by the production practices. For instance, grain sorghum could be sold into conventional markets either to elevators or directly to livestock producers. The most recent numbers available show a statewide average yield of 60.35 bu/ac in 2012 for North Carolina (USDA NASS, 2014), although this may vary considerably with conditions. The 2016 North Carolina sorghum crop had an average price of $6.50/cwt, or approximately $3.64/bu (USDA, 2017). Year-over-year, these prices have been relatively stable since climbing rapidly between 2004 and 2006. Prices do fluctuate within the season; fortunately, as sorghum is a relatively short-maturing crop, it should be possible to plant to target the optimal harvest date, depending on what else is in rotation. On average, these data would indicate revenues of around $390/ac.

Unlike sorghum, camelina does not have established markets. However, camelina has low maintenance requirements, as it needs little fertilization and is relatively disease and pest resistant. This reduces costs, and also makes the crop particularly suitable for production at airports, where access may be restricted. Canola, to which camelina is similar, has had nationwide average prices of $16-18/cwt over the last few years (Ash and Dohlman, 2017; USDA, 2017). Camelina yields in North Carolina are probably still to be optimized, but based off recent yields of 500 lb/ac (Hernandez, 2013), this would result in theoretical revenues of $80-90/ac. Given the on-site demand that airports have for fuel to run equipment, such as tanker and maintenance trucks and tractors for mowing and other maintenance, it may be possible to convert the oil from camelina into biodiesel to blend into the fuel supply, and sell the meal for its feed value. Camelina seed has an oil content between 30 and 40% (Enjalbert and Johnson, 2011; Schillinger et al., 2014). At previous yields, this would result in 150-200 lb of oil per acre. Canola oil is currently valued at $0.35-0.40/lb (Ash and Dohlman, 2017; Canola Council of Canada, 2017). If it could be marketed at this value, the camelina oil would be worth $55.50-80/ac.

Biodiesel yields as high as 95% have been achieved from camelina oil (Wu and Leung, 2011). The biodiesel generated has a density of 7.4 lb/gal, similar to other biodiesels. This would result in a production of 20-27 gallons of biodiesel per acre. At a value of $2.30 per gallon of off-road diesel, this would be worth $47-62/ac. This process would also result in 300 – 350 lb of meal per acre. Although established markets do not exist for the meal, it may be possible to find local livestock producers willing to purchase it. For comparison purposes, recent values of canola meal (Caffrey et al., 2014) were around $0.12-0.13/lb (Ash and Dohlman, 2017; Canola Council of Canada, 2017). This valuation would result in revenues of $36-45.50/ac from meal.

Site Selection

Airports under consideration were downselected from the initial 57 prospective sites (Table 1) based on five criteria: 1) Total amount of pasture, grass, or crop land available; 2) Slopes less than 10%; 3) Production site proximity to airport runway and ease of access; 4) Soil drainage classification; and 5) Land use prior to production. To improve the likelihood of contiguous productive land space and availability for camelina production among the 57 North Carolina airports initially identified as suitable all airports with less than 100 acres of land use classified as grass and pasture land, or crop land were removed. This added criteria narrowed the potential site locations to sixteen (Table 19), including those studied in this project.

Table 19. Revised Prospective North Carolina Airports by County from 2014

County	Airport Name	Grassland and Pasture Acreage	Cropland (Acres)
Alamance	Burlington-Alamance Regional	113.4	0
Cabarrus	Concord Regional	217	0
Cleveland	Shelby Municipal	101.4	0
Currituck	Currituck County	98.3	112.3
Dare	Billy Mitchell	107.6	0
Duplin	***Duplin County***	***134.9***	***38.9***
Hyde	Hyde County	0	282.1
Johnston	***Johnston County***	***212.1***	***124.5***
Lenoir	***Kinston Jetport***	***168.4***	***9.2***
Person	***Person County***	***104.5***	***0***
Randolph	Asheboro Municipal	117.4	0
Rowan	Rowan County	108	0
Scotland	Laurinburg-Maxton	57.4	217.4
Washington	Plymouth Municipal	6.9	152.9
Wilkes	Wilkes County	210.7	0
Wilson	Wilson Industrial Air Center	142.9	20.9

Given the shallow depth of seeding needed for improved camelina emergence any site where soil displacement could either bury, expose, or transport small seed was deemed less desirable. Land slopes between 2% and 10% are typically farmed on contour as a best management practice and as slopes increase using strip cropping practices are employed. For the extent of this study strip cropping was not applicable and contour farming could not be guaranteed thus all airports and potential sites with slopes greater than 2% were discouraged and slopes above 10% were excluded from the assessment.

Suitable and safe access to the crop production area is also a requirement as equipment will enter and exit the site at various times throughout the year. The pursuit of crop production activities should not interfere with the day to day operations of the airport; therefore, all airports with direct access to potential site locations were preferred. Some relaxation of this preference is necessary, as was the case at Kinston Regional Jetport and Person County airport, where only remote access through the airport was available.

Scotland County, North Carolina (NC165)

Scotland County, North Carolina (NC165)

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
BrB	Bragg loamy sand, 1 to 4 percent slopes	460.1	100.0%
McA	McColl loam, 0 to 1 percent slopes, ponded	0.0	0.0%
Totals for Area of Interest		**460.2**	**100.0%**

For both of these airports access to the site was made possible by travelling along airport property perimeter and outside the runway safety area. As a result, direct access criteria was revised to limit prospective sites to those where runway and runway safety area crossing was not necessary. The Laurinburg-Maxton airport in Scotland County was one such example of a site that was deemed undesirable because of the location of the potential production site relative to the three runways (Figure 17).

While camelina is known for drought tolerance after successful crop establishment; during germination, emergence, and early growth stages camelina lacks seedling vigor to thrive in high soil moisture conditions. High early season soil moisture can stunt crop growth throughout the season, or growth will cease altogether and the crop will not yield. This led to filtering sites with a soil drainage classification of "well to moderately well drained".

The final criteria for site selection dealt with the physical condition of the space and prior land use. If a site had small sapling trees or heavy shrub density, lacked uniformity due to ruts or other soil surface issues, or was not being routinely mowed the site was not selected. Heavy residual biomass from infrequent mowing or a non-uniform soil surface can negatively impact camelina seed emergence and should be avoided where possible.

Figure 17. Laurinburg-Maxton Airport criteria 3 failure.

Table 20 shows a summary of available hay, pasture, or cropland for each airport using updated data from 2017 and after taking into consideration criteria 1, 2, and 3. Applying these filters considerably reduced the amount acreage potential available for crop production from the initial down selection. Once criteria for is applied for the soil drainage classification the number of applicable airports is further reduced. Table 21 shows the remaining acres for camelina production after applying the criteria 4 filter to the output of Table 20. Cropland and Hay/Pasture land are combined into one acreage value after criteria 4 was applied.

Table 20.Available Airport acreage in 2017 meeting criteria 1 through 3

		2017 Acres		
County	Airport Name	Hay/Pasture Land	Cropland	Total
Alamance	Burlington-Alamance Regional	25.58	0.00	25.58
Cabarrus	Concord Regional	123.21	0.00	123.21
Cleveland	Shelby Municipal	86.07	0.00	86.07
Currituck	Currituck County	37.58	67.61	105.19
Dare	Billy Mitchell	0.00	0.00	0.00
Duplin	Duplin County	0.00	73.83	73.83
Hyde	Hyde County	0.00	288.22	288.22
Johnston	Johnston County	134.77	53.37	188.15
Lenoir	Kinston Jetport	0.22	199.93	200.15
Person	Person County	111.86	3.78	115.64
Randolph	Asheboro Municipal	126.99	0.00	126.99
Rowan	Rowan County	82.06	0.00	82.06
Scotland	Laurinburg-Maxton	6.23	119.43	125.65
Washington	Plymouth Municipal	0.00	131.34	131.34
Wilkes	Wilkes County	80.06	0.00	80.06
Wilson	Wilson Industrial Air Center	25.13	20.02	45.15

Total		839.76	957.53

County	Airport Name	Combined Acres (2017)
Alamance	Burlington-Alamance Regional	23.47
Cabarrus	Concord Regional	120.04
Cleveland	Shelby Municipal	83.25
Currituck	Currituck County	70.43
Dare	Billy Mitchell	0.00
Duplin	Duplin County	66.25
Hyde	Hyde County	0.00
Johnston	Johnston County	145.13
Lenoir	Kinston Jetport	91.22
Person	Person County	110.90
Randolph	Asheboro Municipal	118.83
Rowan	Rowan County	80.70
Scotland	Laurinburg-Maxton	91.48
Washington	Plymouth Municipal	0.23
Wilkes	Wilkes County	72.30
Wilson	Wilson Industrial Air Center	28.93
Total		1103.15

Table 21. 2017 Available Airport acreage meeting criteria 1 through 4

Interestingly, the Billy Mitchell Airport in Dare County sits on 1200 acres, but with recent updates to land coverage and the filtering criteria there are 0 acres that could be considered for crop production purposes. Acreage at Hyde County and Plymouth Municipal airports were reduced to zero or nearly zero suitable for crop production based on the classification of surrounding soils. Burlington-Alamance Regional, Currituck County Airport, and Wilson Industrial Air Center all showed less than 30 acres as a possibility for crop production. These small acreages are also below the break-even acreage necessary to make camelina crop production practices profitable (Figure 16). Rowan County Airport should the most promise for camelina production with 490 acres of well-drained soils, concentrated in one area of the airport. Other airports that demonstrated reasonable characteristics for site feasibility based on the criteria filters included Concord Regional, Shelby Municipal, Asheboro Municipal, and Wilkes County Airport. Aerial maps, and soil and slope information for the 16 prospective airports further assessed are presented in Appendix D. In practice some of the issues encountered with spaces meeting these criteria or adjusting criteria during the project are discussed in the *marginal space considerations section* below. Duplin County, Person County, Johnston County, and Kinston Jetport were the airports that met the initial criteria during this study and aerial maps, soil type maps, and slope information for each of these sites can be found in Appendix E. Note that locations selected for study were determined prior to completing this analysis.

Research Studies

Crop production control sites (research station plots consistently used in agricultural production) were selected in areas in close proximity to the selected airport sites to mimic climate and environmental conditions while minimizing land preparation and suitability challenges. These sites also provided additional space to examine varietal differences, planting dates, seeding rates, planting methods and tillage treatment on performance of the camelina crop. Space at research stations and field labs were set aside at 1) Butner Beef Cattle Research Unit – near Person Co Airport (Durham County); 2) Central Crops Research Station – near Johnston Co Airport. (Johnston County); 3) Caswell Research Farm – near Kinston Regional (Lenoir County); and 4) Williamsdale Field Lab, Wallace, NC (Duplin County) which experiences an eastern NC climate and supports our bioenergy crop production work.

Fall 2014-Fall 2015 Variety Trial-Four different varieties of camelina were planted at the research stations (Blaine Creek, Suneson, SO-40 and SO-50) by no-till drill at a seeding rate of 7 lbs/ac between November 20th and December 8th, 2014. Camelina emergence and establishment was monitored over time. Poast was applied as a post-emergent herbicide to help manage grass weeds at the Caswell Research Farm. Poor emergence in 2014-15 and low anticipated yields resulted in no formal harvesting activities for camelina at the research stations. The Sustainable Oil varieties (SO-40 and SO-50) demonstrated the best overall performance in emergence and adaptability to the North Carolina climate experienced this past winter/spring. The Blaine Creek variety was planted at the airports based on previous yield data and ease of availability, however this variety selection may have also contributed to camelina crop production failures in NC (Winter 2014-15). The appropriate variety selection may help overcome some of the challenges in growing camelina on marginal, non-uniform landscapes, given the crop's sensitivities to soil moisture and planting depth that were realized this season. Aside from maturation issues, weeds proved problematic at the research stations. Application of Poast at the Caswell Research Farm to manage weeds prior to harvest was not as effective as anticipated. After in-field dry down, a hand harvest was completed at Caswell for the SO-50 and SO-40 varieties in July 2015. The plants collected were dried and stored for seed thrashing and separation.

Lab Study: Evaluation of Germination Rates of Seed Varieties-The four varieties of camelina being used in the project to date (Blaine Creek, Suneson, SO-40 and SO-50) were planted in incubation chambers to quantify germination rate. Initial replicates (4) of the study were placed in incubation chambers with light applied for 8 hours continuously for every 24 hour period for a total of 14 days. 240 seeds of each variety were planted per replicate. Plants were watered with a squirt bottle and soil was monitored such that moisture content remained between theoretical field capacity and wilting point at all times. Germination tests were performed in accordance with ISTA standards. Standards governed seed lot selection, seed planting rate, and number of seeds planted based on total seed lot. These standards allowed for results of sample lot to be applied and generalized to overall population.

The seed varieties performed consistently across the four replicates (Figure 18). SO-40, SO-50, and Blaine Creek proved to germinate at a rate between 88-90%. All three of these cultivars germinated within the first two days of planting. Suneson germinated slower and overall had a lower germination rate than the other varieties, averaging 80% across the four replicates. Upon completion, these replicates were placed outdoors, all of which died within 3 days of being placed outside. This may be due to shock induced by the introduction to natural light, as well as a host of other factors. Moisture content was maintained properly during this time period. Three additional treatments were completed to determine the likely cause of plant death when placed outside. For the first treatment 20 seeds of each variety were initially grown in incubation chambers and then placed outside with constant examination. The plants quickly wilted within 24 hours, showing rapid death and decay. During this 24 hour period, the plants exhibited a white hue upon the stem. This symptom coincides with the light shock hypothesis. The second treatment was planted directly in the ground in a planting area that previously produced vegetable crops. No germination occurred with direct planting by hand. Moisture was maintained at all times. The third treatment was performed with 20 seeds of each variety with germination initiated in incubation chambers and then transplanted in the ground, while monitoring water. Plants quickly wilted within 24 hours while exhibiting a whitish hue. The loss of emerged plants when placed outside or planted in the ground as well as no germination among seeds directly planted at optimal depths outdoors with close monitoring may be indicative of the sensitivity of camelina seeds to climatic conditions.

Figure 18. Germinated camelina seeds for different varieties

2016-2017 Tillage and Planting Date Study-Tillage, seeding rate and planting time studies were completed for camelina SO-50 at the Williamsdale Field Lab (Wallace, NC; Coastal Plain). These studies were designed to provide more data and improve our understanding of how planting time (late fall, late winter, early spring), tillage (till, no-till) and seed rate (8, 12, 16 lbs/ac) treatment combinations effect camelina emergence and yields as well as weed pressure on soils in a previous crop rotation. Tillage treatments included tillage and no-till and planting dates were November 2016 and March 2017. In addition to the replicated treatment study, a ~1.8 acre plot was planted in March 2017 (16 lbs/ac, drilled, 7.5" rows, conventional tillage) to observe the effects of a different field soils under the same climate and seeding rate on general camelina performance. Emergence, plant development, field conditions were recorded. Plant counts to quantify emergence and germination were completed for all treatment plots. Plants counted within a 1 m x 1 m square randomly placed in each treatment plot were determined in triplicate. Emergence in the ~1.8 acre plot was decent, on average 970,310 plants/acre. Emergence in planting time/tillage/seeding rate experimental plots was poor and the crop was quickly taken over by broadleaf weeds. Poast herbicide applications were successfully at managing the grasses but not broadleaf weed pressure. There was an issue with the planting time/tillage field selected that may be related to atrazine carryover that we needed to address. Soil moisture led to plant losses with newly emerged plants as well as developed plants after 45 days. Signs of fungal disease were also observed in May for these research plots. Plant Counts for the replicated tillage and planting date trials were between 0 and 121,406 plants/acre and averaged 55,757 plants/acre. Plant counts ranged from 941,569 to 1,684,843 plants/acre for the ~1.8 acre large plot and averaging 1,339,511 plants/acre. Due to heavy weed pressure and plant death the replicated tillage and planting date plots were not harvested. The ~1.8 acre large conventional tillage plot was harvested in June 2017 and yielded 111.25 dry lb/ac.

2017-2018 Camelina Planting Method and Planting Date Study- Seedbed, seed contact methods (cultipacking, land roller) after conventional tillage and planting date (mid-Nov 2017, late-Feb 2018) were investigated to determine if additional contact can improve camelina emergence. Planting methods included drilled and broadcast/rolled, with and without pre-plant incorporated (PPI) herbicide. Experimental treatments are presented in Table 22. Drilled plots were planted at a 14.9 lb/ac seeding rate while broadcast plots were seeded at rates ranging from 21.78 to 39.93 lb/ac. Plant counts for the March planting date and across land smoothing method ranged from 542,279 to 1,424,495 plants/acre. All the mid-November 2017 planted plots by drill had little to no emerged seed by the time of plant counts in March 2018; however, by harvest yields ranged between 11 and 49 lb/acre Table 23.

Table 22. 2018 Research Strip Plot Experimental Treatments

2018 Williamsdale White House Strip Plot Treatments

Plot ID	Treatment	Seeding Method	Planting Date	Seeding Rate (lb/ac)	Harvest Date
101	NO-PPI	Broadcast-Roll	3/5/2018	21.78	6/21/2018
102	NO-PPI	Drilled	2/28/2018	14.93	6/21/2018
103	PPI-Packer	Broadcast-Roll	2/28/2018	32.67	6/21/2018
104	PPI-Roller	Drilled	2/28/2018	14.93	6/21/2018
105	NO-PPI	Drilled	11/14/2017	14.93	6/21/2018
201	PPI-Packer	Broadcast-Roll	2/28/2018	39.93	6/21/2018
202	NO-PPI	Drilled	2/22/2018	14.93	6/21/2018
203	NO-PPI	Drilled	11/14/2017	14.93	6/21/2018
204	PPI-Roller	Drilled	2/28/2018	14.93	6/21/2018
205	NO-PPI	Broadcast-Roll	3/5/2018	29.04	6/21/2018
301	NO-PPI	Broadcast-Roll	3/5/2018	83.49	6/21/2018
302	PPI-Packer	Broadcast-Roll	2/28/2018	25.41	6/21/2018
303	NO-PPI	Drilled	2/22/2018	14.93	6/21/2018
304	NO-PPI	Drilled	11/14/2017	14.93	6/21/2018
305	PPI-Roller	Drilled	2/28/2018	14.93	6/21/2018

Yield values for the planting date study ranged from 8 to 144 dry lbs/ac with the highest values observed for the preplant incorporated broadcast spring planted plots. Field moisture ranged from 11 to 34% for the planting date study. At the Caswell research station (control site for Kinston Regional Jetport) plant counts were 918,637 plants/acre on average while harvest yields were 73.2 dry lbs/ac with a field moisture 16.4%.

Table 23. 2018 Camelina Yields from Research Station Studies

2018 Research Station Camelina Yield Summary

Location	Field	Plot ID	Stands (plant/acre)	Seeding Rate (lb/ac) Planted	Emerged	Germination Rate (%)	Dry Yield (lbs/ac)	Moisture Content (Mw)
Williamsdale	Whitehouse	HSR	2,547,498	27.54	6.37	23.1%	193.1	4.8%
		LSR	1,025,879	16.95	2.56	15.1%	170.3	4.5%
		VSR	-				169.5	5.1%
	Strip Plots	101	1,771,176	21.78	4.43	20.3%	28.4	14.9%
		102	33,724	14.93	0.08	0.6%	24.6	14.4%
		103	1,571,531	32.67	3.93	12.0%	31.5	11.4%
		104	21,583	14.93	0.05	0.4%	13.8	30.0%
		105	-	14.93	0.00	0.0%	11.8	27.0%
		201	893,007	39.93	2.23	5.6%	56.5	14.5%
		202	21,583	14.93	0.05	0.4%	40.3	16.2%
		203	-	14.93	0.00	0.0%	23.9	11.5%
		204	48,562	14.93	0.12	0.8%	28.9	34.0%
		205	503,160	29.04	1.26	4.3%	8.4	20.2%
		301	968,548	83.49	2.42	2.9%	81.9	13.1%
		302	1,246,433	25.41	3.12	12.3%	143.8	13.2%
		303	58,005	14.93	0.15	1.0%	33.3	24.1%
		304	-	14.93	0.00	0.0%	49.1	28.4%
		305	9,443	14.93	0.02	0.2%	20.2	32.9%
Caswell Research Station	Drilled	Drilled	918,637	11.50	2.30	20.0%	73.2	16.4%

Fall Cover Crop Study- In Fall 2017 hairy vetch was planted (23.4 lbs/ac, no-till drill) for rotation with camelina at Williamsdale Field Labs (Wallace, NC) to assess potential soil health benefits, input cost reductions, weed suppression and yield improvements. The SO-50 camelina rotation planting was completed in February and March 2018 under three different scenarios: 1) Direct drilled into green cover crop; 2) drilled into cover crop with chemical burndown at planting, and; 3) cover crop burndown, conventional tillage, then drilled. Plant Counts across all plots ranged from 20,234 to 299,468 plants/acre. The Fall cover crop study was not harvested because of the grass competition due in part to the lack of Poast herbicide being applied. The Fall cover crop study was not harvested because of the grass competition due in part to the lack of Poast herbicide being applied.

In August 2018, a multi-species cover crop consisting of cereal rye (70%), hairy vetch (15%) and crimson clover (15%) was planted in plots that were previously planted in camelina. Strip plots that were used for the planting date camelina study (~0.41 acres) were planted with the cover crop mix no-till with chemical burn down at planting. The fall cover crop study with camelina was continued for a second rotation with the multi-species mix (0.5 ac plots). Plots were planted no-till with chemical burn down applied at planting. One sub-plot had no-till camelina and the second sub-plot had full tillage camelina prior to this in the sequence. Weather issues with persistent rainfall and Hurricane Florence drowned and eroded emerging cover crop planted at the Williamsdale Field Lab such that effects of the cover crop mix on soil health and subsequent camelina performance were not able to be measured.

Broadcast Rate and Method Study- A broadcast planting study was initiated on a ~1.8 acre space at the Williamsdale Field Labs to assess broadcast seeding rate and seed covering method effectiveness. This study examined the effects of broadcast seeding rate (27.5 lbs/ac, 17 lbs/ac) and seed covering method (roller, field cultivator) on conventionally tilled space without preplant incorporated herbicide (No PPI). Yield results for both seed covering methods were similar. Plant counts for the low and high seeding rates were 1,025,879 and 2,547,498 plants/ac, respectively. Camelina dry yields for the low and high seeding rates were 170 lb/ac and 193 lb/ac, respectively.

FINDINGS AND CONCLUSIONS

The project assessed wildlife risks that would be associated with crop production on fields in close proximity to airport runways and provides airport managers with information regarding the costs and potential benefits of producing crops on airports which could offer supplemental income to help offset operating costs. Overall, this work helped answer questions surrounding land use, revitalizing underutilized spaces, and risk associated with wildlife from an emerging energy crop, camelina. We studied one geographic region of NC and selected four candidate airports over the course of the project with local environmental variations to establish wildlife surveys on control and planted (camelina-sorghum rotation; camelina-multi-species cover crop) plots (~7-10 acres each).

Marginal Spaces: Considerations

Project activities revealed opportunities to return fallow acreage back to and/or turning what may be labelled marginal lands into suitable soils for crop production. The time to “evolve” these type of underutilized spaces is critical to successful use for crop production. In an attempt to get the fallow spaces selected at the airport sites into more effective crop production acreage, we faced various challenges at the different locations. Multiple variables required management, including soil fertility, pH, drainage, topography, field variability, weeds, fungal pathogens, and insects. Integration of these factors with crop rotations creates challenges in defining a universal management strategy; however, with multiple growing seasons reasonable results can be achieved that offer improved performance predictability.

Previous land use can greatly influence the initial conditions that have to be addressed. The project had 4 distinct previously land use conditions. The sites at Person County Airport had not been in crop production prior to the study and continuously fallow for several years with continuous mowing. The space was mostly covered with turf with some broadleaves. The Kinston Regional site at some time in the recent past was in row crop production, primarily corn or soybeans, but at project initiation had been overgrown in brush and was only mowed at most on a quarterly schedule (pending funding). The site required bush-hogging to reveal the soil surface. The larger site at Duplin County had just been cleared of unmanaged trees and land-planed. For most purposes the space was considered undisturbed. The Johnston County Airport site was regularly maintained in turf grass, similar to a golf with low lying areas that could not effectively mowed presenting heavy weed pressure. To support a no-till planting operation for camelina and sorghum these sites required sizing and mulching of above-ground plant biomass greater than three inches to improve access to the soil surface and facilitate good seed contact.

Soil quality and fertility reflect soil type, available nutrients (macronutrients and micronutrients), pH, and organic matter present in a given field. Soil type can influence fertility requirements and management. Crops respond differently to these factors and it is important to maintain certain fertility levels to ensure desirable crop performance. The site at Person County Airport had soils that were moved from a different location of the airport during construction of the runway, leading to a larger proportion of that soil possessing subsoil characteristics (as opposed to top soil). The soil was a mix of Helena-Sedgefield (93.8%) and Vance (6.2%) sandy loams and soil textures ranging from sandy loam to clay loam. Sections of the plot at Kinston Regional Jetport showed a sandy loam texture with three distinct soil types, Pactolus loamy sand (63%), Murville fine sand (35.3%), and Pocalla Loamy sand (1.5%). Duplin County Airport had textures that included sand and loamy sand for three distinct soil types (Autryville, 71.5%; Woodington, 19.1%; and Marvyn and Gritney, 9.4%) soil type. Johnston County Airport had a soil that was common in sloped areas and was an Appling Marlboro complex. The initial pH of all the sites were slightly acidic and all lacked nutrients suitable for camelina and sorghum production (Table 24).

Table 24. Soil pH changes at Airport Locations 2015-2019

2015-2019 Airport Soil pH

	Crop Year				
Site	2015	2016	2017	2018	2019
Person Co. Airport	5.7	5.7	5.8	5.9	5.9
Kinston Jetport	5.4	5.5	5.5		
Duplin Co. Airport				5.2	5.3
Johnston Co. Airport	5.2	6.1			

Soil structure and grading relate to land capability class and impacts compaction, drainage and erosion experienced by a given location. Seed germination, root formation, and plant stability are all affected by these soil properties. Person County airport presented relatively high surface compaction, which resulted in lower infiltration rates. That in combination with poor surface drainage created areas that held considerable amounts of moisture and at times standing water. Person County also had a significant number of rocks (upwards of 160 ft^3) that ranged in size from 4 inches to 24 inches in diameter. The site at Kinston Regional Airport was relatively flat with slopes between 0-3%. Drainage ditches surrounded the field and it remained relatively well drained. This site also had considerable surface residues after removing brush by bush-hogging. Water saturation issues were mostly linked to excessive rainfall. The Duplin County Airport site had light, highly erodible, sandy soils that were susceptible to both soil and wind erosion. Areas with slopes greater than 6%, which existed along the outer edges of the plots, had considerable erosion where deep rills formed and contributed to subsurface drainage. The site at Johnston County Airport had a 1-6% slope with terraces, where the presence of the turf grass was critical to soil stability. This characteristic of the site, limited management decisions that would involve aggressive soil disruption and chemical termination of the turf. Edges of the plot at Johnston County Airport also had drainage issues with highly saturated soils, likely in areas that previously served as drainage ditches.

Field uniformity can be influenced by the presence of low and high areas randomly throughout a field, surface undulations across a field, and varying weed pressure. Normalizing these field characteristics is important to plant development and timing of emergence, herbicide applications, and harvest operations. Ultimately, lack of field uniformity negatively impacts crop yields. All of the airport sites had uniformity challenges within each plot location and across sites, related to the site considerations previously described. In summary, Person County had poor infiltration and grading for surface flow; Johnston County had surface drainage with the slope yet did not provide a good seed bed; Kinston Regional had the best seed bed post tillage and decent infiltration, yet with wet climates during crop production windows did not support crop production; Duplin County was relatively uniform within the plot, with the exception being the gradient change at the edge of plot and for certain areas the soil type.

Considering the initial state of the different sites, soil pH and fertility were the properties that could be managed across all sites for adopting a no-till planting operation. It takes time for lime addition to activate and change soil pH, requiring repeated monitoring and addition to reach a pseudo-steady state and reliable soil pH level. In some cases, sufficient micronutrients can even play a factor in crop success. The grain sorghum crop introduced at Kinston Regional Airport was more susceptible to sugarcane aphid infestation because of a lack of Mn and possibly Zn in the soil. These aphids destroyed the crop. Poor grain formation and loss of standing plants resulted in a crop that could not be harvested.

Aside from soil pH and fertility, marginality of these airport spaces, early management strategies to mitigate challenges with crop production practices and results required two other field characteristics to be addressed. Seed bed condition was most critical, particularly for camelina production. For the soils and soil surfaces at each of the airports conventional tillage operations, disking, field cultivation, and cultipacking, were initiated to improve uniformity of the seed bed. An additional operation of land rolling was also implemented in lieu of cultipacking to provide a firmer surface for application of no-till planting. Drainage and infiltration were also critical aspects that required attention. These characteristics were partially improved using tillage operations as these disturbed the soil surface and structure. Some sites would have benefited from additional grading to minimize erosion, and improve surface drainage and field uniformity within each plot. Selection of crop rotations, back to back or annual, can offer soil health benefits that support improved soil fertility, reduced soil compaction, lower risk of disease, and weed suppression. The grain sorghum rotated with the camelina helped reduce emergence of weeds, return organic matter back to the soil post-harvest, and maintain dynamic interactions between soil, crop and biological activity. The multi-species cover crop served a similar rotation purpose with the crop species having a more targeted purpose of reducing surface compaction with deeper plant root systems, nitrogen fixation to reduce needs to apply fertilizer, and introduce beneficial biological activity (e.g. insects, soil microbes). The multi-species cover crop also supported the potential to improve soil characteristics and not require routine tillage operations prior to planting. All of these management practices when introduced appropriately to a given space can help remediate "marginal" spaces into functional crop production areas.

Camelina: General NC Production and Agronomic Challenges

The diversity of North Carolina geoclimatic regions and soils present unique challenges and opportunities for the production of camelina within the state. From 2014 to 2019 attempts were made to explore the agronomic challenges associated with establishment, plant development, harvest timing and equipment, and sensitivities for camelina production for North Carolina. Camelina provides the North Carolina grower an alternative to cereal crops as a winter rotational crop, with a secondary benefit of providing greater diversification in an overall rotational system. Camelina can also be used as a short season crop with potential for revenue generation or cover crop for growers not currently engaged in winter crop production.

Crop establishment

For all regions of North Carolina examined throughout the duration of this study a shallow seed placement (1/4 inch or less) seeded, regardless of seeding method, into a clean fully tilled and firmed seedbed in late winter (e.g. late February) or early spring (e.g. late March) has proven to be most successful for consistent crop establishment and emergence. Attempts to plant in early winter or late fall for dormant seeding camelina into a cold seedbed or seeding for emergence prior to the first killing frost were made, respectively, it is not recommended. Seed germination and plant counts varied throughout the study with respect to initial planting rates however stands are best when seeding rates were above 10 lbs/acre given the low germination (<25%) rates seen infield through 2019. Camelina seed is extremely small averaging 450,000 seed/lb resulting in need for the addition of filler material (e.g. fertilizer) in some situations to achieve a uniform seeding rates and/or spread. To help provide optimal seed bed conditions in either no-till or full tillage systems a good burndown herbicide prior to planting and/or tillage is recommended followed by a Poast herbicide application in-season. Camelina, at the time of this study, has only two widely labeled herbicides for use in the United States. One herbicide, Poast, is labeled for control of grasses and can be applied post camelina plant emergence. The second herbicide, Sonalan, is labeled for both grass and broadleaf control of weeds in camelina only when applied as a PPI herbicide. As a result broadleaf weed pressure late in the cropping season cannot be effectively controlled without desiccating the crop.

In most direct seeding systems with tillage, a single pass with a disc to bury residue, followed by up to two passes with a field cultivator is recommended to level the soil surface and provide a uniform seed bed. During the first pass with a field cultivator there is the opportunity to apply an appropriately labeled pre-plant incorporated (PPI) herbicide. Following the final field cultivator pass either a cultipacker or roller can be used to provide a firm and level seedbed for the seed drill. For producers looking to forgo the cost of purchasing the seed drill the option of broadcast seeding camelina into a clean seed bed is available. This system allows the grower to utilize the same single pass disc and two pass field cultivator with PPI, but prior to any soil firming the camelina seed would be broadcast onto the soil surface. After seed broadcasting the grower should lightly till with a field cultivator or roll the seed into the soil. Investigations of establishing camelina when direct drilling into no-till seedbeds have shown that good soil to seed contact at the shallow depths without cover crop or residue hair-pinning is both difficult to achieve and paramount for successful emergence. If good seed to soil contact with complete seed furrow closure and without residue hair-pinning can be achieved the option of applying a pre-emergence contact herbicides (e.g. paraquat and glufosinate) and select systemic herbicides (e.g. 2,4-D and glyphosate) have shown promise.

Crop development

Shallow seeding camelina in the late winter or early spring encourages fast plant emergence with freshly emerged plants being seen as early as 7-10 days after planting when soil temperatures are adequate. It should be noted that higher seeding rates encourage competition between the camelina plants resulting in vigorous plant growth early in the season but discourage plant branching which could reduce overall yields. Following plant emergence and initial growth within the 45 to 60 days after planting window the plant can be expected to flower. By day 70 the plant has bolted and seed pods have formed. Generally, crop progression can be stunted or concluded in times of high precipitation or and unseasonably high daytime temperatures. While drought tolerant, it has been observed in this study that camelina will shed its leaves and even self-terminate under stress due to high soil moisture content, poor drainage, and abnormally high temperatures. However, temperatures high enough to cause sudden death in camelina have not been seen during this study until late in the growing season usually after seed set. Harvest should be anticipated around day 85 to 90 after planting given the North Carolina climates following a late winter or early spring planting and a decent growing season.

Harvest timing and equipment

Harvest times vary from mid-June to early July depending on planting date, temperature, and rainfall. One aspect of harvest timing is allowing plants and seeds to dry down naturally while standing in-field past the typical 90 days after planting interval. While this tactic is advantageous for reaching moisture contents for effective seed storage (e.g. <10% wet basis) it increases the likelihood of pod shatter due to weather events or mechanical agitation from harvest equipment prior to harvest resulting in seed dropping to out of the pod. During this study effective harvest moisture contents around 20% wet basis provided the best environment for harvesting equipment. One potential alternative to direct cutting camelina is to swath the crop at a higher moisture content then optimal for storage followed by mechanical harvest once the plants have naturally desiccated. Swathing can also help minimize the inadvertent harvested of emerged weed seed following camelina leaf shed.

Harvest equipment during this study included a modified combine with reduced cleaning system air volume. This reduction was achieved by setting the cleaning fan speed to the minimal setting and blocking off the majority of the fan inlet. Effectively choking air flow over the combine cleaning system. Combine speeds ranged from 2 mph to 5 mph depending on crop moisture and feeding conditions. The combine chaffer and shoe sieves were set most closely to manufactures initial recommendations for alfalfa seed harvest. These settings for seed with wet basis moisture contents greater than 15% provided minimal seed loss and adequate chaff separation. When harvesting seed at moisture contents less than 15% the combine cleaning system losses increased as the dry seed would blow over the sieves with the dry chaff. Combine concave and cylinder speed settings could be adjusted to provide good thrashing across the moisture content ranges encountered during this study. Combine header reel speed and position were adjusted to provide minimal necessary amount of mechanical contact between the reel and the crop with the intent to limit seed pod shattering and header loss at harvest.

Wildlife Attractiveness

To date we are not aware of any other studies aside from our work with USDA-APHIS to quantify the potential wildlife attractiveness of camelina. At the end of Phase I, survey results documented that an increased number of bird species and total birds observed occurred at the treatment plots versus the control. It was also documented that fewer surveys were conducted that resulted in no birds being observed at the treatment plots versus the control. The species of most notable concern to aviation safety are those that are large bodied and/or flock in large numbers. The treatment plots did document an increase in the number of flocking birds such as brown-headed cowbirds, European starlings, American robin and red-winged blackbirds. Mourning doves were also documented in much higher numbers at the treatment plots. Species of concern were also documented using the control plots. Turkey vultures and Northern harriers were recorded more frequently in the control plots.

With the limited sample size of airports obtaining a statistically valid understanding of the potential attraction that the production of camelina has on wildlife has been difficult in Phase I. The project can make general descriptive statistics on bird use during camelina production that show the mean number of birds observed in camelina plots was about double that of the control plots. In addition, almost six times more deer were observed in the plots with camelina or sorghum than were observed in control plots. Phase II was initiated to collect additional data points and replications to improve statistical grounding in wildlife assessments for the region. During this phase of the project, survey analysis documented that an increased number of bird species and total number of birds observed occurred at the treatment plots when compare to the control plots. The species of most notable concern to aviation safety are those that are large bodied and/or flock in large numbers and some of these species were documented in the treatment plots. This included an increase in the number of flocking birds such as Mourning Doves, Killdeer, European Starlings, and Red-winged Blackbirds. Eastern Meadowlarks were also documented at a higher mean number per observation in the treatment plots, but the overall total number of Eastern Meadowlarks observed was higher in the control plots. The Eastern Meadowlark was the most frequently documented species of concern at the control plots.

Overall with the limited sample size of only 3 airports at any given time we were unable to obtain a statistically valid understanding of the potential attraction that the production of camelina has on wildlife. We were, however, able to develop general descriptive statistics on bird use during camelina production that showed the mean number of birds observed in camelina plots was about double that of the control plots. In addition, more than 4 times more deer were observed in the treatment plots than were observed in control plots. These findings aligned similarly with our Phase I study results. These data provide a better understanding of the wildlife species that airport managers in this region may need to respond to if they use camelina as a source of revenue.

We are grateful that this project has helped us generate data and knowledge to support efforts to address additional research needs for camelina as a renewable biomass/oilseed crop; and recognize NC DOT as instrumental to development and demonstration of camelina potential in the Southeast Atlantic region.

RECOMMENDED ACTIONS

We learned a considerable amount of knowledge on how to cultivate camelina in NC, a pioneering venture for our state and southeast region, and were able to identify several opportunities to improve and develop the use of camelina as an oilseed feedstock. If desired and with the realization of market demand for camelina seed/oil, determining the cost-benefit growing camelina on airports for revenue relative to increases in wildlife activity within a safe threshold may be warranted. Aside from recording the presence of specific wildlife species, there is room to further analyze and interpret collected data to assess what is encouraging wildlife to engage the plot and what stage in the culture management practices are influencing wildlife presence. For example, mourning doves prefer bare ground for feeding and leaving crop residue/fodder in the field may show different wildlife behaviors. Additional efforts to isolate crop production activities (e.g. tillage, planting, harvest) on an airport in comparison to the crop itself would be valuable to any efforts to include use of managed airport space for farming. It would be beneficial to survey wildlife behavior at targeted airports spaces for an extended period of time at both the control and treatment site prior to crop production practices to better establish baseline differences in wildlife patterns with seasonal changes. During the duration of this study most control sites were far enough away from the camelina site that wildlife activity in each region of the airport may have been different, naturally as a result of surrounding features (woods, water). Specifically, with respect to Duplin County airport the camelina plot was surrounded by a wooded area without any fencing, unlike the control plot. This distance between the control and treatment plot was by design to ensure that there was minimal if any effect of the camelina plot on the control plot however, no long term baseline data for wildlife activity was established.

Safety was always at the heart of the inception of this research project. While project personnel were trying to identify opportunities for airport managers to generate revenue to support their daily operations, understanding the impact of these efforts on attracting wildlife safety hazards was critical. Through discussions with NC DOT Aviation, any additional wildlife presence as a result of crop production practices was deemed enough to advise against using camelina cropping systems to support airport operations. Recognizing that a camelina crop could present wildlife hazards to an airport operation, we worked closely with airport managers on plans of action once we were no longer active within our field sites. Johnston County Airport and Kinston Regional Jetport sites remained fallow over summer and winter months. In effort to mitigate any volunteer camelina emergence, we recommended that managers continue mowing the fields as part of their turf grass management. This management approach in combination with the sensitivity of camelina seed to our NC climates has proven to effective in terminating a camelina crop and eliminating volunteer camelina from emerging in our research plot studies on research stations over the last 5 years. Once the project ceased at Person County and Duplin County Airports, the same recommendation was made for site management, where sites were left fallow over the summer post-harvest and regular mowing operations were resumed. Moving forward, useful data were generated and will be available if and when a time arises for camelina to be a part of future conversations.

IMPLEMENTATION AND TECHNOLOGY TRANSFER PLAN

1. Anticipated yields of successful establishment of camelina can be fairly substantial (~1000-1500 lbs/acre). Attempts were made to identify potential end-users of the harvested seeds. The following seed and fuel companies were identified as possible contacts with the assistance of Rob Natelson and Kelly Zering (Ag Resource Economics Collaborators from related projects).
2. City of Raleigh Biofuel Production Program; Mobile Biofuel Processor. https://www.raleighnc.gov/services/content/PubUtilAdmin/Articles/BiofuelProduction.html.
3. Specialty Oils (part of Technology Crops International) http://www.techcrops.com/specialty_oils.html
4. Blue Ridge Biofuels (biodiesel producer in Asheville);Crushing at EcoComplex in Catawba County http://www.catawbacountync.gov/ecocomplex/
5. Soyatech http://www.soyatech.com/bluebook_ref/references/UScrushers.pdf
6. Whole Harvest Products LLC in Warsaw, NC (Duplin County) crushes soybeans http://www.wholeharvest.com/
7. Perdue Agribusiness in Cofield, NC https://www.perdueagribusiness.com/oilseed-crush
8. .Sustainable Oils (www.susoils.com/index.php) part of Global Clean Energy Holdings http://www.gceholdings.com/
9. Great Plains The Camelina Company https://www.camelinacompany.com/Default.aspx
10. Linnaeus http://linnaeus.net/
11. Three Farmers http://threefarmer.ca/
12. AltAir Fuels http://www.altairfuels.com/
13. Permafuels http://www.permafuels.com/
14. Renewable Energy Group (REG) http://www.regsyntheticfuels.com/

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APPENDIX A: SEED PRODUCTION DATA

Camelina - Single Cropped, Tilled

		Expenses			Gross			
		Implement	Tractor	Total	Revenue	Expenses	Net Profit	
Acres	Tractor Hours Req'd	$/ac	$/ac	$/ac	$	$	$	$/ac
5	9	$ 375.00	$ 119.71	$494.71	$ 1,515.80	$ 3,148.82	$ (1,633.01)	$ (326.60)
10	17	$ 187.80	$ 67.56	$255.36	$ 3,031.60	$ 3,896.67	$ (865.07)	$ (86.51)
15	25	$ 125.60	$ 50.50	$176.10	$ 4,547.40	$ 4,656.13	$ (108.72)	$ (7.25)
20	33	$ 94.45	$ 41.97	$136.42	$ 6,063.20	$ 5,414.59	$ 648.62	$ 32.43
25	42	$ 75.88	$ 36.85	$112.73	$ 7,579.01	$ 6,176.04	$ 1,402.96	$ 56.12
30	50	$ 63.50	$ 33.44	$ 96.94	$ 9,094.81	$ 6,937.50	$ 2,157.30	$ 71.91
35	58	$ 54.66	$ 31.00	$ 85.66	$ 10,610.61	$ 7,698.96	$ 2,911.65	$ 83.19
40	67	$ 48.08	$ 29.18	$ 77.25	$ 12,126.41	$ 8,462.42	$ 3,663.99	$ 91.60
45	75	$ 43.36	$ 27.75	$ 71.11	$ 13,642.21	$ 9,243.88	$ 4,398.33	$ 97.74
50	83	$ 38.88	$ 26.62	$ 65.50	$ 15,158.01	$ 9,990.34	$ 5,167.67	$ 103.35
55	92	$ 35.55	$ 25.69	$ 61.23	$ 16,673.81	$10,754.80	$ 5,919.01	$ 107.62
60	100	$ 32.78	$ 24.91	$ 57.69	$ 18,189.61	$11,520.26	$ 6,669.36	$ 111.16
65	108	$ 30.48	$ 24.25	$ 54.73	$ 19,705.41	$12,287.71	$ 7,417.70	$ 114.12
70	117	$ 28.50	$ 23.69	$ 52.19	$ 21,221.21	$13,055.17	$ 8,166.04	$ 116.66
75	125	$ 26.81	$ 23.21	$ 50.02	$ 22,737.02	$13,824.63	$ 8,912.38	$ 118.83
80	133	$ 25.31	$ 22.78	$ 48.09	$ 24,252.82	$14,592.09	$ 9,660.73	$ 120.76
85	142	$ 24.02	$ 22.40	$ 46.43	$ 25,768.62	$15,362.55	$10,406.07	$ 122.42
90	150	$ 22.87	$ 22.07	$ 44.93	$ 27,284.42	$16,132.01	$11,152.41	$ 123.92
95	158	$ 21.85	$ 21.77	$ 43.62	$ 28,800.22	$16,903.47	$11,896.75	$ 125.23
100	167	$ 20.93	$ 21.50	$ 42.43	$ 30,316.02	$17,673.93	$12,642.10	$ 126.42
105	175	$ 20.10	$ 21.26	$ 41.36	$ 31,831.82	$18,445.38	$13,386.44	$ 127.49
110	183	$ 19.37	$ 21.03	$ 40.41	$ 33,347.62	$19,218.84	$14,128.78	$ 128.44
115	192	$ 18.71	$ 20.83	$ 39.54	$ 34,863.42	$19,993.30	$14,870.12	$ 129.31
120	200	$ 18.09	$ 20.65	$ 38.74	$ 36,379.22	$20,765.76	$15,613.46	$ 130.11
125	208	$ 17.54	$ 20.48	$ 38.01	$ 37,895.03	$21,540.22	$16,354.81	$ 130.84
130	217	$ 17.03	$ 20.32	$ 37.35	$ 39,410.83	$22,315.68	$17,095.15	$ 131.50
135	225	$ 16.56	$ 20.17	$ 36.74	$ 40,926.63	$23,091.14	$17,835.49	$ 132.11
140	233	$ 16.15	$ 20.04	$ 36.19	$ 42,442.43	$23,869.60	$18,572.83	$ 132.66
145	242	$ 15.75	$ 19.91	$ 35.66	$ 43,958.23	$24,646.05	$19,312.18	$ 133.19
150	250	$ 15.39	$ 19.79	$ 35.19	$ 45,474.03	$25,424.51	$20,049.52	$ 133.66

Grain Sorghum - Single Cropped, Tilled

		Expenses			Gross			
		Implement	Tractor	Total	Revenue	Expenses	Net Profit	
Acres	Tractor Hours Req'd	$/ac	$/ac	$/ac	$	$	$	$/ac
5	8	$ 375.00	$ 119.71	$494.71	$ 1,544.00	$ 3,185.69	$ (1,641.69)	$ (328.34)
10	17	$ 187.80	$ 67.56	$255.36	$ 3,088.00	$ 3,977.87	$ (889.87)	$ (88.99)
15	25	$ 125.60	$ 50.50	$176.10	$ 4,632.00	$ 4,777.93	$ (145.93)	$ (9.73)
20	33	$ 94.45	$ 41.97	$136.42	$ 6,176.00	$ 5,576.99	$ 599.02	$ 29.95
25	42	$ 75.88	$ 36.85	$112.73	$ 7,720.00	$ 6,379.04	$ 1,340.96	$ 53.64
30	50	$ 63.50	$ 33.44	$ 96.94	$ 9,264.00	$ 7,181.10	$ 2,082.90	$ 69.43
35	58	$ 54.66	$ 31.00	$ 85.66	$ 10,808.00	$ 7,983.16	$ 2,824.84	$ 80.71
40	67	$ 48.08	$ 29.18	$ 77.25	$ 12,352.00	$ 8,787.22	$ 3,564.78	$ 89.12
45	75	$ 43.36	$ 27.75	$ 71.11	$ 13,896.00	$ 9,609.28	$ 4,286.72	$ 95.26
50	83	$ 38.88	$ 26.62	$ 65.50	$ 15,440.00	$10,396.34	$ 5,043.66	$ 100.87
55	92	$ 35.55	$ 25.69	$ 61.23	$ 16,984.00	$11,201.40	$ 5,782.60	$ 105.14
60	100	$ 32.78	$ 24.91	$ 57.69	$ 18,528.00	$12,007.46	$ 6,520.55	$ 108.68
65	108	$ 30.48	$ 24.25	$ 54.73	$ 20,072.00	$12,815.51	$ 7,256.49	$ 111.64
70	117	$ 28.50	$ 23.69	$ 52.19	$ 21,616.00	$13,623.57	$ 7,992.43	$ 114.18
75	125	$ 26.81	$ 23.21	$ 50.02	$ 23,160.00	$14,433.63	$ 8,726.37	$ 116.35
80	133	$ 25.31	$ 22.78	$ 48.09	$ 24,704.00	$15,241.69	$ 9,462.31	$ 118.28
85	142	$ 24.02	$ 22.40	$ 46.43	$ 26,248.00	$16,052.75	$10,195.25	$ 119.94
90	150	$ 22.87	$ 22.07	$ 44.93	$ 27,792.00	$16,862.81	$10,929.19	$ 121.44
95	158	$ 21.85	$ 21.77	$ 43.62	$ 29,336.00	$17,674.87	$11,661.13	$ 122.75
100	167	$ 20.93	$ 21.50	$ 42.43	$ 30,880.00	$18,485.93	$12,394.08	$ 123.94
105	175	$ 20.10	$ 21.26	$ 41.36	$ 32,424.00	$19,297.98	$13,126.02	$ 125.01
110	183	$ 19.37	$ 21.03	$ 40.41	$ 33,968.00	$20,112.04	$13,855.96	$ 125.96
115	192	$ 18.71	$ 20.83	$ 39.54	$ 35,512.00	$20,927.10	$14,584.90	$ 126.83
120	200	$ 18.09	$ 20.65	$ 38.74	$ 37,056.00	$21,740.16	$15,315.84	$ 127.63
125	208	$ 17.54	$ 20.48	$ 38.01	$ 38,600.00	$22,555.22	$16,044.78	$ 128.36
130	217	$ 17.03	$ 20.32	$ 37.35	$ 40,144.00	$23,371.28	$16,772.72	$ 129.02
135	225	$ 16.56	$ 20.17	$ 36.74	$ 41,688.00	$24,187.34	$17,500.66	$ 129.63
140	233	$ 16.15	$ 20.04	$ 36.19	$ 43,232.00	$25,006.40	$18,225.61	$ 130.18
145	242	$ 15.75	$ 19.91	$ 35.66	$ 44,776.00	$25,823.45	$18,952.55	$ 130.71
150	250	$ 15.39	$ 19.79	$ 35.19	$ 46,320.00	$26,642.51	$19,677.49	$ 131.18

Camelina - Single Cropped, No-Till

		Expenses			Gross			
		Implement	Tractor	Total	Revenue	Expenses	Net Profit	
Acres	Tractor Hours Req'd	$/ac	$/ac	$/ac	$	$	$	$/ac
5	4	$ 250.40	$ 108.25	$358.65	$ 1,515.80	$ 2,428.54	$ (912.74)	$ (182.55)
10	7	$ 125.30	$ 57.07	$182.37	$ 3,031.60	$ 3,094.32	$ (62.72)	$ (6.27)
15	11	$ 83.73	$ 40.01	$123.75	$ 4,547.40	$ 3,762.11	$ 785.29	$ 52.35
20	14	$ 62.95	$ 31.48	$ 94.43	$ 6,063.20	$ 4,429.90	$ 1,633.31	$ 81.67
25	18	$ 50.56	$ 26.37	$ 76.93	$ 7,579.01	$ 5,099.69	$ 2,479.32	$ 99.17
30	21	$ 42.30	$ 22.96	$ 65.26	$ 9,094.81	$ 5,769.47	$ 3,325.33	$ 110.84
35	25	$ 36.40	$ 20.52	$ 56.92	$ 10,610.61	$ 6,439.26	$ 4,171.35	$ 119.18
40	28	$ 32.00	$ 18.69	$ 50.69	$ 12,126.41	$ 7,110.05	$ 5,016.36	$ 125.41
45	32	$ 28.73	$ 17.27	$ 46.00	$ 13,642.21	$ 7,787.83	$ 5,854.37	$ 130.10
50	35	$ 25.84	$ 16.13	$ 41.97	$ 15,158.01	$ 8,451.62	$ 6,706.39	$ 134.13
55	39	$ 23.62	$ 15.20	$ 38.82	$ 16,673.81	$ 9,123.41	$ 7,550.40	$ 137.28
60	42	$ 21.77	$ 14.43	$ 36.19	$ 18,189.61	$ 9,795.20	$ 8,394.42	$ 139.91
65	46	$ 20.23	$ 13.77	$ 34.00	$ 19,705.41	$10,468.98	$ 9,236.43	$ 142.10
70	49	$ 18.90	$ 13.21	$ 32.11	$ 21,221.21	$11,141.77	$10,079.44	$ 143.99
75	53	$ 17.76	$ 12.72	$ 30.48	$ 22,737.02	$11,815.56	$10,921.46	$ 145.62
80	56	$ 16.76	$ 12.29	$ 29.06	$ 24,252.82	$12,489.34	$11,763.47	$ 147.04
85	60	$ 15.89	$ 11.92	$ 27.81	$ 25,768.62	$13,164.13	$12,604.49	$ 148.29
90	63	$ 15.12	$ 11.58	$ 26.71	$ 27,284.42	$13,838.92	$13,445.50	$ 149.39
95	67	$ 14.44	$ 11.28	$ 25.73	$ 28,800.22	$14,514.71	$14,285.51	$ 150.37
100	70	$ 13.82	$ 11.01	$ 24.83	$ 30,316.02	$15,189.49	$15,126.53	$ 151.27
105	74	$ 13.28	$ 10.77	$ 24.05	$ 31,831.82	$15,866.28	$15,965.54	$ 152.05
110	77	$ 12.78	$ 10.55	$ 23.33	$ 33,347.62	$16,543.07	$16,804.55	$ 152.77
115	81	$ 12.34	$ 10.35	$ 22.69	$ 34,863.42	$17,220.85	$17,642.57	$ 153.41
120	84	$ 11.93	$ 10.16	$ 22.09	$ 36,379.22	$17,897.64	$18,481.58	$ 154.01
125	88	$ 11.55	$ 9.99	$ 21.54	$ 37,895.03	$18,575.43	$19,319.60	$ 154.56
130	91	$ 11.22	$ 9.83	$ 21.05	$ 39,410.83	$19,254.22	$20,156.61	$ 155.05
135	95	$ 10.90	$ 9.69	$ 20.59	$ 40,926.63	$19,933.00	$20,993.62	$ 155.51
140	98	$ 10.62	$ 9.55	$ 20.17	$ 42,442.43	$20,612.79	$21,829.64	$ 155.93
145	102	$ 10.36	$ 9.43	$ 19.79	$ 43,958.23	$21,292.58	$22,665.65	$ 156.31
150	105	$ 10.12	$ 9.31	$ 19.43	$ 45,474.03	$21,973.36	$23,500.67	$ 156.67

Grain Sorglum - Single Cropped, No-Till

		Expenses			Gross			
		Implement	Tractor	Total	Revenue	Expenses	Net Profit	
Acres	Tractor Hours Req'd	$/ac	$/ac	$/ac	$	$	$	$/ac
5	4	$ 250.40	$ 108.25	$358.65	$ 1,544.00	$ 2,469.14	$ (925.14)	$ (185.03)
10	7	$ 125.30	$ 57.07	$182.37	$ 3,088.00	$ 3,175.52	$ (87.52)	$ (8.75)
15	11	$ 83.73	$ 40.01	$123.75	$ 4,632.00	$ 3,883.91	$ 748.09	$ 49.87
20	14	$ 62.95	$ 31.48	$ 94.43	$ 6,176.00	$ 4,592.30	$ 1,583.70	$ 79.19
25	18	$ 50.56	$ 26.37	$ 76.93	$ 7,720.00	$ 5,302.69	$ 2,417.31	$ 96.69
30	21	$ 42.30	$ 22.96	$ 65.26	$ 9,264.00	$ 6,013.07	$ 3,250.93	$ 108.36
35	25	$ 36.40	$ 20.52	$ 56.92	$ 10,808.00	$ 6,723.46	$ 4,084.54	$ 116.70
40	28	$ 32.00	$ 18.69	$ 50.69	$ 12,352.00	$ 7,434.85	$ 4,917.15	$ 122.93
45	32	$ 28.73	$ 17.27	$ 46.00	$ 13,896.00	$ 8,153.23	$ 5,742.77	$ 127.62
50	35	$ 25.84	$ 16.13	$ 41.97	$ 15,440.00	$ 8,857.62	$ 6,582.38	$ 131.65
55	39	$ 23.62	$ 15.20	$ 38.82	$ 16,984.00	$ 9,570.01	$ 7,413.99	$ 134.80
60	42	$ 21.77	$ 14.43	$ 36.19	$ 18,528.00	$10,282.40	$ 8,245.60	$ 137.43
65	46	$ 20.23	$ 13.77	$ 34.00	$ 20,072.00	$10,996.78	$ 9,075.22	$ 139.62
70	49	$ 18.90	$ 13.21	$ 32.11	$ 21,616.00	$11,710.17	$ 9,905.83	$ 141.51
75	53	$ 17.76	$ 12.72	$ 30.48	$ 23,160.00	$12,424.56	$10,735.44	$ 143.14
80	56	$ 16.76	$ 12.29	$ 29.06	$ 24,704.00	$13,138.94	$11,565.06	$ 144.56
85	60	$ 15.89	$ 11.92	$ 27.81	$ 26,248.00	$13,854.33	$12,393.67	$ 145.81
90	63	$ 15.12	$ 11.58	$ 26.71	$ 27,792.00	$14,569.72	$13,222.28	$ 146.91
95	67	$ 14.44	$ 11.28	$ 25.73	$ 29,336.00	$15,286.11	$14,049.89	$ 147.89
100	70	$ 13.82	$ 11.01	$ 24.83	$ 30,880.00	$16,001.49	$14,878.51	$ 148.79
105	74	$ 13.28	$ 10.77	$ 24.05	$ 32,424.00	$16,718.88	$15,705.12	$ 149.57
110	77	$ 12.78	$ 10.55	$ 23.33	$ 33,968.00	$17,436.27	$16,531.73	$ 150.29
115	81	$ 12.34	$ 10.35	$ 22.69	$ 35,512.00	$18,154.65	$17,357.35	$ 150.93
120	84	$ 11.93	$ 10.16	$ 22.09	$ 37,056.00	$18,872.04	$18,183.96	$ 151.53
125	88	$ 11.55	$ 9.99	$ 21.54	$ 38,600.00	$19,590.43	$19,009.57	$ 152.08
130	91	$ 11.22	$ 9.83	$ 21.05	$ 40,144.00	$20,309.82	$19,834.18	$ 152.57
135	95	$ 10.90	$ 9.69	$ 20.59	$ 41,688.00	$21,029.20	$20,658.80	$ 153.03
140	98	$ 10.62	$ 9.55	$ 20.17	$ 43,232.00	$21,749.59	$21,482.41	$ 153.45
145	102	$ 10.36	$ 9.43	$ 19.79	$ 44,776.00	$22,469.98	$22,306.02	$ 153.83
150	105	$ 10.12	$ 9.31	$ 19.43	$ 46,320.00	$23,191.36	$23,128.64	$ 154.19

Camelina/Grain Sorghum - Double Cropped, Tilled

		Expenses			Gross			
		Implement	Tractor	Total	Revenue	Expenses	Net Profit	
Acres	Tractor Hours Req'd	$/ac	$/ac	$/ac	$	$	$	$/ac
5	16	$ 750.00	$ 133.15	$883.15	$ 3,059.80	$ 5,765.69	$ (2,705.89)	$ (541.18)
10	31	$ 375.60	$ 81.97	$457.57	$ 6,119.60	$ 7,275.63	$ (1,156.02)	$ (115.60)
15	47	$ 251.20	$ 64.91	$316.11	$ 9,179.40	$ 8,791.57	$ 387.84	$ 25.86
20	63	$ 188.90	$ 56.39	$245.29	$ 12,239.20	$10,305.50	$ 1,933.70	$ 96.69
25	78	$ 151.76	$ 51.27	$203.03	$ 15,299.01	$11,825.44	$ 3,473.56	$ 138.94
30	94	$ 127.00	$ 47.86	$174.86	$ 18,358.81	$13,345.38	$ 5,013.43	$ 167.11
35	110	$ 109.31	$ 45.42	$154.73	$ 21,418.61	$14,865.32	$ 6,553.29	$ 187.24
40	125	$ 96.15	$ 43.59	$139.74	$ 24,478.41	$16,389.26	$ 8,089.15	$ 202.23
45	141	$ 86.71	$ 42.17	$128.88	$ 27,538.21	$17,949.20	$ 9,589.01	$ 213.09
50	157	$ 77.76	$ 41.03	$118.79	$ 30,598.01	$19,439.13	$11,158.88	$ 223.18
55	172	$ 71.09	$ 40.10	$111.19	$ 33,657.81	$20,965.07	$12,692.74	$ 230.78
60	188	$ 65.57	$ 39.33	$104.89	$ 36,717.61	$22,493.01	$14,224.60	$ 237.08
65	204	$ 60.95	$ 38.67	$ 99.62	$ 39,777.41	$24,024.95	$15,752.46	$ 242.35
70	219	$ 57.00	$ 38.11	$ 95.11	$ 42,837.21	$25,556.89	$17,280.33	$ 246.86
75	235	$ 53.63	$ 37.62	$ 91.25	$ 45,897.02	$27,092.83	$18,804.19	$ 250.72
80	251	$ 50.63	$ 37.19	$ 87.82	$ 48,956.82	$28,624.77	$20,332.05	$ 254.15
85	266	$ 48.05	$ 36.82	$ 84.87	$ 52,016.62	$30,162.70	$21,853.91	$ 257.10
90	282	$ 45.73	$ 36.48	$ 82.22	$ 55,076.42	$31,698.64	$23,377.78	$ 259.75
95	298	$ 43.71	$ 36.18	$ 79.89	$ 58,136.22	$33,238.58	$24,897.64	$ 262.08
100	313	$ 41.86	$ 35.92	$ 77.78	$ 61,196.02	$34,776.52	$26,419.50	$ 264.20
105	329	$ 40.21	$ 35.67	$ 75.88	$ 64,255.82	$36,316.46	$27,939.36	$ 266.09
110	345	$ 38.75	$ 35.45	$ 74.20	$ 67,315.62	$37,860.40	$29,455.23	$ 267.77
115	360	$ 37.43	$ 35.25	$ 72.67	$ 70,375.42	$39,406.33	$30,969.09	$ 269.30
120	376	$ 36.18	$ 35.06	$ 71.25	$ 73,435.22	$40,948.27	$32,486.95	$ 270.72
125	392	$ 35.07	$ 34.89	$ 69.96	$ 76,495.03	$42,494.21	$34,000.81	$ 272.01
130	407	$ 34.06	$ 34.73	$ 68.80	$ 79,554.83	$44,042.15	$35,512.68	$ 273.17
135	423	$ 33.13	$ 34.59	$ 67.71	$ 82,614.63	$45,590.09	$37,024.54	$ 274.26
140	439	$ 32.30	$ 34.45	$ 66.75	$ 85,674.43	$47,144.03	$38,530.40	$ 275.22
145	454	$ 31.50	$ 34.33	$ 65.83	$ 88,734.23	$48,693.97	$40,040.26	$ 276.14
150	470	$ 30.79	$ 34.21	$ 65.00	$ 91,794.03	$50,247.90	$41,546.13	$ 276.97

Camelina/Grain Sorghum - Double Cropped, No-Till

		Expenses			Gross			
		Implement	Tractor	Total	Revenue	Expenses	Net Profit	
Acres	Tractor Hours Req'd	$/ac	$/ac	$/ac	$	$	$	$/ac
5	5	$ 500.80	$ 112.18	$612.98	$ 3,059.80	$ 4,334.85	$ (1,275.04)	$ (255.01)
10	10	$ 250.60	$ 61.00	$311.60	$ 6,119.60	$ 5,655.94	$ 463.66	$ 46.37
15	15	$ 167.47	$ 43.95	$211.41	$ 9,179.40	$ 6,981.04	$ 2,198.37	$ 146.56
20	20	$ 125.90	$ 35.42	$161.32	$ 12,239.20	$ 8,306.13	$ 3,933.07	$ 196.65
25	25	$ 101.12	$ 30.30	$131.42	$ 15,299.01	$ 9,635.23	$ 5,663.78	$ 226.55
30	30	$ 84.60	$ 26.89	$111.49	$ 18,358.81	$10,964.32	$ 7,394.48	$ 246.48
35	35	$ 72.80	$ 24.45	$ 97.25	$ 21,418.61	$12,293.42	$ 9,125.19	$ 260.72
40	40	$ 64.00	$ 22.62	$ 86.62	$ 24,478.41	$13,624.51	$10,853.90	$ 271.35
45	45	$ 57.47	$ 21.20	$ 78.67	$ 27,538.21	$14,969.61	$12,568.60	$ 279.30
50	50	$ 51.68	$ 20.06	$ 71.74	$ 30,598.01	$16,286.70	$14,311.31	$ 286.23
55	55	$ 47.24	$ 19.13	$ 66.37	$ 33,657.81	$17,619.80	$16,038.01	$ 291.60
60	60	$ 43.53	$ 18.36	$ 61.89	$ 36,717.61	$18,952.89	$17,764.72	$ 296.08
65	65	$ 40.46	$ 17.70	$ 58.16	$ 39,777.41	$20,289.99	$19,487.42	$ 299.81
70	70	$ 37.80	$ 17.14	$ 54.94	$ 42,837.21	$21,625.08	$21,212.13	$ 303.03
75	75	$ 35.52	$ 16.65	$ 52.17	$ 45,897.02	$22,962.18	$22,934.84	$ 305.80
80	80	$ 33.53	$ 16.23	$ 49.75	$ 48,956.82	$24,299.27	$24,657.54	$ 308.22
85	85	$ 31.79	$ 15.85	$ 47.64	$ 52,016.62	$25,638.37	$26,378.25	$ 310.33
90	90	$ 30.24	$ 15.52	$ 45.76	$ 55,076.42	$26,977.46	$28,098.95	$ 312.21
95	95	$ 28.88	$ 15.22	$ 44.10	$ 58,136.22	$28,318.56	$29,817.66	$ 313.87
100	100	$ 27.64	$ 14.95	$ 42.59	$ 61,196.02	$29,657.66	$31,538.37	$ 315.38
105	105	$ 26.55	$ 14.70	$ 41.26	$ 64,255.82	$31,000.75	$33,255.07	$ 316.71
110	110	$ 25.56	$ 14.48	$ 40.04	$ 67,315.62	$32,343.85	$34,971.78	$ 317.93
115	115	$ 24.68	$ 14.28	$ 38.96	$ 70,375.42	$33,688.94	$36,686.48	$ 319.01
120	120	$ 23.85	$ 14.09	$ 37.94	$ 73,435.22	$35,032.04	$38,403.19	$ 320.03
125	125	$ 23.10	$ 13.92	$ 37.03	$ 76,495.03	$36,377.13	$40,117.89	$ 320.94
130	130	$ 22.43	$ 13.77	$ 36.20	$ 79,554.83	$37,724.23	$41,830.60	$ 321.77
135	135	$ 21.81	$ 13.62	$ 35.43	$ 82,614.63	$39,071.32	$43,543.31	$ 322.54
140	140	$ 21.24	$ 13.48	$ 34.73	$ 85,674.43	$40,420.42	$45,254.01	$ 323.24
145	145	$ 20.72	$ 13.36	$ 34.08	$ 88,734.23	$41,769.51	$46,964.72	$ 323.89
150	150	$ 20.24	$ 13.24	$ 33.48	$ 91,794.03	$43,120.61	$48,673.42	$ 324.49

Camelina/Cover Crop - Double Cropped, No-Till

		Expenses			Gross			
		Implement	Tractor	Total	Revenue	Expenses	Net Profit	
Acres	Tractor Hours Req'd	$/ac	$/ac	$/ac	$	$	$	$/ac
5	4	$ 335.93	$ 110.21	$446.15	$ 1,515.80	$ 2,944.78	$ (1,428.98)	$ (285.80)
10	8	$ 168.03	$ 59.04	$227.07	$ 3,031.60	$ 3,593.82	$ (562.21)	$ (56.22)
15	12	$ 112.18	$ 41.98	$154.16	$ 4,547.40	$ 4,555.02	$ (7.61)	$ (0.51)
20	16	$ 84.32	$ 33.45	$117.77	$ 6,063.20	$ 5,555.55	$ 507.66	$ 25.38
25	20	$ 67.71	$ 28.33	$ 96.04	$ 7,579.01	$ 5,708.75	$ 1,870.26	$ 74.81
30	24	$ 56.60	$ 24.92	$ 81.52	$ 9,094.81	$ 6,414.95	$ 2,679.86	$ 89.33
35	28	$ 48.70	$ 22.48	$ 71.18	$ 10,610.61	$ 7,122.15	$ 3,488.46	$ 99.67
40	32	$ 42.82	$ 20.66	$ 63.47	$ 12,126.41	$ 7,831.35	$ 4,295.06	$ 107.38
45	36	$ 38.37	$ 19.24	$ 57.61	$ 13,642.21	$ 8,546.21	$ 5,096.00	$ 113.24
50	40	$ 34.57	$ 18.10	$ 52.66	$ 15,158.01	$ 9,248.75	$ 5,909.26	$ 118.19
55	44	$ 31.61	$ 17.17	$ 48.78	$ 16,673.81	$ 9,959.94	$ 6,713.87	$ 122.07
60	48	$ 29.13	$ 16.39	$ 45.53	$ 18,189.61	$10,670.14	$ 7,519.47	$ 125.32
65	52	$ 27.09	$ 15.74	$ 42.83	$ 19,705.41	$11,384.01	$ 8,321.40	$ 128.02
70	56	$ 25.32	$ 15.17	$ 40.49	$ 21,221.21	$12,096.21	$ 9,125.00	$ 130.36
75	60	$ 23.80	$ 14.69	$ 38.49	$ 22,737.02	$12,810.08	$ 9,926.94	$ 132.36
80	64	$ 22.48	$ 14.26	$ 36.74	$ 24,252.82	$13,524.28	$10,728.54	$ 134.11
85	68	$ 21.34	$ 13.88	$ 35.22	$ 25,768.62	$14,240.14	$11,528.47	$ 135.63
90	72	$ 20.32	$ 13.55	$ 33.87	$ 27,284.42	$14,956.34	$12,328.08	$ 136.98
95	76	$ 19.42	$ 13.25	$ 32.67	$ 28,800.22	$15,673.21	$13,127.01	$ 138.18
100	80	$ 18.61	$ 12.98	$ 31.59	$ 30,316.02	$16,390.41	$13,925.61	$ 139.26
105	84	$ 17.90	$ 12.74	$ 30.64	$ 31,831.82	$17,109.27	$14,722.55	$ 140.21
110	88	$ 17.25	$ 12.52	$ 29.76	$ 33,347.62	$17,828.14	$15,519.48	$ 141.09
115	92	$ 16.67	$ 12.31	$ 28.99	$ 34,863.42	$18,549.01	$16,314.42	$ 141.86
120	96	$ 16.14	$ 12.13	$ 28.26	$ 36,379.22	$19,268.87	$17,110.35	$ 142.59
125	100	$ 15.66	$ 11.96	$ 27.62	$ 37,895.03	$19,991.07	$17,903.95	$ 143.23
130	104	$ 15.23	$ 11.80	$ 27.03	$ 39,410.83	$20,713.94	$18,696.89	$ 143.82
135	108	$ 14.83	$ 11.65	$ 26.48	$ 40,926.63	$21,436.80	$19,489.82	$ 144.37
140	112	$ 14.47	$ 11.52	$ 25.99	$ 42,442.43	$22,161.67	$20,280.76	$ 144.86
145	116	$ 14.14	$ 11.39	$ 25.53	$ 43,958.23	$22,886.54	$21,071.69	$ 145.32
150	120	$ 13.84	$ 11.27	$ 25.11	$ 45,474.03	$23,613.40	$21,860.63	$ 145.74

APPENDIX B: CROP PRODUCTION SCENARIO ENTERPRISE BUDGETS

Camelina Custom, Conventional Till		**10 ac**		
Estimated Yield		*2500 lb/ac*		
	Unit	Cost/Unit	Quantity	Total Cost
Variable Costs				
Custom Small Grain Rate	Acre	$101.95	10	$ 1,019.50
Seed	LBS	$ 2.28	12	$ 273.60
Fertilizer				
Fertilizer	LBS	$ 0.21	150	$ 312.00
Lime	LBS	$ 0.02	300	$ 52.50
Herbicide				
Glyphosate	OZ	$ 0.25	42	$ 105.00
Poast	OZ	$ 0.86	20	$ 172.00
Labor				
Custom Fertilizer Application	Acre	$ 5.40	10	$ 54.00
Total Costs				$ 1,988.60
Gross Receipts				
Camelina				
Seed	LBS	$ 0.12	2500	$ 3,031.60
Oil	LBS	$ 0.22	875	$ 1,950.39
Meal	LBS	$ 0.08	1625	$ 1,312.42
Total Receipts (Seed Only)				$ 3,031.60
Total Receipts (Oil and Meal Only)				$ 3,262.81
Net Profit (Seed Only)				**$1,043.00**
Net Profit (Oil and Meal Only)				**$1,274.21**

Grain Sorghum Custom, Conventional Till		**10 acre**		
Estimated Yield		*80 bu/ac*		
	Unit	Cost/Unit	Quantity	Total Cost
Variable Costs				
Custom Small Grain Rate	Acre	$101.95	10	$ 1,019.50
Seed	LBS	$ 2.04	9	$ 183.60
Fertilizer				
Fertilizer	LBS	$ 0.21	150	$ 312.00
Lime	LBS	$ 0.02	300	$ 52.50
Herbicide				
Glyphosate	OZ	$ 0.25	42	$ 105.00
S-Metolachlor	OZ	$ 1.02	16	$ 163.20
Labor				
Custom Fertilizer Application	Acre	$ 5.40	10	$ 54.00
Total Costs				$ 1,889.80
Gross Receipts				
Grain Sorghum	BU/Acre	$ 3.86	80	$ 3,088.00
Total Receipts				$ 3,088.00
Net Profit				**$1,198.20**

Camelina, Till		10 ac			
	Estimated Yield	2500 *lbs/ac*			
	Unit	Cost/Unit	Quantity	Total Cost	
Fixed and Variable Costs					
Seed	LBS	$ 2.28	12	$ 273.60	
Herbicides					
Glyphosate	OZ	$ 0.25	42	$ 105.00	
Poast	OZ	$ 0.86	20	$ 172.00	
Fertilizer					
17-17-17-5	LBS	$ 0.21	150	$ 312.00	
Lime	TON	$ 35.00	0.15	$ 52.50	
Machinery					
Tractor (75hp)	Acre	$ 67.56	1	$ 675.60	
No-Till Seed Drill (8')	Acre	$ 58.50	1	$ 585.00	
Pull Type Fertilizer Spreader	Acre	$ 19.50	1	$ 195.00	
3pt. Sprayer	Acre	$ 47.30	1	$ 473.00	
Tandem Disk	Acre	$ 37.80	1	$ 378.00	
Field Cultivator	Acre	$ 12.10	1	$ 121.00	
Roller	Acre	$ 12.60	1	$ 126.00	
Labor					
All operations	HRS	$ 7.50	17	$ 127.50	
Custom Harvesting (10' grain header)	LBS	$ 0.012	2500	$ 300.00	
Total Costs				**$3,896.20**	
Gross Receipts					
Camelina					
Seed	LBS/Acre	$ 0.12	2500	$ 3,031.60	
Oil	LBS/Acre	$ 0.22	875	$ 1,950.39	
Meal	LBS/Acre	$ 0.08	1625	$ 1,312.42	
Total Receipts (Seed Only)				$ 3,031.60	
Total Receipts (Oil and Meal Only)				$ 3,262.81	
Net Profit (Seed Only)				**$ (864.60)**	
Net Profit (Oil and Meal Only)				**$ (633.39)**	

Camelina, No-Till		10 ac			
	Estimated Yield	2500 *lbs/ac*			
	Unit	Cost/Unit	Quantity	Total Cost	
Fixed and Variable Costs					
Seed	LBS	$ 2.28	12	$ 273.60	
Herbicides					
Glyphosate	OZ	$ 0.25	42	$ 105.00	
Poast	OZ	$ 0.86	20	$ 172.00	
Fertilizer					
17-17-17-5	LBS	$ 0.21	150	$ 312.00	
Lime	TON	$ 35.00	0.15	$ 52.50	
Machinery					
Tractor (75hp)	Acre	$ 57.07	1	$ 570.70	
No-Till Seed Drill (8')	Acre	$ 58.50	1	$ 585.00	
Pull Type Fertilizer Spreader	Acre	$ 19.50	1	$ 195.00	
3pt. Sprayer	Acre	$ 47.30	1	$ 473.00	
Labor					
All operations	HRS	$ 7.50	7	$ 52.50	
Custom Harvesting (10' grain header)	LBS	$ 0.012	2500	$ 300.00	
Total Costs				$ 3,091.30	
Gross Receipts					
Camelina					
Seed	LBS/Acre	$ 0.12	2500	$ 3,031.60	
Oil	LBS/Acre	$ 0.22	875	$ 1,950.39	
Meal	LBS/Acre	$ 0.08	1625	$ 1,312.42	
Total Receipts (Seed Only)				$ 3,031.60	
Total Receipts (Oil and Meal Only)				$ 3,262.81	
Net Profit (Seed Only)				**$ (59.70)**	
Net Profit (Oil and Meal Only)				**$ 171.51**	

Grain Sorghum, Conventional Till		**10 ac**		
Estimated Yield		*80 bu/ac*		
	Unit	Cost/Unit	Quantity	Total Cost
Fixed and Variable Costs				
Seed	LBS	$ 2.04	9	$ 183.60
Herbicides				
Glyphosate	OZ	$ 0.25	42	$ 105.00
Dual II Magnum	OZ	$ 1.02	16	$ 163.20
Fertilizer				
17-17-17-5	LBS	$ 0.21	150	$ 312.00
Lime	TON	$ 35.00	0.15	$ 52.50
Machinery				
Tractor (75hp)	Acre	$ 67.56	1	$ 675.60
No-Till Seed Drill (8')	Acre	$ 58.50	1	$ 585.00
Pull Type Fertilizer Spreader	Acre	$ 19.50	1	$ 195.00
3pt. Sprayer	Acre	$ 47.30	1	$ 473.00
Tandem Disk	Acre	$ 37.80	1	$ 378.00
Field Cultivator	Acre	$ 12.10	1	$ 121.00
Roller	Acre	$ 12.60	1	$ 126.00
Labor				
All operations	HRS	$ 7.50	17	$ 125.00
Custom Harvesting (10' grain header)	BU	$ 0.60	80	$ 480.00
Total Costs				$ 3,974.90
Gross Receipts				
Grain Sorghum	BU/Acre	$ 3.86	80	$ 3,088.00
Total Receipts				$ 3,088.00
Net Profit				**$ (886.90)**

Grain Sorghum, No-Till		**10 ac**		
Estimated Yield		*80 bu/ac*		
	Unit	Cost/Unit	Quantity	Total Cost
Fixed and Variable Costs				
Seed	LBS	$ 2.04	9	$ 183.60
Herbicides				
Glyphosate	OZ	$ 0.25	42	$ 105.00
Dual II Magnum	OZ	$ 1.02	16	$ 163.20
Fertilizer				
17-17-17-5	LBS	$ 0.21	150	$ 312.00
Lime	TON	$ 35.00	0.15	$ 52.50
Machinery				
Tractor (75hp)	Acre	$ 57.07	1	$ 570.70
No-Till Seed Drill (8')	Acre	$ 58.50	1	$ 585.00
Pull Type Fertilizer Spreader	Acre	$ 19.50	1	$ 195.00
3pt. Sprayer	Acre	$ 47.30	1	$ 473.00
Labor				
All operations	HRS	$ 7.50	7	$ 52.50
Custom Harvesting (10' grain header)	BU	$ 0.60	80	$ 480.00
Total Costs				$ 3,172.50
Gross Receipts				
Grain Sorghum	BU/Acre	$ 3.86	80	$ 3,088.00
Total Receipts				$ 3,088.00
Net Profit				**$ (84.50)**

Camelina - Cover Crop, No-Till		**10 ac**		
Camelina - Estimated Yield		*2500 lb/ac*		
	Unit	Cost/Unit	Quantity	Total Cost
Fixed and Variable Costs				
Seed				
Camelina	LBS	$ 2.28	12	$ 273.60
Multi-Species Cover Crop	LBS	$ 1.00	15	$ 150.00
Herbicides				
Glyphosate	OZ	$ 0.25	42	$ 105.00
Poast	OZ	$ 0.86	20	$ 172.00
Fertilizer				
17-17-17-5	LBS	$ 0.21	150	$ 312.00
Lime	TON	$ 35.00	0.15	$ 52.50
Machinery				
Tractor (75hp)	Acre	$ 54.09	1	$ 540.90
No-Till Seed Drill (8')	Acre	$ 58.50	2	$ 1,170.00
Pull Type Fertilizer Spreader	Acre	$ 19.50	1	$ 195.00
3pt. Sprayer	Acre	$ 31.53	1	$ 315.30
Labor				
All operations	HRS	$ 7.50	8	$ 60.00
Custom Harvesting (10' grain header)	BU	$ 0.60	50	$ 300.00
Total Costs				$ 3,646.30
Gross Receipts				
Camelina	LBS/Acre	$ 0.12	2500	$ 3,031.60
Total Receipts				$ 3,031.60
Net Profit				**$ (614.70)**

Camelina - Grain Sorghum, Conventional Till		**10 ac**		
Camelina - Estimated Yield		*2500 lb/ac*		
Grain Sorghum - Estimated Yield		*80 bu/ac*		
	Unit	Cost/Unit	Quantity	Total Cost
Fixed and Variable Costs				
Seed				
Camelina	LBS	$ 2.28	12	$ 273.60
Grain Sorghum	LBS	$ 2.04	9	$ 183.60
Herbicides				
Camelina				
Glyphosate	OZ	$ 0.25	42	$ 105.00
Poast	OZ	$ 0.86	20	$ 172.00
Grain Sorghum				
Glyphosate	OZ	$ 0.25	42	$ 105.00
Dual II Magnum	OZ	$ 1.02	16	$ 163.20
Fertilizer				
17-17-17-5	LBS	$ 0.21	300	$ 624.00
Lime	TON	$ 35.00	0.15	$ 52.50
Machinery				
Tractor (75hp)	Acre	$ 81.97	1	$ 819.70
No-Till Seed Drill (8')	Acre	$ 58.50	2	$ 1,170.00
Pull Type Fertilizer Spreader	Acre	$ 19.50	2	$ 390.00
3pt. Sprayer	Acre	$ 47.30	2	$ 946.00
Tandem Disk	Acre	$ 37.80	2	$ 756.00
Field Cultivator	Acre	$ 12.10	2	$ 242.00
Roller	Acre	$ 12.60	2	$ 252.00
Labor				
All operations	HRS	$ 7.50	32	$ 240.00
Custom Harvesting (10' grain header)				
Camelina	BU	$ 0.60	50	$ 300.00
Grain Sorghum	BU	$ 0.60	80	$ 480.00
Total Costs				$ 7,274.60
Gross Receipts				
Grain Sorghum	BU/Acre	$ 3.86	80	$ 3,088.00
Camelina	LBS/Acre	$ 0.12	2500	$ 3,031.60
Total Receipts				$ 6,119.60
Net Profit				**$ (1,155.00)**

Camelina - Grain Sorghum, No-Till		**10 ac**			
Camelina - Estimated Yield		*2500 lb/ac*			
Grain Sorghum - Estimated Yield		*80 bu/ac*			
	Unit	Cost/Unit	Quantity	Total Cost	
Fixed and Variable Costs					
Seed					
Camelina	LBS	$ 2.28	12	$ 273.60	
Grain Sorghum	LBS	$ 2.04	9	$ 183.60	
Herbicides					
Camelina					
Glyphosate	OZ	$ 0.25	42	$ 105.00	
Poast	OZ	$ 0.86	20	$ 172.00	
Grain Sorghum					
Glyphosate	OZ	$ 0.25	42	$ 105.00	
Dual II Magnum	OZ	$ 1.02	16	$ 163.20	
Fertilizer					
17-17-17-5	LBS	$ 0.21	300	$ 624.00	
Lime	TON	$ 35.00	0.15	$ 52.50	
Machinery					
Tractor (75hp)	Acre	$ 61.00	1	$ 610.00	
No-Till Seed Drill (8')	Acre	$ 58.50	2	$ 1,170.00	
Pull Type Fertilizer Spreader	Acre	$ 19.50	2	$ 390.00	
3pt. Sprayer	Acre	$ 47.30	2	$ 946.00	
Labor					
All operations	HRS	$ 7.50	11	$ 82.50	
Custom Harvesting (10' grain header)					
Camelina	BU	$ 0.60	50	$ 300.00	
Grain Sorghum	BU	$ 0.60	80	$ 480.00	
Total Costs				$ 5,657.40	
Gross Receipts					
Grain Sorghum	BU/Acre	$ 3.86	80	$ 3,088.00	
Camelina	LBS/Acre	$ 0.12	2500	$ 3,031.60	
Total Receipts				$ 6,119.60	
Net Profit				**$ 462.20**	

APPENDIX C: UNPUBLISHED LITERATURE REVIEW

Abstract

Camelina sativa, CS, is a cruciferous oil-seed crop belonging to the Brassicaceae family. Common names include false flax, and gold of pleasure. The seeds of *Camelina sativa* contain 30-40% oil of total dry weight compared to soybeans that contain between 15-20% oil by dry weight. *Camelina sativa* also has unique properties such as a short growing season (120 days) that make it intriguing for use in cropping systems, it is resistant towards drought, and it is resistant towards pests. These qualities make CS an increasingly favorable oilseed crop for use as a feedstock for biofuels and bioproducts, especially for use as jet fuel due to the high amounts of isoparaffin, a branched chain hydrocarbon with high octane ratings. Aside from bio-based products Camelina oils may also be used as food-grade oils to support a growing food industry. Camelina meal can have significant economical uses as well, particularly as an animal feed. To date a suitable compilation of the literature on *Camelina sativa* as an industrial oil-seed crop is not available, therefore the objectives of this research effort were to produce a literature review that describes the chemical composition, agronomic process, uses, and industrial significance of the *Camelina sativa* plant. This literature review, as a presentation of the current state of related research will be an invaluable tool for groups wishing to begin research on the crop or the crop products.

Overview

Camelina sativa, CS, is a cruciferous oil-seed crop belonging to the Brassicaceae family and has been cultivated since the Bronze Age, about 3000 BC (4). In the last sixty years CS cultivation has been minimal due to crop subsidies and higher yielding oil-seed crops, which are usually used for food grade oils such as canola and soybean oil (23). The recent interest in a sustainable non-food oil-seed crop for the production of biofuels has renewed interest in Camelina. Common names include false flax, and gold of pleasure (2). The oil produced from pressing the Camelina seed contains between 36% and 47% oil by dry weight, which is double the oil content of soybeans and equal to the average oil content of canola (17). Camelina oil is composed of 90% unsaturated fatty acids and contains extraordinarily high amounts of Omega-3 fatty acids for a plant species, making it a potential dietary oil (18). The majority of *Camelina sativa* oil is composed of a-linolenic acid and oleic acid, making up ~36% and ~16.4% of total oil dry weight respectively, ~15.8% of total oil dry weight. The complete fatty acid composition can be found in table 1.

The Camelina seed contains between 35-45% protein by dry weight, including many essential amino acids necessary for the daily-recommended crude protein intake of domesticated livestock (47). The high content of these essential amino acids, in which a complete amino acid profile can be found in table 2, makes Camelina a viable feedstock for domesticated animals, such as cattle, chickens and rabbits as further literature will imply (9,36,37,38).

The high content of linoleic acid and a-linolenic acid suggests CS oil would be highly susceptible to oxidation, which causes increased free-fatty acid content and short shelf life. This however was not the case; CS oil was stored without light for seven years and proved to have only mild rancidity (18). Camelina has high levels of tocopherols, which are speculated to cause the long shelf life (18) Tocopherols are found in many leafy greens and other dietary foods in the form of a-tocopherol that naturally accumulates in humans and is commonly known as vitamin E. The tocopherols, mostly g-tocopherol, and phenolic compounds found in *Camelina sativa* are especially important during storage and prolonging onset of oxidation of the oil (3, 4, 11). Phenolic compounds isolated from CS were added to safflower oil and shown to significantly reduce the production of oxidative products during storage for 20 days at 50^{o}C (4). The function of these compounds within the oil are especially important when considering the production of biofuels or industrial products since the products could quite possibly be stored for weeks until consumed. During this time the double bonds exposed to oxygen can be saturated and render the oil unusable.

Camelina sativa has unique properties such as a short growing season (120 days), resistance towards drought, and it is resistant towards pests (2,5). These qualities make CS an increasingly favorable oilseed crop in Northern Europe and Midwest United States for use as a feedstock for biofuels and bioproducts, especially for use as jet fuel due to the high amounts of isoparaffins, a branched chain hydrocarbon with high octane ratings (7).

Currently, 86% of industrialized countries plant-derived oil supplies are being used in the food industry (6). This makes the designation of oil-seed crops to produce biofuels and bioproducts a rarity at best, and as petroleum products rise in prices, non-food uses of plant-derived oils have grown in interest. The use of *Camelina sativa* oil, and other plant-derived oils can significantly reduce the amount petroleum products being used while having both economical and environmental benefits (6). This fact has led to a renewed interest in *Camelina sativa* as an alternative oil-seed crop for its use as a biofuel, lubricating oil, and animal feedstock. This literature review, as a presentation of the current state of related research will be an invaluable tool for groups wishing to begin research on the crop or the crop products.

Agronomic

Plant

Camelina sativa is a short, annual or winter annual crop, and when fully grown, contains a cluster of pale-yellow flowers with four petals. CS height can range between 30-90 cm, and has branched stems that grow hard and woody upon maturity (7, 73). The leaves can range from 5-8 cm and shaped like an arrow with sharp points. The reproductive part of the flower, a pear shaped capsule ranging between 6-14 mm in length (73). The capsule contains roughly 15 oval-shaped yellow seeds between .5-1 mm long and 1-2 mm in length weighing 0.8-1.8g per 1000 seeds (2, 73). Upon ripening and drying during storage the yellow-brown seeds turn dark-brown/reddish in color (2). CS is a self-pollinating, auto-gamous plant with chromosome number 2n=40 (11). The plant however, benefits from high populations of insect pollinators (11).

Land Preparation

Camelina is known for its hardiness in varying types of soils with little fertilizer input. It seems to thrive in most soils except soils containing high amounts of clay and organic matter (2). A study conducted in Canada and published in 2013 suggests application of Nitrogen to the soil is necessary for growers to receive full potential of their crops (74). Optimal Nitrogen levels vary by regions and soil conditions, but the study suggests that soil Nitrogen levels should be 100Kg/Ha and 90Kg/Ha for Europe and the US respectively (74). Other studies found the use of nitrogen seemed to maximize seed yield (7, 2). As Nitrogen levels increased seed oil content decreased while seed protein content increased, which can be worrisome to farmers wishing to maximize Camelina oil production, however, oil yields per Ha were shown to be maximized when Nitrogen values were optimized to produce the greatest seed yields regardless of seed oil value (74). It is common for Camelina to be planted in a no-till manner with success, however the common till method has shown considerable success over the no-till method in the north-central United States in a double-cropping situation (7). A mono-crop study on seeding date performed in Chile used the broadcast method with yields higher and lower than the US study depending on locations (16). Repeated harrowing is needed to prevent weed competition during the sowing process (2). Once the plant has reached the foliage phase of growth the plant exhibits a considerable amount of strength against weed pressure. In order to prevent considerable weed competition, it may be advisable to use an herbicide before planting (11).

Planting

Due to the small seed size, Camelina requires a very accurate seedbed. Both direct drilling and broadcasting have been proven to produce reliable stands. Direct drilling should be set at a depth between 5-12mm, with an optimum depth below 10mm (14, 7). The general seeding rate is between 3-8 kg/Ha, however overplanting of up to 9 kg/Ha has shown to improve crop density when using the broadcast method (13,7, 11). When using the broadcast method it is recommended to follow the planter with a light harrow to help incorporate the seed into the soil (14).

Pests

Common insects such as flea beetles and common aphids have not cause any economically significant damage to Camelina, which can be pests to canola, and protection against disease has been based on the population's genetic resistance (2). In the early stage of development Camelina can be susceptible to high weed pressure but as it begins the rosette stage of development, it can produce significant weed competition (2, 11).

Maturity

Germination occurs within 9-12 days, days to maturity range between 85-120 depending on winter and summer varieties. The winter varieties tend to mature sooner, around 100 days (2, 11, 7). Variables such as climate, water content of the soil, soil composition and nutritive value, and planting date and method effect maturity. In a study conducted in Chile and the US, it was shown that the coolest climates produced the greatest yields (16). An optimum mean growing temperature of 25°C was found by one study (12). It was also suggested that the soil be well drained to reduce crop loss due to over saturation of the plant, which caused more problems than planting severely dry soil (16, 15, 74). During a 2-year field study of different plant populations of Camelina, stand reduction of 50% and 90% was tested. A stand reduction is a test used to assess a crops ability to recover from being knocked over or forced to the ground by hail, frost, or other causes. A percent of the crop is trampled or knocked over at a specific stage within development to determine the stage at which the plant will lose the ability to recover from traumatic events. A 50% stand reduction during the rosette or bolting stage reported no affect on grain yield (13). A 90% stand reduction reduced grain yield by 50% at the bolting stage, but only by 19% during the rosette stage (13).

Harvest

Camelina is usually combined directly but can be swathed if the climate does not permit timely drying while standing (72). Swathing should be done just below the canopy of the pods, leaving as much standing stalk as possible, in order to reduce the loss of the windrow from windy conditions. Swathing should occur when 75-85% of the seeds in the pod turn from green to yellow (72). A combine with either a multigrain header setup for canola or alfalfa seed is sufficient to harvest the Camelina seed. However, the combine's fan speed must be reduced to insure the greatest yield. In combination with a lower fan speed, a fine screen must be used, ~.25 in, in order to prevent loss of seed and contamination of the grain with chaff (72). For proper storage seed moisture content must be below 8%.

Processing

Camelina seed must be further processed to make use of the oil from the seed. The most common way of doing this is cold pressing the oil. In a study performed in 2014 Camelina cold-press extraction yields were shown to be 4% greater than Canola (75). The respective yields for Camelina and Canola pressed at 15Hz were 88.2% and 84.1% (75). Solvent extraction of oil with hexane showed yields of up to 99% (75, 23).

Seed Selection

When choosing a crop every farmer must consider the climate regions, annual rainfall, soil composition, anticipated yield and expected maintenance of a specific crop. In a recent study performed in 2012 seven different Camelina genotypes were tested to determine the most suitable for industrial use (50). Four distinct genotypes Vinimik 17, Ames 26665, Ames 26667, and Ames 26673 were all considered to be prime good candidates for industrial plant oil production based on seed weight, oil content, and oil yield (50). Specific correlations are seen between certain phenological traits and grain and oil yield. A negative correlation was observed between genotypes that yielded a large 1000-seed weight and oil yield, making these genotypes of little industrial use due to low oil yields (51). However a positive correlation was observed between genotypes with high grain yields and oil yields suggesting these phenological characteristics are more suited to industrial use (51). Planting date and environmental factors play a major role in the seed yield, oil content, maturity date, and oil yield. Linolenic acid (Omega 3) content was negatively correlated with time to flowering and oil content (51). Camelina crops have been successfully planted in early fall, winter, and early spring and has proven to have exceptional cold tolerance, withstanding -27 C weather at a 70% survival rate (52). Due to Camelina's little residue, growth and crop yields are negatively correlated with excess tillage of the soil and it is recommended that Camelina be planted in the "no till" manner (52) Aids with erosion, good for rotation farmers. Recently the complete genome of *Camelina sativa* has been mapped. Camelina resembles the genome structure of *Arabidopsis thaliana* very closely (53). The close resemblance to *Arabidopsis thaliana* has allowed for a quick mapping of the *Camelina sativa* genome and side by side comparison to the model species. The genome suggests that hybridization occurs very rapidly making Camelina a highly adaptive species, thus allowing for quick phenotype adjustments based on climate and soil property after multiple plantings (53). This can aid farmers in the years following the original planting of Camelina so long as they carry over a percentage of seed from the harvest to plant the following year.

Economics

Camelina production can be a cost effective venture. Camelina can easily be grown in a double cropping system in areas where mono-cropping is common due to it's short growing season and low maintenance (7). Camelina can also be produced for on-farm use. In a study conducted in Colorado, the production of Camelina for the production of oil as a replacement of diesel fuel was tested for economic feasibility (8). The researchers suggest that if diesel prices exceed \$0.83 L then it would be cheaper to produce Camelina, provided the meal byproduct can be sold (8). If the meal cannot be sold, the price of diesel must reach \$1.31 L, at this value and higher the farmer had the greatest chance of breaking even on the off-set of fuel costs alone (8).

Camelina Based Biofuel

Methods

Two major forms Camelina biofuel production and use will be discussed and evaluated, conventional transesterification of vegetable oil and hydrotreatment of the vegetable oil. Biodiesel is produced through the transesterification of triglycerides using a catalyst such as potassium hydroxide or sodium hydroxide and methanol to make long chain fatty acid methyl ester. The long single chain fatty acids still contain the double bonds and the structure of the individual fatty acids making up the triglyceride. One of the biggest problems with Camelina biodiesel and biodiesel produced from highly unsaturated vegetable oils is their high Iodine value.

The Iodine value is a tool used to diagnose the number of unsaturated double bonds found within a given sample of vegetable oil. The unsaturated double bonds allow the oil to have better cold flow properties but as a result leave the oil more susceptible to oxidation as the double bonds react within atmospheric oxygen. When the oil becomes oxidized the cetane value and energy density of the fuel decreases, making the fuel less desirable. The Iodine value represents the degree of susceptibility to oxidation when iodine is added to the oil and reacts with the double bonds. The Iodine number is the amount of Iodine necessary to saturate all of the double bonds within a given sample of vegetable oil, the higher the Iodine number the more susceptible to oxidation and the shorter the shelf life of the fuel. Camelina derived biofuel is unacceptable for use as a conventionally produced biodiesel because it does not meet the US biodiesel standards due to the high iodine value of Camelina methyl esters, even though it has better cold flow properties than most commonly used vegetable oils for biodiesel.

Testing of methyl-ester biodiesel made with Camelina has shown equal or increased levels of performance in diesel transport engines (26,27). However, in some cases, especially for lower RPM situations the injection timing of the biofuel produced from Camelina needs to be delayed due to the high content of poly-unsaturated methyl esters (28). Camelina biodiesel was tested in a 1Z TDI engine manufactured by Volkswagen/Audi. This engine is a common option in both America and Europe for use in a few different models of automobiles. The performance of mixed 30% biodiesel and 70% petroleum diesel showed Camelina based biodiesels equaled performance standards of current biodiesel crops such as soybeans and canola (30). Camelina biodiesel performed as well as canola based biofuels in tests performed with a Peugeot Xad and an Isuzu Trooper UBS55 (31). The test vehicles showed a slight decrease in fuel economy when using Camelina biodiesel as opposed to petroleum diesel fuels, which can be attributed to the slightly lower energy content of Camelina biodiesel (31).

The Camelina biodiesel produced met every EN 14214 standard except for the iodine number, which the EN 14214 states the iodine value cannot exceed 120; the Camelina biodiesel tested consistently exceeded this value by 30 points. However, it was reported that a high iodine value did not cause any adverse effects on motor lubricity during the tests (31). A separate study found that biodiesel had a lower heating value than petroleum diesel producing lower horsepower and torque curves measured on an engine dynamometer (55). This is expected as biodiesel generally has a lower heat of combustion than petroleum diesel.

Hydrotreated diesel fuel has sparked an interest from large businesses and environmental agencies alike. The hydrotreated fuel is a drop in replacement to petroleum diesel without any necessary engine adaptations. When burned in a conventional diesel engine hydrotreatd renewable diesel has shown a decrease in carbon monoxide by 78% decrease in nitrous oxides by 14% and a decrease in particulate matter by 46% (66). One study examined the droplet burn characteristic of Camelina hydrotreated jet fuel in comparison with conventional petroleum based jet fuel (68). The droplet of hydrotreated fuel had a much lower sooting capacity than Jet-A fuel, while Jet-A burned brighter due to the higher amount of aromatics, such as sulfur within the fuel (68). The droplets have very similar burning histories, burning rates, and in evolutions of flame, this is not very surprising when examining the chemical properties of the volatile compound of the Camelina derived hydrotreated fuel and Jet-A which are amost identical in hydrocarbon composition (68).

A test performed in a T63 Turbine engine compared beef tallow derived hydrotreated jet fuel and camelina derived hydrotreated jet fuel with the burning of JP-8 (63). All fuels demonstrated adequate engine performance and no signs of degradation, while the hydrotreated fuels produced less smoke and sulfur oxide emissions and the camelina fuel showed the lowest production of carbon monoxide (63). Camelina based hydro-treated jet fuel is rich in isoparaffins, and has met every quality standard set by commercial airlines (23). Isoparriffins are saturated hydrocarbons ranging from 7-14 carbons. Hydrocarbons produced from Camelina and other bio-stocks are physically very similar to petroleum based jet fuel, and have many of the same properties without the presence of excess heteroatoms such as sulfur and nitrogen. Hydro treating is the process of adding hydrogen to the polyunsaturated fatty acids, which increases the cetane number, and creates a denser, and more thermodynamic fuel.

Hydrotreating the fuel effectively lowers the cloud point of the Camelina based jet-fuel and reduces the iodine number (23). Hydrotreating also reduces the biofuel susceptibility to oxidation allowing for longer storage times and allows the biofuel to meet all aviation standards. This hydro treated isoparaffin-rich biofuel reduces particulate matter and lower greenhouse emissions by 70-80%, while performing as well as conventional fuels with no significant changes to the engine (22).

Current Interest

Camelina has gained interest in the aviation world for its high paraffinic content when hydrotreated, it is not a food crop, short growing season, and a relatively low input crop. Many of the large oil refineries today are already set up to hydrotreat Camelina oil. Hydrotreating (solid data/#s) and hydrocracking are used to treat the long chain unsaturated fatty acids by saturating the double bonds within the vegetable oil. This boosts the cetane value of the oil and prevents oxidation. This process also breaks up the long chains hydrocarbons into shorter paraffinic hydrocarbons (7-14 hydrocarbons) better suited for the cold. This process makes the fuel a drop in alternative to petroleum-based biofuel, and is chemically equivalent without the excess aromatics and additives found within petroleum-based fuels. Both methods of biofuel production have their advantages and disadvantages, but methyl ester biodiesel is neither a drop in fuel or approved for sale in the US, while hydrotreating produces many products such as jet fuel, diesel, and naphtha that are chemically equivalent to there respective petroleum products.

The US Navy unveiled a flight test in 2010 of a F/A-18 Super Hornet fueled by a 50/50 blend of Camelina derived jet fuel and Petroleum jet fuel. The US Navy partnered with Sustainable Oils, a company formed in 2007 now called Global Clean Energy Holdings which specializes in the production of Camelina oil and Camelina derived hydrotreated jet fuel. The Montana based company won a contract to provide 40,000 gallons of fuel a year to the US Navy in a joint operation to reduce the use of foreign oil and lower the environmental impact of Air combat and training missions. (Press release)

The Renewable Energy Group publicized in late 2014 that they have produced over 1,000,000,000 billion gallons of hydrotreated biofuel which adds to $3.9 Billion to the US GDP and has greatly reduced the amount of crude oil imports. The REG recently acquired Dynamic Fuels, LLC of Geismar, Louisiana which was previously owned by Tyson Foods, INC. The Dynamic Fuels plant will add a 75 million gallon capacity per year to the REG capacity.

Commercial Interest

Camelina oil has been considered for use in paints, varnishes, cosmetics, pharmaceuticals, pet food, fish food, and jet fuel (6). As a dietary supplement Camelina can be consumed by humans alone or as a food additive (18). The oil offers high values of a-linolenic acid, and linoleic acid that promote heart and joint health (18). Camelina oil can be stored for years in a cool, dark environment with little to no lose in nutritive value (18).

Camelina Meal

The byproduct of pressing the *Camelina sativa* seed is the Camelina meal, composing of protein (40%) leftover oil (10-15%) and fibrous material. If the meal can be sold, usually for a feed to animals, the economical impact of the production of Camelina based biofuels can be reduced (10). Field costs contribute the most to overall cost of producing Camelina usually around 75-80%, and if the meal can be sold Camelina oil is significantly cheaper to produce than canola oil (10). The meal has been studied as a possible ration source for many different animals, including rabbits, broiler and laying chickens, ruminants, turkeys and fish.

Camelina meal was fed at levels of 10% total ration to broiler chickens in one study, showing increased levels of omega-3 and omega-6 fatty acids, essential fatty acids in human nutrition, in thigh and breast tissue, and no significant difference in final weight when compared to usual broiler rations (38). A separate study found the values of omega-3 and omega-6 to be 2 to 2.9 fold higher in broiler chickens fed Camelina meal (36). However, in yet another study of Camelina meal fed to broiler chickens, high glucosinolates within the meal depressed the feed intake and growth of broiler chickens (37).

When fed to laying chickens at 10% of total feed intake egg quality and laying stayed the same, while increasing yolk omega-3 levels, yet when fed to laying chickens at >15% of total feed ration Camelina meal lowered egg production (39). The same trend is seen when fed to turkeys, increased omega-3 and 6 in thigh and breast meat. Ration levels greater than 15%, a decrease in end body weight has been observed (40). Using Camelina oil as a substitute for fish oil in farmed Atlantic salmon has been recommended to increase DHA and EPA in young fish, but the meal itself was deemed unsuitable as a feed ration (41).

Two separate studies showed that Camelina meal fed to rabbits at no more that 15% of total feed ration had no adverse effects on the overall health or end weight of the rabbits (42, 43). When fed to ruminants, such as beef cattle, Camelina meal was shown to be a viable replacement for corn and soybean based protein sources, without interfering with fertility, while increasing dietary fatty acid content (44).

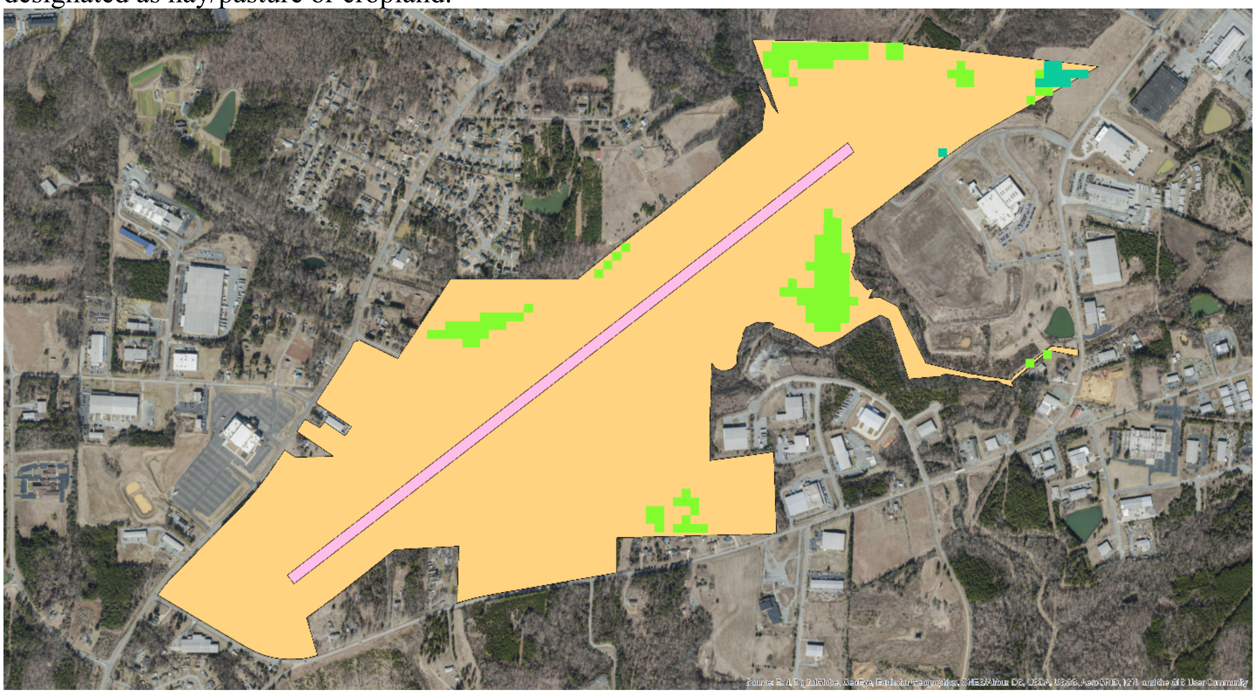
In 2009 the Department of Veterinary Medicine, a division of the FDA, approved Camelina meal for feedlot cattle in quantities of up to 10% of total feed weight (76). In a study conducted in Wyoming, both the meal and glycerin byproduct from biodiesel production were fed to beef heifers with no adverse side effects (9). Camelina meal was fed to the heifers for 60 days at an amount of 0.33% of the heifers total body weight (9). It was shown to increase serum fatty acid content in the heifer, and was a cheaper alternative to corn-soybean meal, suggesting the use of Camelina meal as a feedstock, could be economically feasible (9).

Conclusion

In conclusion, *Camelina sativa* offers unique agronomic traits and advantages when used a in a mono-crop or double-crop system. Low water use and little fertilizer input suggests producing Camelina in a rotation is economically feasible and could be advantageous. The uses of Camelina derived biofuels have shown to be both environmentally and economically friendly. As petroleum prices increase a growing need for natural alternatives will surface, and Camelina products can be a valuable crop option for future farmers.

Burlington-Alamance Regional Airport – Alamance County

The total size of the Burlington-Alamance Regional airport is approximately 373 acres. After applying criteria 3 the total available space for camelina production reduces to 358 acres. Criteria 1 and 2 further reduce available acreage to 25.58 acres. Criteria 4 leaves a final available acreage for camelina production of 23.47 acres. While this site benefits for above average drainage the majority of the land space is not designated as hay/pasture or cropland.



Alamance County - Drainage

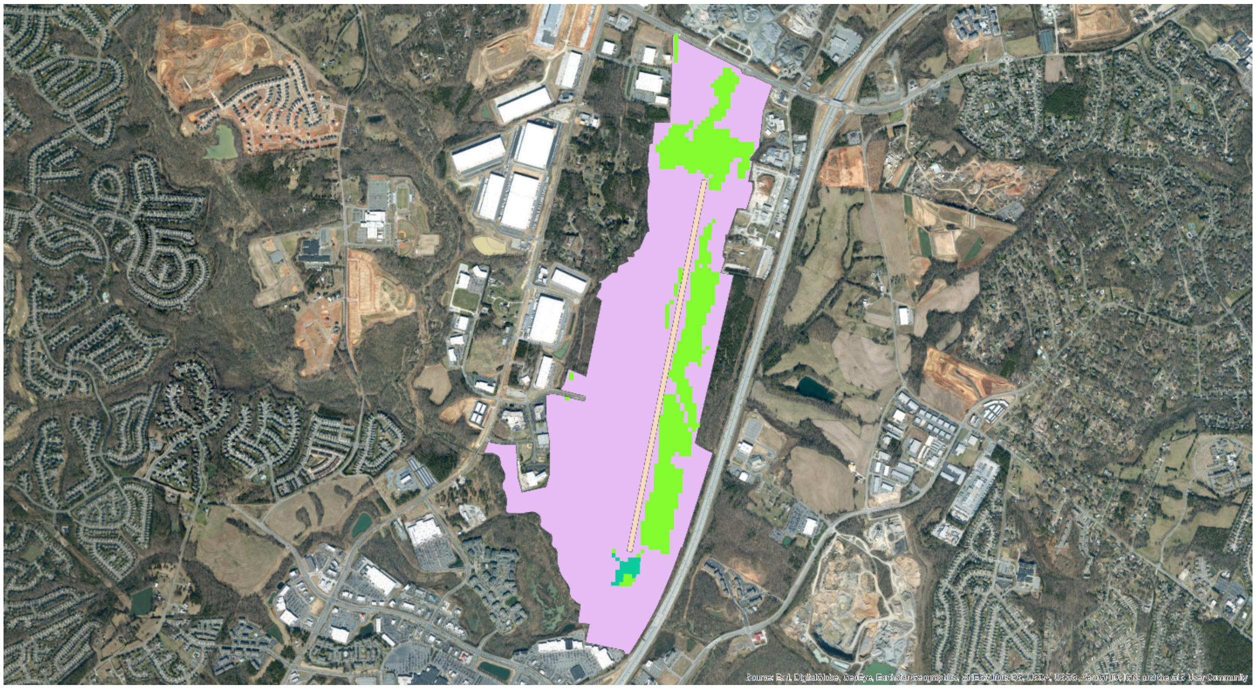
Drainage	Acres
Excessively Drained	0.00
Well Drained	21.70
Moderately Well Drained	1.77
Total	23.47

Alamance County - Land Cover

Land Cover	Acres
Developed, Open Space	100.08
Developed, Low Intensity	67.39
Developed, Medium Intensity	44.26
Developed, High Intensity	9.12
Barren Land	2.22
Deciduous Forest	23.80
Evergreen Forest	1.33
Shrub/Scrub	10.90
Herbaceuous	75.61
Hay/Pasture	**25.58**

Concord Regional Airport – Cabarrus County

The total size of the Concord Regional airport is approximately 613 acres. After applying criteria 3 the total available space for camelina production reduces to 597 acres. Criteria 1 and 2 reduce the available acreage to 123 acres. Criteria 4 leaves a final available acreage for camelina production of 120 acres. The majority of the non-runway space at Concord is hay/pasture land with moderately well drained to well drained soils.



Cabarrus County - Land Cover

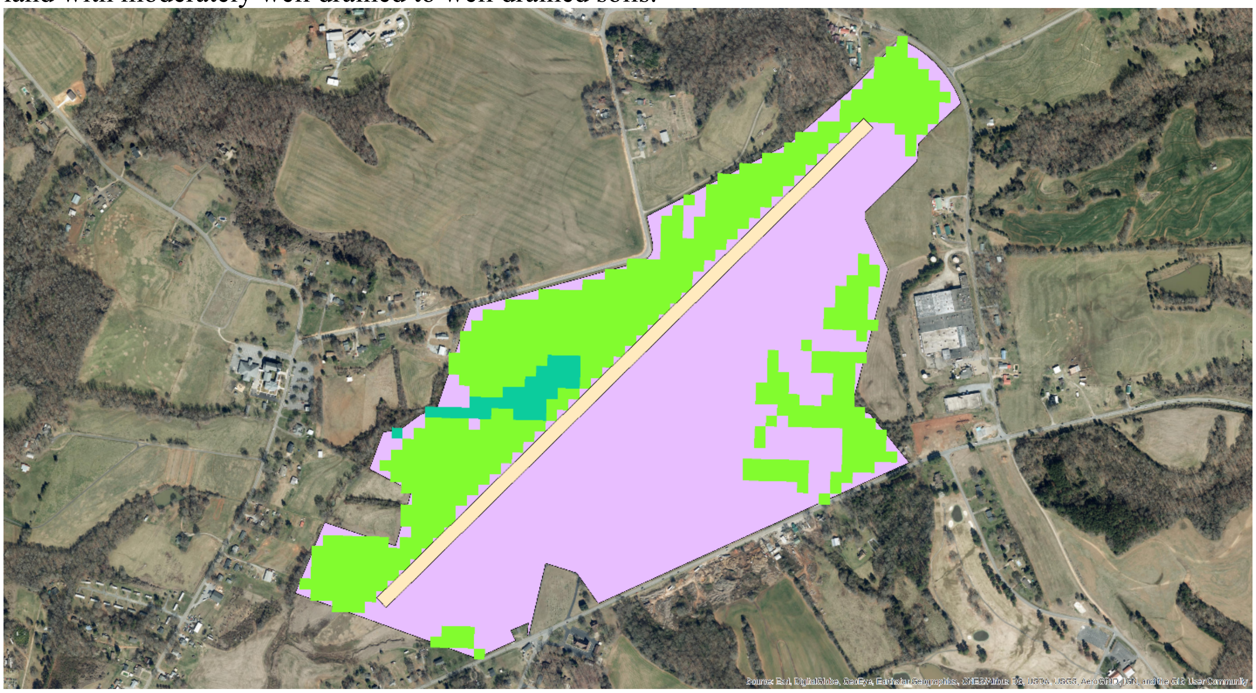
Land Cover	Acres
Open Water	11.56
Developed, Open Space	92.07
Developed, Low Intensity	87.85
Developed, Medium Intensity	63.38
Developed, High Intensity	41.14
Deciduous Forest	69.39
Evergreen Forest	8.45
Shrub/Scrub	27.58
Herbaceuous	49.82
Hay/Pasture	**123.21**
Woody Wetlands	23.13
Total	597.57

Cabarrus County - Drainage

Drainage	Acres
Excessively Drained	0.00
Well Drained	115.91
Moderately Well Drained	4.13
Total	120.04

Shelby Municipal Airport – Cleveland County

The total size of the Shelby Municipal airport is approximately 217 acres. After applying criteria 3 the total available space for camelina production reduces to 207 acres. Criteria 1 and 2 reduce the available acreage to 86 acres. Criteria 4 leaves a final available acreage for camelina production of 83 acres. The majority of the non-runway space to the northwest side of the runway and at the north end is hay/pasture land with moderately well drained to well drained soils.



Cleveland County - Land Cover

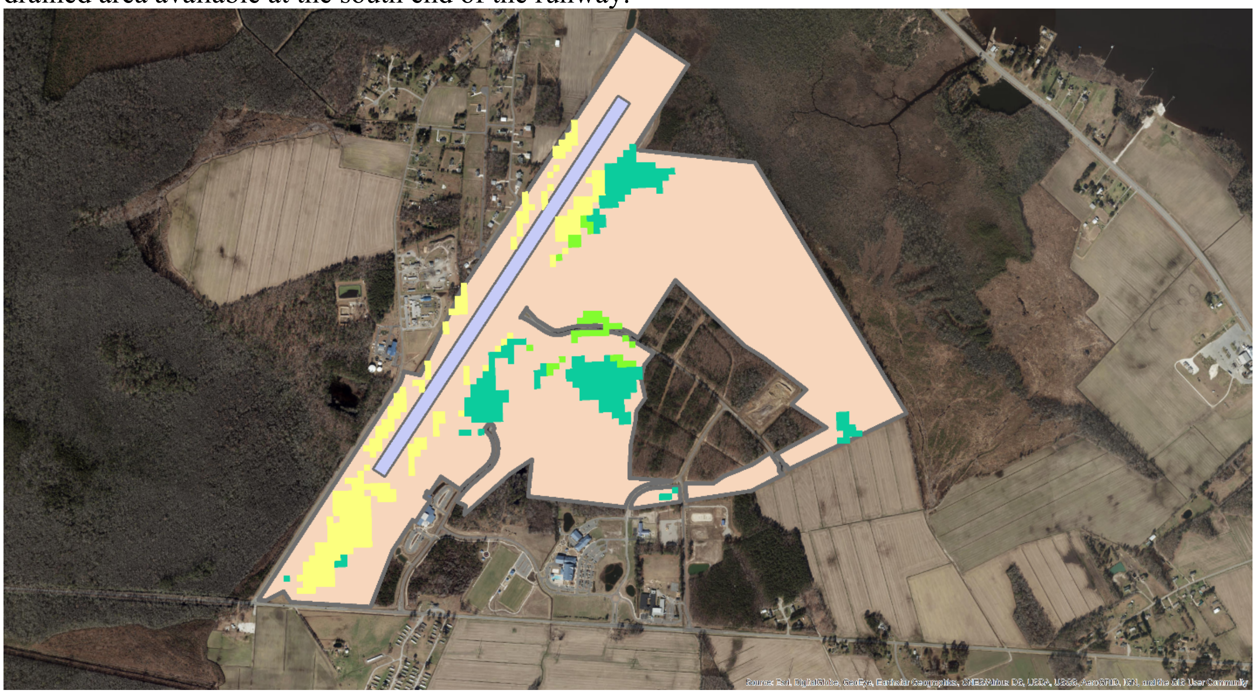
Land Cover	Acres
Developed, Open Space	64.94
Developed, Low Intensity	41.14
Developed, Medium Intensity	5.56
Developed, High Intensity	6.67
Deciduous Forest	3.11
Hay/Pasture	**86.07**
Total	207.49

Cleveland County - Drainage

Drainage	Acres
Excessively Drained	0.00
Well Drained	78.23
Moderately Well Drained	5.02
Total	83.25

Currituck County Airport – Currituck County

Currituck county airport is approximately 445 acres with a runway accounting for 20 acres. Criteria 1 and 2 reduce the available acreage to 105 acres. Criteria 4 leaves 70.43 acres for camelina production. Space for camelina production is spread throughout the property with approximately 30 acres of moderately well drained area available at the south end of the runway.



Currituck County - Land Cover

Land Cover	Acres
Open Water	9.34
Developed, Open Space	86.51
Developed, Low Intensity	9.34
Developed, Medium Intensity	9.34
Deciduous Forest	11.79
Evergreen Forest	37.36
Mixed Forest	7.78
Shrub/Scrub	50.26
Herbaceuous	10.67
Hay/Pasture	**37.58**
Cultivated Crops	**67.61**
Woody Wetlands	90.51
Total	428.11

Currituck County - Drainage

Drainage	Acres
Excessively Drained	34.43
Well Drained	5.53
Moderately Well Drained	30.47
Total	70.43

Billy Mitchell Airport – Dare County

Billy Mitchell airport is approximately 1200 acres. By 2017 land cover estimates, none of the property is in hay/pasture land or cropland. The majority of the airport space would be inhospitable to camelina production.

Dare County - Land Cover

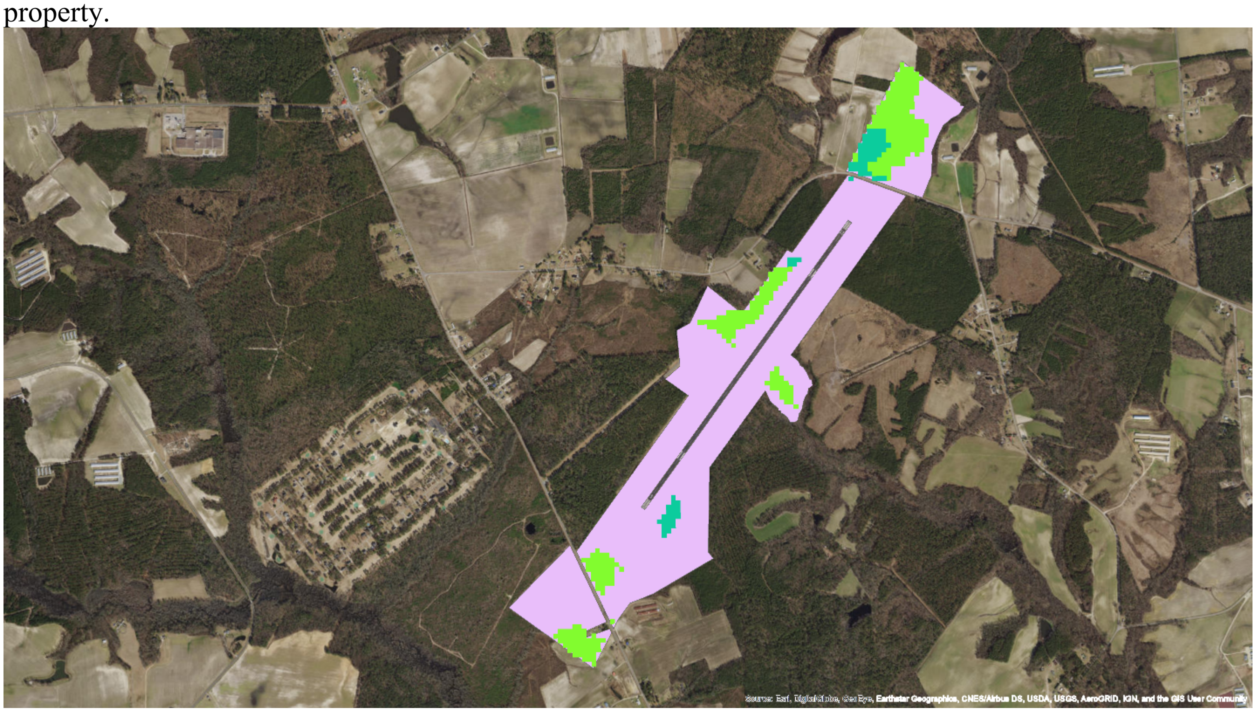
Land Cover	Acres
Developed, Open Space	26.24
Developed, Low Intensity	70.28
Developed, Medium Intensity	19.57
Developed, High Intensity	4.89
Barren Land	308.02
Evergreen Forest	249.30
Shrub/Scrub	92.96
Herbaceuous	81.17
Woody Wetlands	198.82
Emergent Herbaceuous Wetlands	153.23
Total	1204.49

Dare County - Drainage

Drainage	Acres
Excessively Drained	0.00
Well Drained	0.00
Moderately Well Drained	0.00
Total	0.00

Duplin County Airport – Duplin County

Total land space at Duplin County airport is estimated at 358 acres. Drainage classifications vary from poorly drained to well drained. Space meeting criteria 1 through 4 for camelina production is determined to be around 66.3 acres with the greatest portions near the airport terminal and at the northeast end of the property.



Duplin County - Land Cover

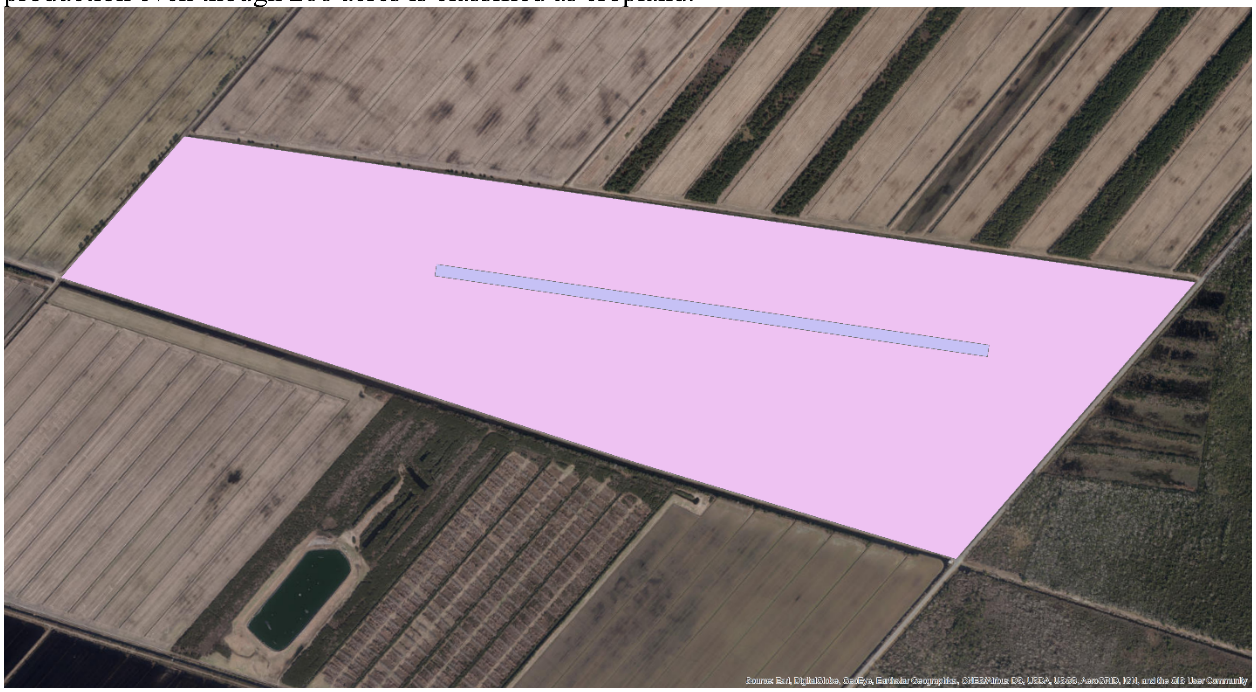
Land Cover	Acres
Developed, Open Space	129.43
Developed, Low Intensity	6.89
Developed, Medium Intensity	11.12
Developed, High Intensity	1.56
Barren Land	0.22
Evergreen Forest	11.34
Mixed Forest	9.79
Shrub/Scrub	48.26
Herbaceuous	43.81
Cultivated Crops	**73.83**
Woody Wetlands	7.56
Emergent Herbaceuous Wetlands	2.67
Total	346.49

Duplin County - Drainage

Drainage	Acres
Excessively Drained	0.00
Well Drained	54.67
Moderately Well Drained	11.59
Total	66.25

Hyde County Airport – Hyde County

Total land space at Hyde County airport is approximately 389 acres with all acres being classified as very poorly drained. This suggests that Hyde County airport would not be a good candidate for camelina production even though 288 acres is classified as cropland.

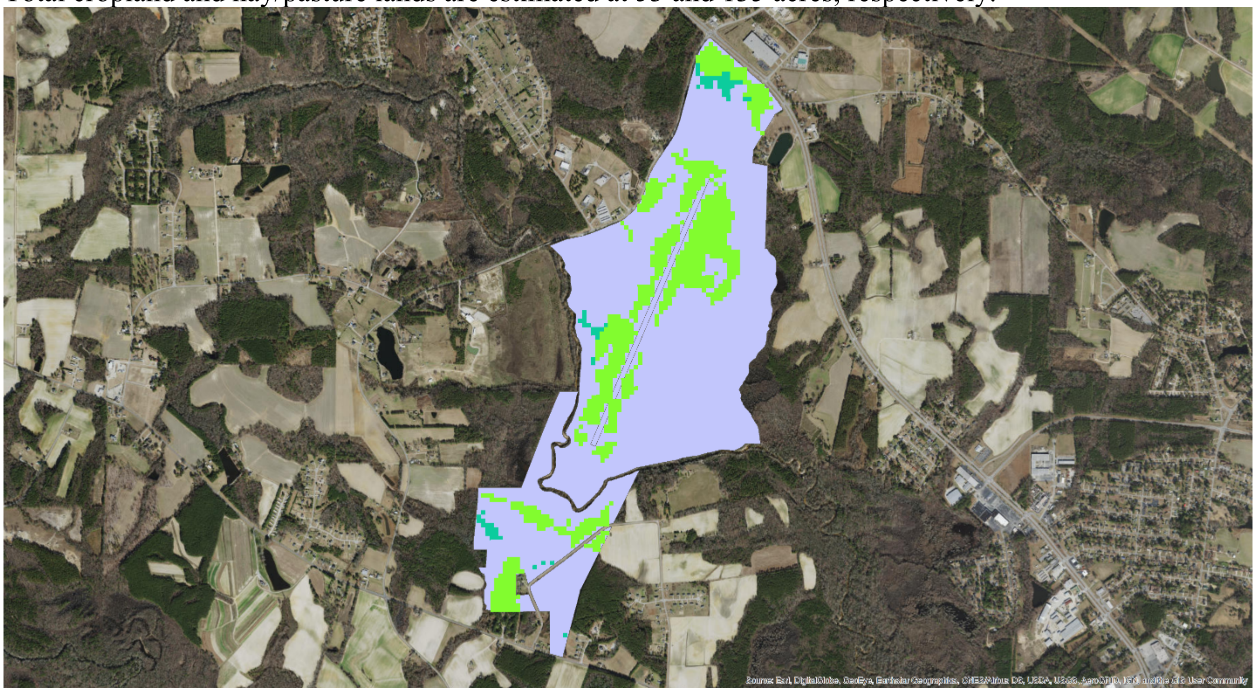


Hyde County - Land Cover

Land Cover	Acres
Open Water	0.00
Developed, Open Space	76.73
Developed, Low Intensity	9.56
Developed, Medium Intensity	4.89
Developed, High Intensity	0.00
Deciduous Forest	0.00
Evergreen Forest	0.00
Mixed Forest	0.00
Shrub/Scrub	0.00
Herbaceuous	0.00
Hay/Pasture	**0.00**
Cultivated Crops	**288.22**
Woody Wetlands	0.00
Emergent Herbaceuous Wetlands	0.00
Total	379.40

Johnston County Airport – Johnston County

Approximately 145 of the 644 total acres at Johnston County airport are suitable for camelina production based on criteria 1 through 4. Most of these acres are localized near the runway or alongside highway 70. Total cropland and hay/pasture lands are estimated at 53 and 135 acres, respectively.



Johnston County - Land Cover

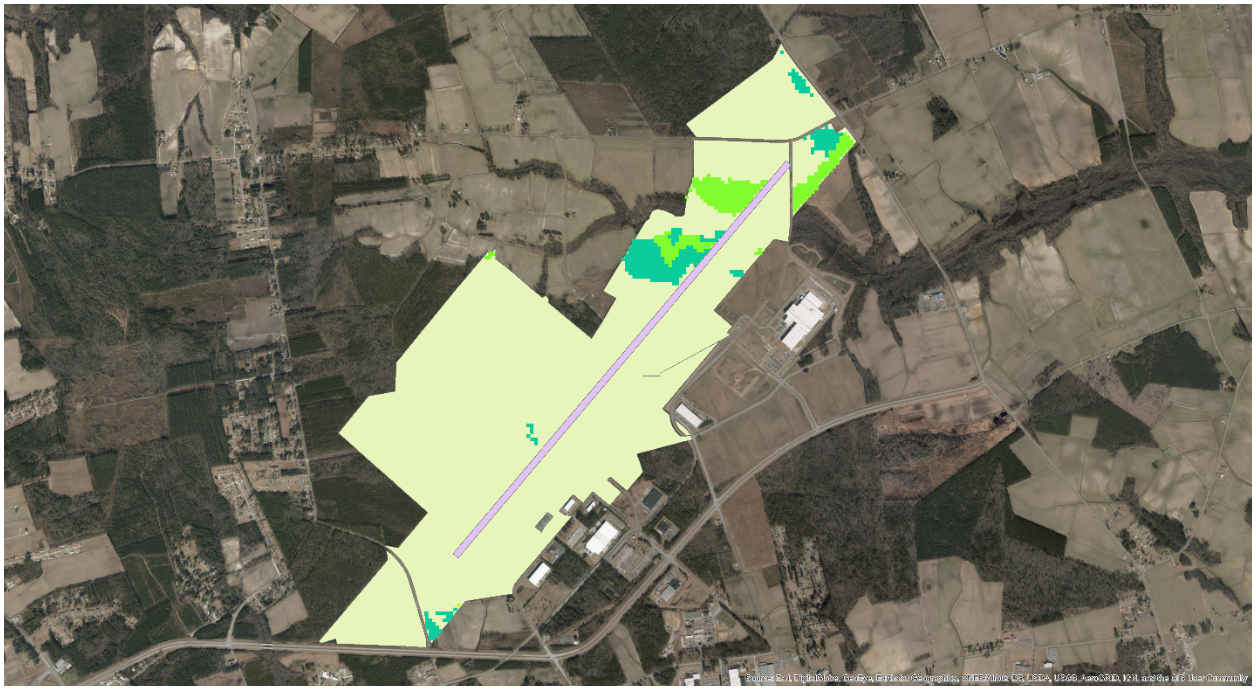
Land Cover	Acres
Developed, Open Space	2.89
Developed, Low Intensity	7.78
Developed, Medium Intensity	5.12
Developed, High Intensity	37.58
Deciduous Forest	14.68
Evergreen Forest	54.04
Mixed Forest	66.50
Shrub/Scrub	11.34
Herbaceuous	32.69
Hay/Pasture	**134.77**
Cultivated Crops	**53.37**
Woody Wetlands	115.42
Emergent Herbaceuous Wetlands	104.97
Total	641.16

Johnston County - Drainage

Drainage	Acres
Excessively Drained	0.00
Well Drained	134.73
Moderately Well Drained	10.40
Total	145.13

Kinston Regional Jetport – Lenoir County

Kinston Regional Jetport comprises of 1233 total acres with approximately 200 acres classified as cropland or hay/pasture lands. 91 acres within the cropland and hay/pasture lands are suitable for camelina production given the restrictions outlined in criteria 1 through 4.



Lenoir County - Land Cover

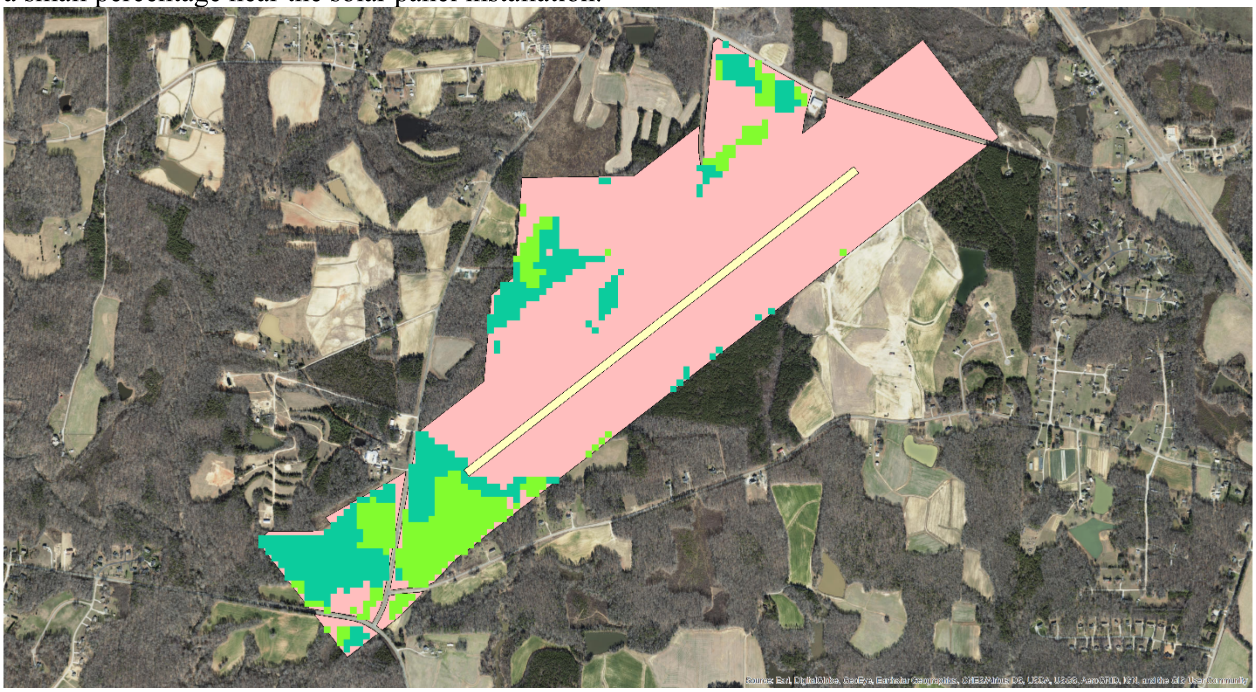
Land Cover	Acres
Developed, Open Space	290.67
Developed, Low Intensity	50.26
Developed, Medium Intensity	127.88
Developed, High Intensity	44.70
Barren Land	4.89
Deciduous Forest	48.26
Evergreen Forest	21.57
Mixed Forest	32.25
Shrub/Scrub	79.39
Herbaceuous	87.85
Hay/Pasture	**0.22**
Cultivated Crops	**199.93**
Woody Wetlands	187.70
Emergent Herbaceuous Wetlands	23.35
Total	1198.93

Lenoir County - Drainage

Drainage	Acres
Excessively Drained	0.15
Well Drained	45.16
Moderately Well Drained	45.90
Total	91.22

Person County Airport – Person County

Person County airports overall land space is 456 acres with nearly 111 acres suitable for camelina production. The majority of the well drained property is localized to the southwest end of the runway with a small percentage near the solar panel installation.



Person County - Land Cover

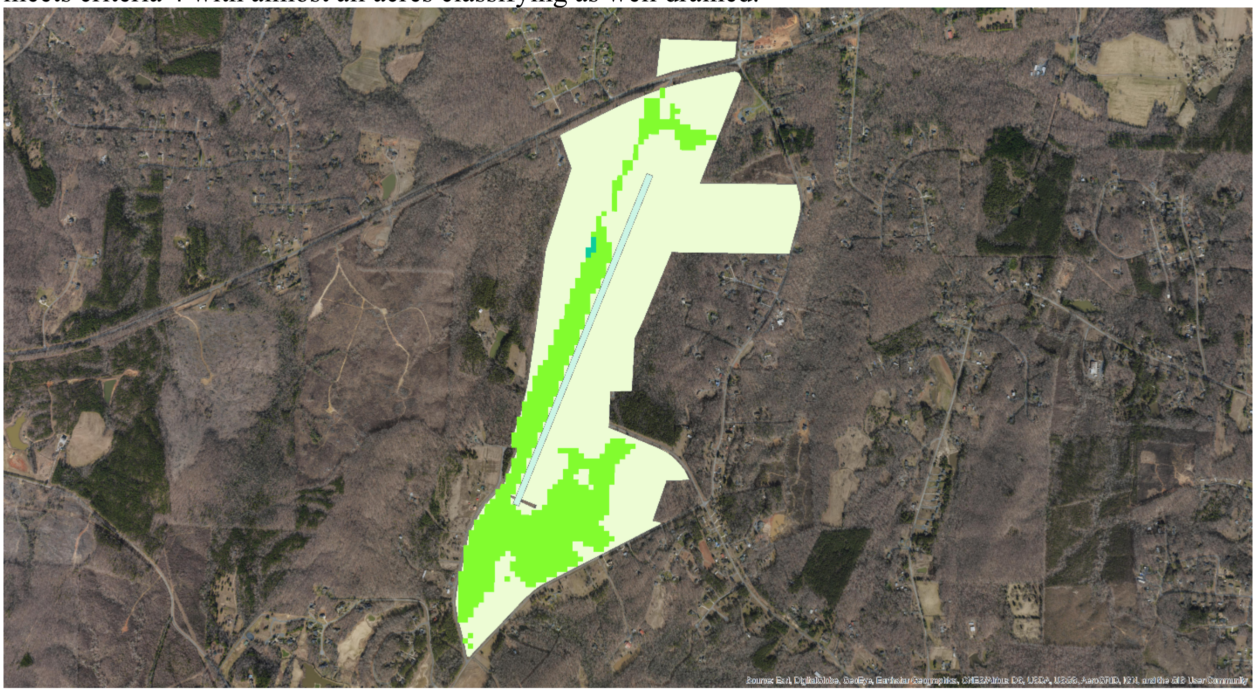
Land Cover	Acres
Open Water	2.00
Developed, Open Space	212.61
Developed, Low Intensity	30.47
Developed, Medium Intensity	23.57
Developed, High Intensity	2.67
Deciduous Forest	15.12
Evergreen Forest	2.45
Mixed Forest	2.67
Shrub/Scrub	5.34
Herbaceuous	29.80
Hay/Pasture	**111.86**
Cultivated Crops	**3.78**
Emergent Herbaceuous Wetlands	1.11
Total	443.45

Person - Drainage

Drainage	Acres
Excessively Drained	0.00
Well Drained	47.87
Moderately Well Drained	63.04
Total	110.90

Asheboro Municipal Airport – Randolph County

Asheboro Municipal airport shows promise with approximately 119 acres of hay/pasture land that also meets criteria 4 with almost all acres classifying as well drained.



Randolph County - Land Cover

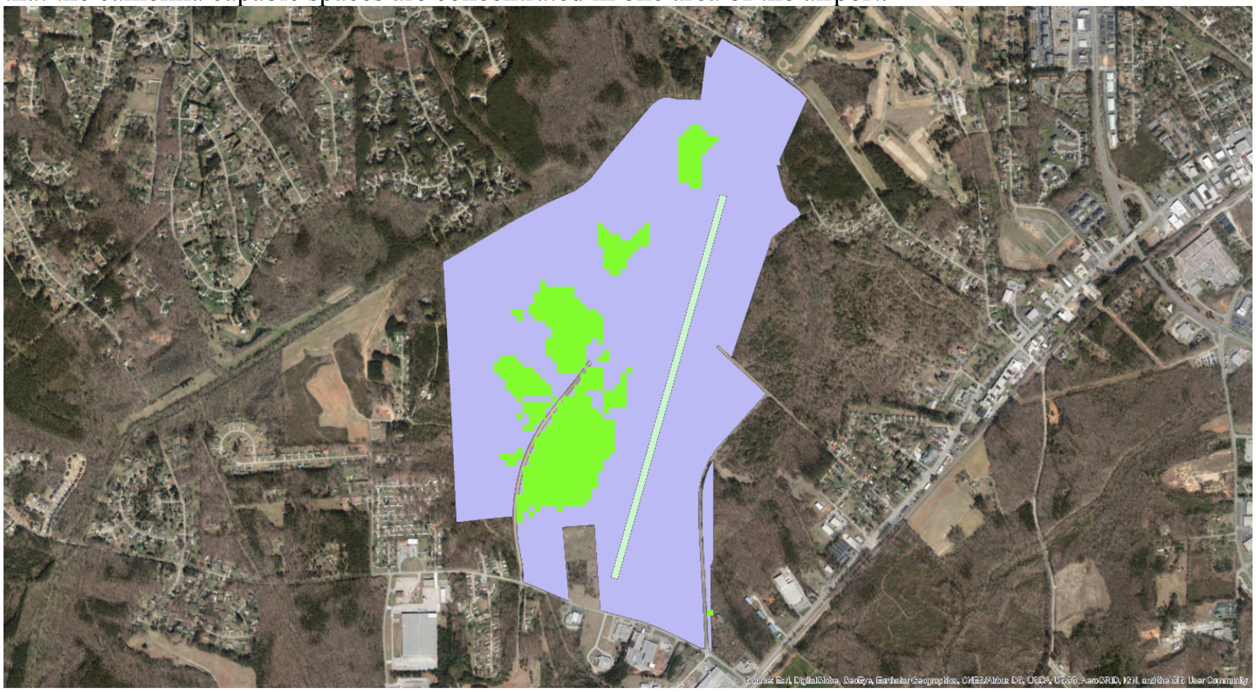
Land Cover	Acres
Developed, Open Space	31.14
Developed, Low Intensity	22.46
Developed, Medium Intensity	43.81
Developed, High Intensity	4.23
Deciduous Forest	148.78
Evergreen Forest	2.45
Mixed Forest	6.67
Shrub/Scrub	22.46
Herbaceuous	1.33
Hay/Pasture	**126.99**
Total	410.32

Randolph - Drainage

Drainage	Acres
Excessively Drained	0.00
Well Drained	118.09
Moderately Well Drained	0.74
Total	118.83

Rowan County Airport – Rowan County

Rowan County airport is 560 acres in total space with 490 acres classified as well drained. Of these acres only 80.7 acres meet the requirements outlined in criteria 1. However, it would be an attractive site given that the camelina capable spaces are concentrated in one area of the airport.



Rowan County - Land Cover

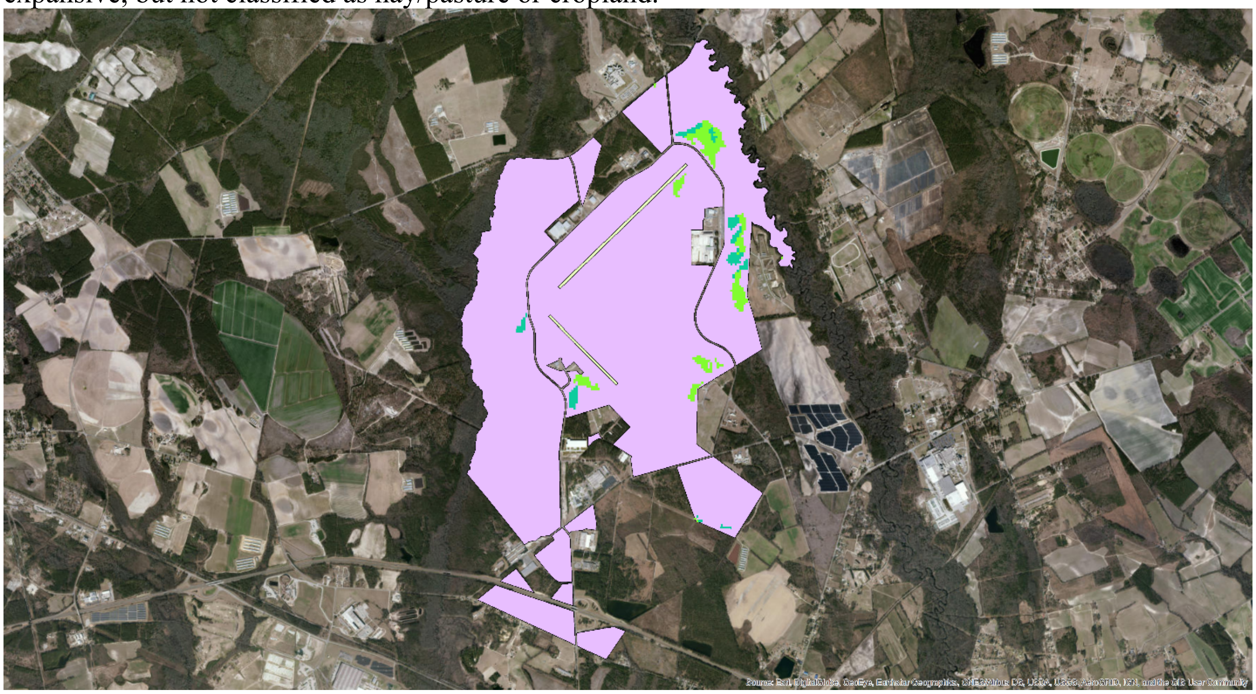
Land Cover	Acres
Developed, Open Space	147.89
Developed, Low Intensity	36.47
Developed, Medium Intensity	35.14
Developed, High Intensity	20.91
Deciduous Forest	148.11
Evergreen Forest	34.03
Mixed Forest	1.33
Shrub/Scrub	9.34
Herbaceuous	22.68
Hay/Pasture	**82.06**
Woody Wetlands	11.56
Total	549.54

Rowan - Drainage

Drainage	Acres
Excessively Drained	0.00
Well Drained	80.70
Moderately Well Drained	0.00
Total	80.70

Laurinburg-Maxton Airport – Scotland County

Of the 2951 acres available at Laurinbug-Maxton airport only 91 acres are suitable for camelina production given the criteria outlined. Most of the land at this airport is nestled between the two remaining runways just beyond the eastern most runway. The space between the three runways is expansive, but not classified as hay/pasture or cropland.



Scotland County - Land Cover

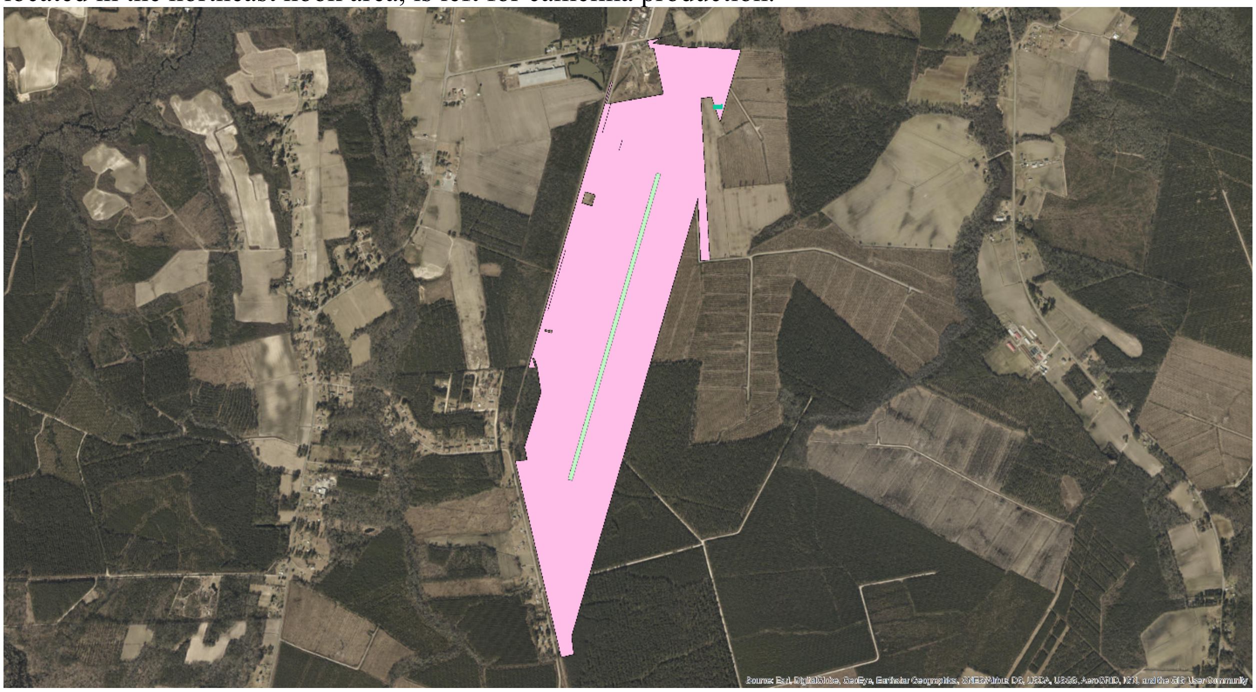
Land Cover	Acres
Open Water	14.01
Developed, Open Space	933.61
Developed, Low Intensity	185.25
Developed, Medium Intensity	119.20
Developed, High Intensity	3.56
Deciduous Forest	37.81
Evergreen Forest	272.65
Mixed Forest	11.79
Shrub/Scrub	230.18
Herbaceuous	59.60
Hay/Pasture	6.23
Cultivated Crops	119.43
Woody Wetlands	807.73
Emergent Herbaceuous Wetlands	150.34
Total	2951.39

Scotland - Drainage

Drainage	Acres
Excessively Drained	0.00
Well Drained	62.59
Moderately Well Drained	28.89
Total	91.48

Plymouth Municipal Airport – Washington County

Plymouth Municipal airport retains approximately 294 acres excluding the runway area. However, all but 2 acres of the airport is classified as either poorly drained or very poorly drained effectively eliminating it from consideration. Furthermore after applying the land use filter to the airport space only 0.23 acres, located in the northeast hook area, is left for camelina production.



Wilkes County Airport – Wilkes County

Wilkes County airport is predominately well drained showing 286 of the total 294 available acres as better than moderately well drained. However, only 80 acres meet the hay/pasture land cover qualification. After applying criteria 1 through 4 the airport is left with 72 acres available for camelina production.

Wilkes County - Land Cover

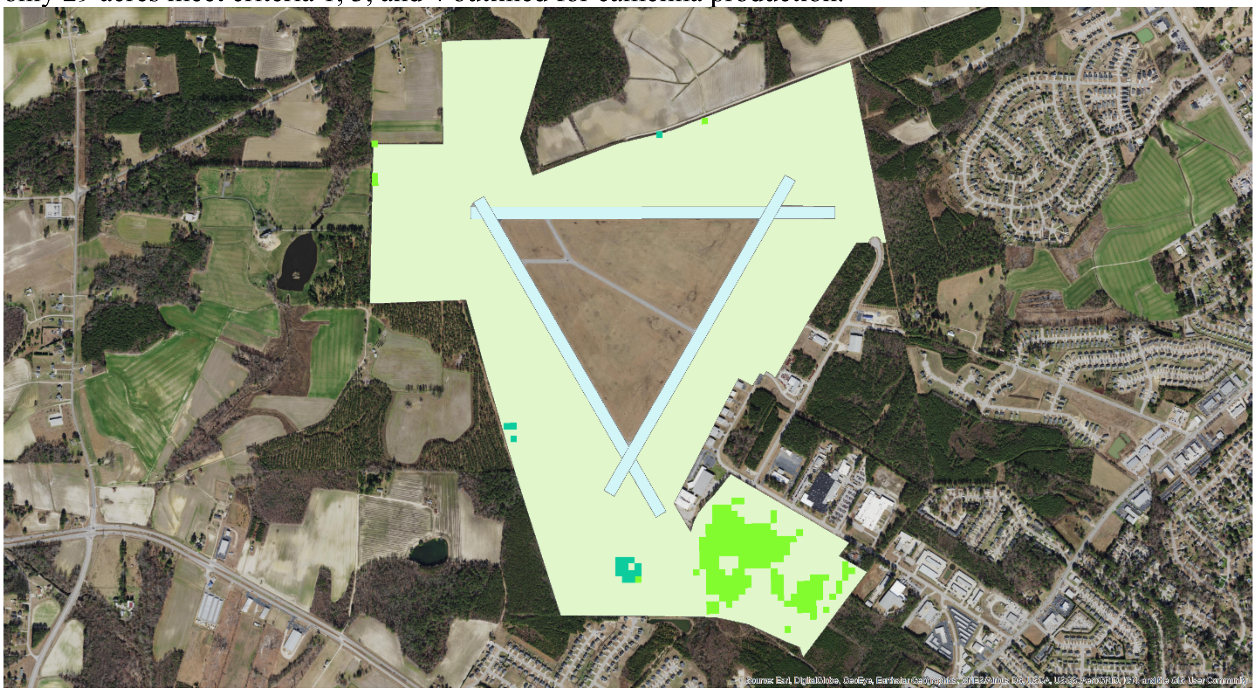
Land Cover	Acres
Developed, Open Space	60.71
Developed, Low Intensity	29.36
Developed, Medium Intensity	31.80
Barren Land	0.44
Deciduous Forest	52.93
Mixed Forest	1.33
Shrub/Scrub	18.01
Herbaceuous	22.24
Hay/Pasture	**80.06**
Total	296.90

Wilkes County - Drainage

Drainage	Acres
Excessively Drained	0.00
Well Drained	72.30
Moderately Well Drained	0.00
Total	72.30

Wilson Industrial Air Center – Wilson County

Wilson Industrial Air Center provides 632 acres of total land space. Criteria 3 limits the usage of the property between the three runways. This decreases the effective land available to 485 acres of which only 29 acres meet criteria 1, 3, and 4 outlined for camelina production.



Wilson County - Land Cover

Land Cover	Acres
Open Water	6.45
Developed, Open Space	142.78
Developed, Low Intensity	23.80
Developed, Medium Intensity	24.46
Developed, High Intensity	2.00
Deciduous Forest	62.27
Evergreen Forest	33.58
Mixed Forest	17.57
Shrub/Scrub	11.34
Herbaceuous	105.64
Hay/Pasture	**25.13**
Cultivated Crops	**20.02**
Woody Wetlands	5.78
Emergent Herbaceuous Wetlands	6.00
Total	486.82

Wilson County - Drainage

Drainage	Acres
Excessively Drained	0.00
Well Drained	26.57
Moderately Well Drained	2.36
Total	28.93

APPENDIX E: SITE SELECTION INFORMATION STUDIED AIRPORTS

Duplin County Airport

Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
AuB	Autryville loamy fine sand, 0 to 6 percent slopes	22.5	88.2%
WoA	Woodington loamy fine sand, 0 to 1 percent slopes	3.0	11.8%
Totals for Area of Interest		**25.5**	**100.0%**

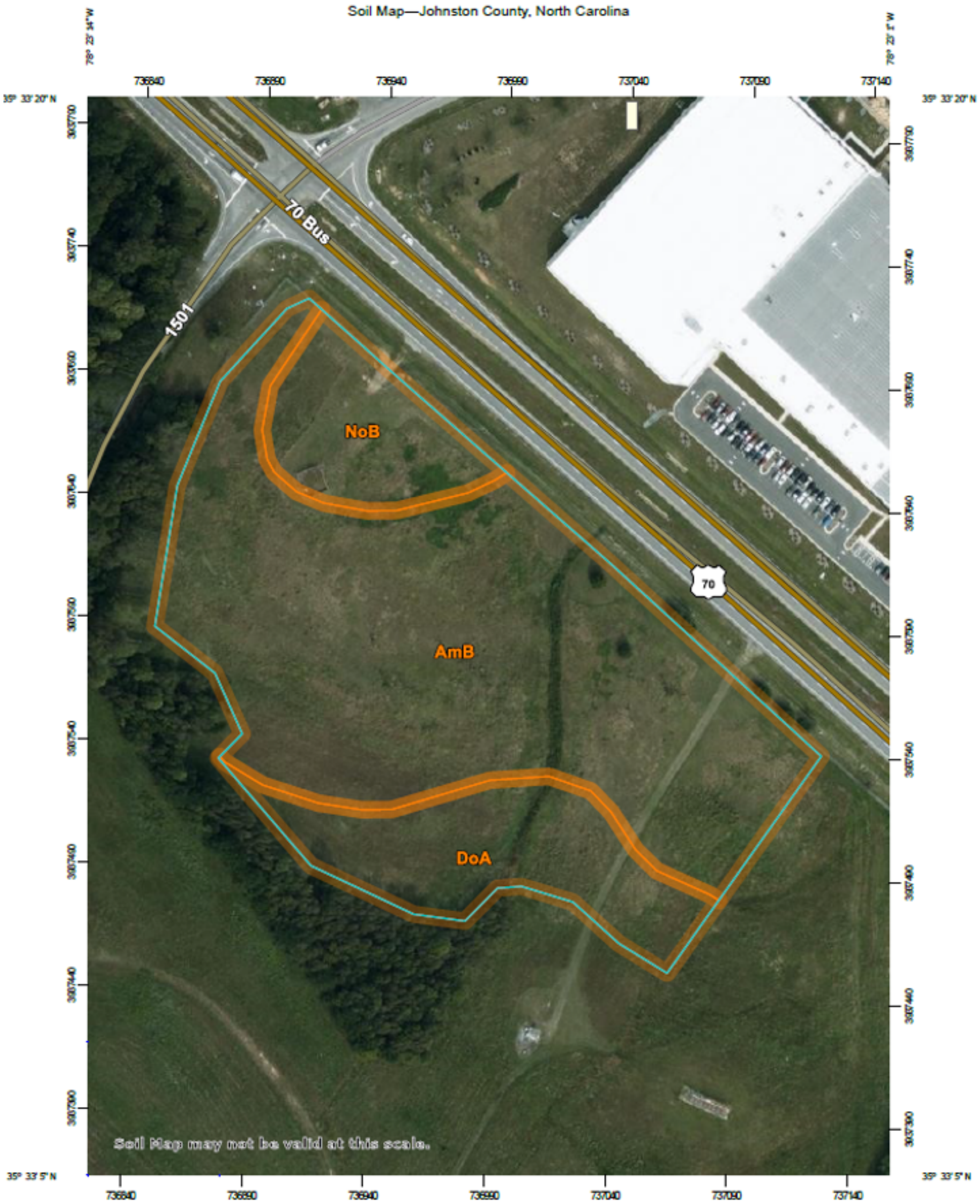
Person County Airport

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
HfB	Helena-Sedgefield sandy loams, 2 to 6 percent slopes	13.7	95.5%
VaB	Vance sandy loam, 2 to 6 percent slopes	0.7	4.5%
Totals for Area of Interest		**14.4**	**100.0%**

Kinston Regional Jetport

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
Mu	Murville fine sand	3.3	34.6%
Pa	Pactolus loamy sand	6.1	64.0%
Po	Pocalla loamy sand, 0 to 6 percent slopes	0.1	1.5%
Totals for Area of Interest		**9.5**	**100.0%**

Johnston County Airport



Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
AmB	Appling-Marlboro complex, 1 to 6 percent slopes	7.1	70.7%
DoA	Dorian fine sandy loam, 0 to 2 percent slopes, rarely flooded	1.8	17.8%
NoB	Norfolk loamy sand, 2 to 6 percent slopes	1.2	11.4%
Totals for Area of Interest		**10.1**	**100.0%**