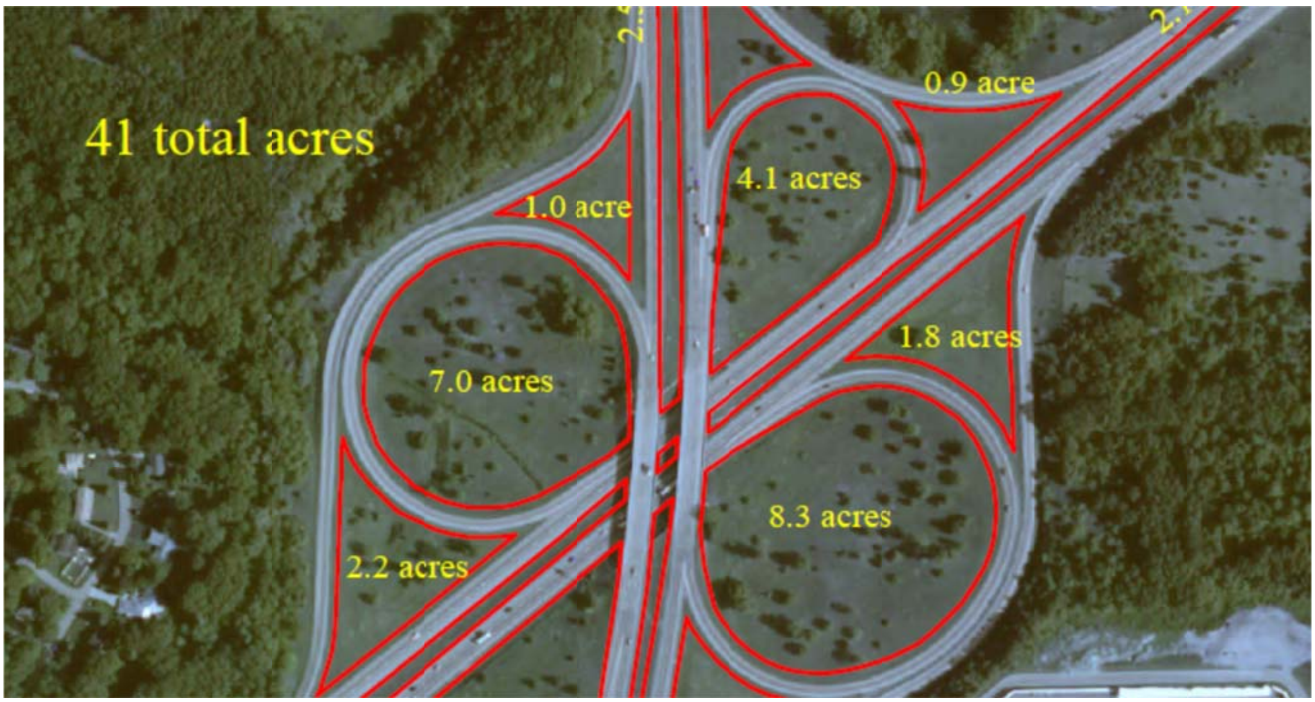
Exploring the Feasibility of Growing, Harvesting and Utilizing Bioenergy Crops on Non-traditional Cropland in Michigan.

M. Charles Gould



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For more information contact:

M. Charles Gould
Extension Educator-Agricultural Energy Efficiency and Bioenergy/Bioproducts
Agriculture and Agribusiness Institute
Michigan State University

12220 Fillmore St, Suite 122
West Olive, MI 49460
Toll Free: 1-888-678-3464, Ext.O-T-T-A-W
Phone: (616) 994-4580
gouldm@msu.edu

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Ted Barrett
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Michigan State University Extension

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Michigan State University
Product Center for Agriculture and Natural Resources

Terry McLean
Michigan State University Extension

Dennis Pennington
Michigan State University Extension

Rebecca Rogers
Michigan State University Extension
Michigan Natural Features Inventory

Ed Schools
Michigan State University Extension
Michigan Natural Features Inventory

Mark Seamon
Michigan State University Extension

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Abstract

The purpose of this project was to explore the feasibility of growing, harvesting and utilizing bioenergy crops on non-traditional cropland that include areas along Michigan roadways and vacant urban lots for energy use such as biofuel, heat and electricity production. An estimate of limited access highway and right of way areas that could be utilized for bioenergy crop production is between 9,516 and 11,895 acres. There is approximately 17,000 acres of land within State Game Areas (SGAs) under cultivation or in pasture. It is estimated that there is 5,000 acres in Detroit and 1,242 acres in Genesee County (Flint area) that could potentially be used to grow bioenergy crops. Michigan has over 200 municipal airports. The Bishop Airport, Muskegon County Airport, Metro Detroit Airport and Willow Run Airport indicate there are approximately 50, 500, 1,169 and 814 acres respectively of potentially useable land for bioenergy crop production.

Bioenergy crops switchgrass (Panicum virgatum), camelina (Camelina sativa), field pennycress (Thlaspi arvense L.), canola (Brassica napus), and oriental mustard (Brassica juncea) were included in the project because they will grow in Michigan.

Opportunities associated with growing bioenergy crops include the following:

- Non-traditional cropland does not compete with land used for the production of food.
- Growing bioenergy crops has the potential to generate economic activity and jobs on land that currently does not generate income or jobs.
- There are well established markets for some bioenergy crops.
- Potential for Michigan Department of Transportation to run their fleet on biodiesel produced from oilseed crops grown on non-traditional cropland.
- Reduced dependence on crude oil-based fuels.

Barriers associated with growing bioenergy crops include the following:

- Getting farm equipment on/off highways.

- Federal and state regulations.
- Plant height.
- Fair to poor soils.
- Potential wildlife attractant.
- Undeveloped markets for some bioenergy crops.
- Michigan lacks the capacity to crush canola, camelina, pennycress and oriental mustard and densify switchgrass.
- New markets can become quickly saturated.
- For some bioenergy crops there are no registered herbicides for weed control.
- Lack of knowledge about growing some bioenergy crops.
- Limited parcel size in right-of-ways and urban areas

I. Introduction

Background

Michigan has the highest rate of unemployment in the nation (15.1%) and has lost 262,700 jobs during the past year (United States Department of Labor, 2009). The Energy Independence and Security Act of 2007 increased the mandated Renewable Fuels Standard (RFS) to 36 billion gallons of renewable fuels by 2022, of which 21 billion gallons must be derived from cellulosic feedstocks. In Michigan, the 2008 Renewable Portfolio Standard requires that 10% of the state's electrical energy supply come from renewable sources by 2015. There is an estimated 1.4 million acres in Michigan highway road right-of-ways with additional urban vacant lands that could be used to grow and harvest biomass and other energy crops. This could be a significant resource in helping Michigan to achieve renewable energy objectives, generate rural economic activity, create jobs and reduce our carbon footprint. If we can produce/harvest biomass on just 10% of that land, we could produce 20.16 million gallons of ethanol or generate 290,000 megawatts of electricity[1] annually.

[1] Assumes 140,000 acres of harvestable land and a biomass yield of 2 dry tons per acre.

Purpose

The purpose of this project is to explore the feasibility of growing, harvesting and utilizing bioenergy crops on non-traditional cropland that include areas along Michigan roadways and vacant urban lots for energy use such as biofuel, heat and electricity production. The resulting data will be instrumental in identify potential barriers, opportunities, partners, sites, and crops for potential development and implementation of this project.

II. Objectives and Methods

The objectives and methods of this project are as follows:

Objectives	Methods
1. Establish a partner network.	A cross section of public and private sector entities will strengthen this program by offering complimentary skills. A wide area of industry including energy crop planning, establishment, production, processing and utilization will be needed.
2. Conduct a literature review.	Project partners will work collectively to identify related programs and research; their successes and barriers that could be incorporated into a potential Michigan project.
3. Quantify potential areas.	GIS support from the Michigan Natural Features Inventory will be utilized to quantify the area that could be utilized for producing and harvesting biomass energy and map those locations within the state. GIS layers to be used include soils, wetlands, brownfields, roads and highways, endangered and protected species, vegetative cover maps and aerial photos. Project partner meetings will be used to refine modeling and mapping protocol in an effort to more accurately describe potential areas, as well as follow state and federal highway maintenance regulations. Ground truthing at three sites will be conducted to further enhance the accuracy of the maps.
4. Identify potential barriers and opportunities.	Project partners will be engaged to identify any potential barriers and opportunities to producing/collecting/utilizing biomass including safety related issues, production related problems, laws and regulations. Input from MDOT and regulatory agencies will be highly valued.
5. Conduct basic economic analysis.	The MSU Product Center for Agriculture will conduct an initial cost/benefit economic analysis of the potential of producing renewable energy utilizing non-traditional cropland, particularly highway right of ways.

6.	Determine basic research plot protocol.	Project partners will utilize the GIS maps and information from the economic analysis to identify research needs and establish protocols for future research. It is the intent to use this protocol to seek additional funding.
7.	Set the direction for future work.	Prepare a final report that will help determine the scope of this project as well as provide a roadmap for future work in this area. This project will act much like a feasibility study – it will be used to determine if future work in this area is warranted and what work needs to be done.
8.	Dissemination of project information.	The final report will be posted on a MSU Extension web site and an article summarizing the final report will be drafted for distribution to the press through ANR Communications. A poster will be developed for the NACAA AM/PIC in Oklahoma and a presentation will be developed for use when speaking to groups.

III. Discussion

Objective 1. Establish a partner network

Individuals from academia, government and the private sector with expertise in economics, transportation infrastructure and energy crop planning, establishment, production, processing and utilization were selected to provide guidance to the project. Their names, affiliation and area of expertise are listed below:

Ted Barrett, CEO, Mid-Michigan Recycling - Expertise in biomass transportation and combustion.

Charles Gould, Bioenergy and Bioproducts Educator, MSU Extension - Expertise in biomass fuel-to-energy processes.

Darwyn Heme, Resource Analyst, MDOT - Expertise in interpreting Michigan and Federal laws pertaining to highway right-of-ways.

Adam Kantrovich, Ottawa County Extension Director, MSU Extension - Expertise in budgets and recordkeeping, as well as crop production.

Bill Knudson, Product Marketing Economist, MSU Product Center - Expertise in conducting feasibility studies.

Terry McLean, Horticulture Educator, MSU Extension - Expertise on urban land utilization.

Dennis Pennington, Bioenergy Educator, MSU Extension - Expertise on biomass crop selection and production.

Rebecca (Becca) Rogers, GIS Information Specialist, Michigan Natural Features Inventory - Expertise on using GIS to solve problems.

Ed Schools, GIS Information Manager, Michigan Natural Features Inventory - Expertise on using GIS to solve problems.

Mark Seamon, Bioeconomy Innovation Counselor, MSU Extension - Expertise on biomass crop selection and production.

Kurt Thelen, Bioenergy Cropping Systems Agronomist, MSU - Expertise on plot design and biomass crop production systems.

Scott Wheeler, Resource Specialist, MDOT - Expertise pertaining to biomass crop management on Michigan highways.

Sixty minute conference calls were held on the 3rd Monday of every month from February through August, 2010 with everyone on the work team, as well as Terri Novak, Grant Administrator, with the Michigan Department of Energy, Labor and Economic Growth.

Objective 2. Literature review

A review of literature on the planning, establishment, production, processing, utilization and economics of switchgrass (*Panicum virgatum*), camelina (*Camelina sativa*), pennycress (*Thlaspi arvense* L.), canola (*Brassica napus*), oriental mustard (*Brassica juncea*) and existing biomass yielded is found in Appendix A. These crops were chosen because they will grow in Michigan. Switchgrass is grown for biomass while camelina, pennycress, canola and oriental mustard are grown for the oil in the seed. Seeds are harvested, crushed to extract the oil, and the oil is processed into biodiesel.

Objective 3. Quantify potential sites for bioenergy crop production

a. Medians and highway interchanges

The overall process consisted of converting limited access highway centerlines to a polygon dataset, manually assessing each polygon for potential useable area, removing restricted areas and mapped wetlands, and then using field testing to adjust the initial results. All polygons (i.e. sites) were designated in one of four ways:

- Less than 20% of polygon is usable.
- 20% - 50% of polygon is usable.

- 50% - 80% of polygon is usable.
- Greater than 80% of polygon is usable.

Field testing (or ground truthing) each site is necessary to validate the area of the site usable for bioenergy crop production. Factors that affect usability, but are not detectable from the aerials, include traffic patterns, topography, wetness and ecological succession in the time since the aerials were taken (2005). It was observed that no two sites are the same. After conducting site visits, 76 of the 316 polygons were rejected as being unsuitable for bioenergy crop production. The amount of useable area within the accepted polygons varied from 10% to 100% with an average of 73% of the polygon area estimated as usable.

An estimate of highway right of way area that could be utilized for bioenergy crop production, including only highway medians and interchange polygons larger than one acre, and after accounting for some areas not being useable or only partially useable, is 9,516 acres. Because other parts of the highway right of way have the potential to be utilized, 9,516 acres should be considered a very conservative estimate. A better estimate would include other parts of the highway right of way that have the potential to be utilized. Medians seem to have more potential for cropping but may be limited in area if MDOT requires mowing along each paved area.

If one includes other parts of the limited access highway rights of way, the estimate of available land ranges from 10,468 acres, assuming 10% additional right of way is available, to 11,895 acres, assuming 25% additional right of way is available. The true value lies somewhere between these two estimates. A reasonable estimate of the limited access highway medians and other rights of way potentially available for bioenergy crop production is 11,182 acres, which is the average of the 10,468 acre estimate and the 11,895 acre estimate. The complete report can be found in Appendix B.

It should be noted that the strategic removal of trees and shrubs on sites where greater than 80% of polygon is usable would increase the number of acres available for bioenergy crop production. Trees and shrubs removal may be the largest hurdle to crop production. Site visits also allowed for observation of traffic patterns. Some sites were eliminated because the projected interface between vehicles and farm equipment was deemed unsafe.

Spatial analysis was performed using ESRI ArcGIS ver 9.3 software. Datasets utilized in the analysis include the Michigan Framework version 9b, National Wetland Inventory (NWI), Michigan Department of Transportation Managed Areas, and National Agriculture Imagery Program (NAIP) imagery.

b. State game areas

Utilizing the remotely sensed Cropland Data Layer (U.S. Department of Agriculture 2008), approximately 17,000 acres of land within State Game Areas (SGAs) are in cultivation or pasture (see Appendix B for the acreage by SGA). The primary purpose of the SGAs is wildlife restoration. All management activities on these properties must meet this objective to fulfill the requirements of the federal funding used to purchase them. Bioenergy crop production as part of wildlife restoration activities could be allowed. Utilization of SGA land for growing oilseed and biomass crops will require that the system used to grow and harvest these crops be compatible with, and help meet, the management objectives for the SGAs. Close coordination with the Michigan Department of Natural Resources and Environment Wildlife Division will be required to determine the likelihood of growing bioenergy crops and to quantify the actual area available for bioenergy crop production.

c. Urban sites

Information on vacant urban lots is hard to come by. There seems to be data for the Detroit and Genesee County areas, but very little beyond that. It is estimated that there are 5,000 vacant acres in Detroit (three times that amount or 15,000 acres when including lots with buildings on them). As part of this analysis, the utility of property owned by the Genesee County Land Bank (Genesee County Land Bank 2010) for bioenergy crop production was briefly examined. The Genesee County Land Bank ownership tends to be properties that have been abandoned or foreclosed on because of unpaid taxes. Other Michigan Counties also have land banks. At the time of this analysis, after dissolving adjoining parcels together, the Genesee County Land Bank owned 3,221 separate parcels that ranged in size from less than 0.001 acres up to 153 acres with a total of 1,242 acres.

In general, the Genesee County Land Bank properties tend to be smaller parcels disjunct from each other. The properties also tend to be urban in nature, some with buildings on them. There are, however, some larger land holdings. These larger holdings, in particular those close to other areas utilized for bioenergy crop production, could add to the total area useable for growing bioenergy crops. Further analysis will be required to determine the utility and potential of land bank properties.

d. Airports

Michigan has over 200 municipal airports. Informal discussions with personnel from the Bishop Airport, Muskegon County Airport, Metro Detroit Airport and Willow Run Airport indicate there are approximately 50, 500, 1,169 and 814 acres respectively of potentially useable land for bioenergy crop production. Appendix B shows the approximate locations of potentially useable land at the Detroit Metro Airport and the Willow Run Airport. A more in depth analysis is required to determine the amount of land viable for bioenergy crop production at these and other airports. Quantifying the bioenergy crop production potential of Michigan airports will require one on one interface with each airport and is beyond the scope of this analysis and report. It does, however, have the potential to greatly add to the amount of land available for biofuel production.

Growing crops on state land has several desirable attributes-

- It does not compete with the production of food.
- It creates the potential to generate economic activity and jobs on land that currently does not generate income or jobs.
- It can reduce the cost of maintenance operations such as mowing.

Objective 4. Identify potential opportunities and barriers

As this report points out, there is plenty of non-traditional cropland in Michigan to grow bioenergy crops; however, there are some barriers that need to be overcome first. The following list sets forth the opportunities and barriers associated with growing bioenergy crops.

Opportunities/Benefits

- Non-traditional cropland does not compete with land used for the production of food.
- Growing bioenergy crops has the potential to generate economic activity and jobs on land that currently does not generate income or jobs.
- There are well established markets for some bioenergy crops.
- Potential for MDOT to run their fleet on biodiesel produced from oilseed crops grown on non-traditional cropland.
- Reduced dependence on crude oil-based fuels.

Barriers/Concerns

- Getting farm equipment on/off highways.
- Federal and state regulations.
- Plant height.
- Fair to poor soils.
- Potential wildlife attractant.
- Undeveloped markets for some bioenergy crops.
- Michigan lacks the capacity to crush canola, camelina, pennycress and oriental mustard and densify switchgrass.

- New markets can become quickly saturated.
- For some bioenergy crops there are no registered herbicides for weed control.
- Lack of knowledge about growing some bioenergy crops.
- Limited parcel size in right-of-ways and urban areas

None of the barriers are insurmountable. However, to address most of them will require working closely with the Michigan Department of Transportation (MDOT). A closer examination of some of the barriers is warranted. Please consider the following:

A. Equipment and personnel safety concerns

Safety around growing bioenergy crops adjacent to limited access highways is an issue that has not been fully addressed. MDOT is concerned with the ability of farming equipment to navigate around busy highways. A safety protocol will be developed to address this concern during Phase II.

B. Federal and state regulations

a. Right-of-way distances

Q1. What are the right-of-way distances on state-owned roads, county-owned roads, township-owned roads and federal highways? More specifically, how are they measured, from what point to what point?

Most right-of-way widths are 66' for state controlled "M" routes, county and local roads. Limited access highways ("I" & "US" routes) typically have right-of-way (ROW) widths ranging from 100-300'. On "M" routes, county, and local roads the ROW width is typically measured from the middle of the road, with half the total width measured to each side. On limited access roads the pavement may be located anywhere within the ROW however there is always ROW fence that defines the outside edges of the right-of-way.

Q2. Explain ownership of right-of-ways.

MDOT's ability to control the use of ROWs and encroachments is governed by the specific types of ROW ownership involved, of which there are several. MDOT's authority to manage roadside vegetation varies based on the type of ROW. Some frequently encountered ROW definitions (note that some types of ROWs may fit into one or more definitions) include:

- Fee ROWs - acquired on behalf of the public and provides MDOT with full and complete ownership. MDOT may construct, maintain and improve the roadway within the limits of the ROW, including management of roadside vegetation.
- Dedicated ROWs - that part of a tract of land which the owner sets apart for a specific purpose and dedicates to that purpose. MDOT, as the jurisdictional roadway authority of a specific roadway, is subject to those rights that may have been reserved as a condition of the dedication. Maintenance of vegetation is one condition that can be included in a dedication of ROW.
- Operational ROWs - where MDOT has the authority to issue permits in operational state trunk line ROWs. An operational ROW is defined as all existing ROWs as shown in the county ROW books. The ROW width is as shown in the books and may be defined in the deed for fee ROW, or by law as in statutory ROW. In the case of new construction with new ROW, it becomes operational ROW when Real Estate certifies that the ROW is clear for letting a project. In this case, refer to the final ROW plans to determine the ROW width. The issue of the width of statutory ROW is dependent on its current use, including existing utilities.
- Statutory ROW - is also sometimes termed "ROW by prescription" or "user ROW". The statutory authority for this ROW is Public Act 285 of 1902, MCL 221.20. This form of ROW has generally been accepted as four rods (66 feet) in width and is shown as this width in the MDOT ROW map books. It is ROW for

which no compensation has been paid and no instrument of conveyance has been given. MDOT regulates the full 66-foot width with the permit process as to its own interests. Since MDOT does not own the fee title to the land, anyone seeking permission to use the ROW (utility companies, etc.) may also have to obtain the permission of the fee holders. There are a number of Supreme Court rulings regarding statutory ROW.

- Limited Access ROW - is acquired in fee simple, which establishes a boundary over which the abutting property owners are denied any rights of direct access, ingress or egress. The rights of ingress and egress are compensable items, which must be acquired. This type of ROW may be used for any highway related purpose.
- Easement ROW - is a permanent ROW granted by the property owner for the benefit of the public, generally for a specific purpose. One activity benefitting the public within easement ROW is the management of roadside vegetation. Where MDOT maintains a road adjacent or through Federal lands the roadway is typically maintained as an easement. Any work outside of the paved shoulder, including vegetation management, requires a Federal permit. An easement for clear vision purposes or drainage purposes normally conveys only the limited rights.

Q3. Explain any potential right-of-way land use restrictions.

All road authorities (state, county and local) must maintain a "clear zone" defined as "that roadside border area, starting at the edge of the traveled way, available for safe use by errant vehicles". The clear zone receives the most consistent vegetation management. Some type of vegetation management will occur in this area on a regular basis (typically vegetation is maintained to a maximum height of 12") to eliminate any hazards presented by plant growth. Typically this area varies in width anywhere from

30-50' or more depending on the design speed of the roadway, design average daily traffic (ADT) volumes, whether the area is a cut or fill slope and the slope of the area.

For the majority of state controlled "M" routes, county, and local roads, maintaining the required clear zone would eliminate the possibility of utilizing the ROW for growing bioenergy crops. Also these roads are located within easement ROWs which would require land owner permission to utilize their property. Road authorities can only manage vegetation on easement ROW for safety related purposes.

b. Hay production and harvesting

Under certain circumstances, forages may be harvested from ROWs, but not medians. The conditions are specified in two MDOT documents found in Appendix C entitled *Cutting Grass/Hay in Limited Access* and *Special Conditions for Harvesting Hay*. In general, the conditions are site specific and restrictive. For example, point 4 of *Special Conditions for Harvesting Hay* states that “No other type of farming shall be allowed such as plowing and planting of a crop”. Unless this is changed, this effectively eliminates planting and growing bioenergy crops on limited access land.

C. Soil sample test results

Eighteen soil samples were taken from 18 random sites across the state. Standard soil sampling protocol was followed. Nine of the soil test results were below optimum (low) in phosphorus and seventeen below optimum in potassium. Only four soil test results came back high in sodium. Organic matter content ranged from 1.6 to 5.4 percent, with the mean being 2.8 percent. Soil pH ranged from 6.8 to 8.2 in seventeen samples, with one sample coming in at 5.7. A summary of the soil test results is found in Appendix D. A map of soil sample locations is found in Appendix E.

There is a need to increase soil fertility. It was observed that the majority of soils were fair to poor in texture and tilth. Some soils seemed to be capable of only producing a marginal cover of vegetation. The majority of soils have been disturbed (i.e. mechanically moved and shaped). Soils can be improved with the application of compost known to have high beneficial microbial diversity. Medians appear to have a higher quality soil more suited for supporting bioenergy crop production.

D. Potential wildlife attractant

The attraction of wildlife is an emerging issue in growing bioenergy crops adjacent to airports and highways. It is feared that bioenergy crops will attract birds around runways and deer to highways that can pose threats to human safety and vehicle damage. However, little is known about bioenergy crops attracting undesirable birds and animals. It is known that deer will eat switchgrass (as long as it is palatable) and canola. Camelina, oriental mustard and pennycress are not mentioned in publications about wildlife food plots (Harper, 2008; Tarr, date unknown; Williams and Baxley, 2006). A wildlife specialist at Michigan State University talked with colleagues around the United States and discovered no one has research-based information on the impact of wildlife on camelina, oriental mustard and pennycress (Gould, 2010).

All the oilseed crops selected for inclusion in this study are members of the mustard family. Plants in this family typically have a disagreeable odor or taste that prevents animals from ingesting them. One study from Colorado State University reported deer damage to some camelina research plots, but the damage was not from deer eating camelina, it was from deer passing through it (see http://www.colostate.edu/depts/swcrc/pubs/tr10-6.pdf).

E. Undeveloped markets for some bioenergy crops.

Of the five bioenergy crops considered in this report, canola has by far the greatest market share. Canola is a futures market commodity, making it easy to sell. Canola oil can be sold for human consumption or biodiesel production. There are very limited to no markets for the other four bioenergy crops. The State of Michigan could jumpstart a market by using biodiesel made from the oil of these oilseed crops in MDOT and other State fleets.

F. Lack of processing facilities

Michigan has soybean crushing and oil extraction facilities. The equipment used to crush soybeans is not easily converted over to accept oilseeds smaller than soybeans. Canola, camelina, pennycress and oriental mustard all have seed smaller than soybeans. Soybean crushing equipment can be modified to accept a smaller seed, but it is expensive to do and time consuming. Right now the only crushing option for small oilseed is out of state. In-state crushing facilities that will accept small oilseeds would help spur the growth of the biodiesel industry in Michigan.

Switchgrass needs to be densified in the form of a pellet or briquette to be used as a green fuel for home heating or commercial power generation. The capacity to densify switchgrass on a large scale does not exist in Michigan. Facilities with the capability to densify switchgrass and other biomass crops would increase the use of pellets and briquettes in Michigan.

G. New markets can become quickly saturated.

Market saturation occurs when the demand for a bioenergy crop evens out and begins to decline. This might be due to factors such as surplus stores of a bioenergy crop, market price reduction, or weak demand for energy.

H. Lack of knowledge about growing some bioenergy crops

A lot is known about growing switchgrass and canola. Switchgrass is grown in Missouri and used to generate electricity or cellulosic ethanol. In 2009, 750,000 tons of canola was grown in the U.S. (see http://www.agmrc.org/commodities__products/grains__oilseeds/canola.cfm). Some is known about growing camelina and oriental mustard. Little is known about growing pennycress. The following is a brief overview on growing the four oilseed crops and switchgrass.

a. Camelina

Camelina is generally grown as a summer annual and is a member of the mustard family. It is a short-season crop that matures in 85-100 days. Camelina grows 1-3 feet tall and has branched stems that become woody as they mature. According to Montana's National Agricultural Statistics Service, nearly 12 million pounds of camelina were harvested in Montana from 19,500 acres in 2009. Camelina is well suited for marginal soils.

(Source: http://www.agmrc.org/commodities__products/grains__oilseeds/camelina.cfm)
(Source: http://extension.oregonstate.edu/catalog/pdf/em/em8953-e.pdf)

b. Field pennycress

Field pennycress is an annual that is a member of the mustard family and grows abundantly in the northern states. It will grow in waste places, open disturbed areas, roadsides, railroads, sometimes in grasslands, old fields, riparian areas and forest edges. It is considered a weed in small grains. Field pennycress grows up to 24 inches tall. It is a prolific seeder (about 7,000 seeds per plant) and forms a long-lived (up to 20-30 years) seed bank, making it difficult to eradicate from an area once it becomes common.

(Source: http://www.agmrc.org/commodities__products/grains__oilseeds/pennycress.cfm)

c. Oriental mustard

Oriental mustard is an annual plant that is well adapted to cool climates and will germinate at low soil temperatures (39°F). It has a short growing season, usually maturing in 90 to 95 days. Mustard is best adapted to grow in fertile, well-drained, loamy soils. Tap roots will grow 5 feet into the soil under dry conditions, which allows for efficient use of stored soil moisture. Plant height at maturity varies from 30 to 45 inches depending on type, variety and environmental conditions.

(Source: http://www.agmrc.org/commodities__products/grains__oilseeds/mustard.cfm)
(Source: http://www.hort.purdue.edu/newcrop/afcm/mustard.html)

d. Canola

Canola production is well suited for northern states. Winter canola varieties have a 20 to 30 percent greater yield potential than spring varieties. Winter survival has been a concern with the winter varieties in the region. However, through cooperative research efforts and public and private breeders, cold-tolerant varieties have been developed that produce competitive yields. Canola will grow 30-69 inches tall.

(Source: http://www.canola-council.org/chapter2.aspx)

(Source: http://www.ksre.ksu.edu/library/crpsl2/MF2734.pdf)

e. Switchgrass

Switchgrass is a perennial warm season bunchgrass native to Michigan that is capable of growing over eight feet tall. It is resistant to many pests and plant diseases, and it is capable of producing high yields with very low applications of fertilizer. Once the crop is established, the need for agricultural chemicals to grow switchgrass is low to nonexistent; however, fertilization may be necessary to maintain harvestable stands. Switchgrass also is very tolerant of poor soils, flooding and drought. Switchgrass is a valuable soil protection cover crop. It binds loose soils and provides valuable wildlife habitat. Switchgrass can be densified and combusted for energy production or used to produce cellulosic ethanol.

(See http://www.bladeenergy.com/Bladepdf/Blade_Switchgrass_Crop_Guide_2009.pdf)

(See http://www.agmrc.org/commodities__products/biomass/switchgrass.cfm)

There are herbicides labeled for weed control in canola and switchgrass but not for oriental mustard, camelina, and pennycress. There are herbicides that will kill all of these crops however.

(See http://msuextension.org/publications/AgandNaturalResources/MT200701Ag.pdf)

(See http://www.uwex.edu/ces/forage/pubs/switchgrass.pdf)

Objective 5. Conduct an economic analysis

An analysis of the cost of production and the breakeven price and yields was conducted for canola, switchgrass, pennycress and camelina grown on land adjacent to roads. A summary of the analysis follows. The complete report is found in Appendix F. It is very important to note that these are rough estimates. Some of the data is several years old. Adjustments for inflation were attempted to make the estimates more accurate, but the reality is that production practices have changed over time. More accurate estimates can be generated when data from test plots becomes available. A cost and viability issue with some of these crops is, in some cases, the need to apply herbicides. In some cases there are no herbicides that are registered for these crops. Good management practices may be necessary to minimize competition from weeds. These issues however, present some of the many additional needs for research and demonstration.

Canola

Winter canola is preferable to spring canola because yields tend to be higher and the costs slightly lower due to the reduced need to spray herbicides for weed control. However, Michigan experience has shown winter survival of winter canola is very low, which has severely limited the number of acres grown in the state. As a result, breakeven prices are lower for winter canola than spring canola. Breakeven prices vary from 16 cents a pound to 30 cents a pound for spring canola and from 13 cents a pound to 26 cents a pound for winter canola, depending on yield.

Switchgrass

Breakeven prices are based on a 10 year period (year 1 planting and establishment, and 9 years of harvest). Three different yields, 4, 6 and 8 tons of dry matter per acre, are used to estimate breakeven prices. The breakeven price varies from $30.07 per ton for the high yield estimate to $72.83 per ton for the low yield estimate. For a 5 percent rate of return the price varies from $40.78 a ton for the high yield estimate to $76.47 a ton for the low yield estimate. To obtain a

10 percent rate of return the price varies from $42.72 a ton for the high yield estimate to $80.11 a ton for the low yield estimate.

Camelina

Camelina has the potential to be profitable. In 2008, a Montana-based company offered contracts for the 2009 crop at 20 cents per pound. Breakeven prices vary from 6 to 8 cents per pound, depending on yield. A 5 percent rate of return ranges 6 to 9 cents per pound, and a 10 percent rate of return ranges from 7 to 10 cents per pound, depending on yield.

If herbicides are avoided, the breakeven prices decline by about ½ a cent per pound. Most of these costs are based on figures in Montana; the experience in Michigan may be different. Also, the yield figures may be optimistic. If actual yields are lower, break even prices will be higher. Furthermore, camelina is a minor crop. Small changes in output and acres planted could lead to a large decline in prices. Finding a market and locking in a price is very important.

Pennycress

Given the lack of hard data on pennycress these figures should be considered very rough estimates. The yield estimates are for Alberta and the cost estimates are based primarily on Montana figures. The experience in Michigan could be very different. Due to potentially higher yields the breakeven prices are lower for pennycress than they are for camelina, and are generally in the 4 to 6 cents per pound range.

Objective 6. Determine demonstration area protocol

Random soil samples were taken across the state to establish baseline data for bioenergy crop demonstration areas in Phase II of this project. Demonstration plots will be put in at six limited access sites, two airport sites, two urban sites and four agricultural sites. Demonstration plots will vary in size from one to three acres, except for the agricultural sites, which will be 25 acres. Limited access sites will grow oriental mustard and switchgrass, while urban and agricultural sites will grow switchgrass, canola, camelina, oriental mustard and pennycress.

An important determinant to include oriental mustard in the demonstration areas was the results of the fatty acid profile performed at Michigan State University (see Appendix G). A fatty acid profile is a measure of fatty acids that are most desirable for biodiesel production. The extraction of oil from oriental mustard seed with hexane resulted in approximately 35% oil yield. This is within the range seen in literature (28%-48%) for similar seeds. The oil was converted to fatty acid methyl esters and analyzed by gas chromatography. The results are as follows:

Total saturated fats	7%
Monounsaturated fat (oleic acid)	48%
Polyunsaturated fat (linoleic acid and alpha-linolenic acid)	42%
Unaccounted peaks	3%

Objective 7. Set direction for potential future work

A. Phase II and III projects

The knowledge learned from this project will be used to develop a Phase II project. Phase II will demonstrate bioenergy production and conversion technologies that address key issues and validate outcomes described in Phase I. Demonstration areas on roadways, airports, urban lots and farm scale plots will be established. These sites will be used to verify the production and economic data presented in this project. Dr. Dallas Hanks with the Utah Freeways to Fuel project estimates that oilseed crops grown along roadways will yield 500 gallons of oil per linear mile under Utah growing conditions. Utah has an arid climate and alkaline soils. Michigan has a more temperate climate and soils with a more neutral pH. It is expected that yields will exceed those projected in Utah, but that needs to be verified.

Phase II will also provide preliminary data on preprocessing (pelletizing and extrusion of oil from oilseed crops) to be used in Phase III. It will also set up Phase III, which will establish a biomass supply system that is sustainable and economical. Phase II takes the

next step to commercializing the biomass production system. It is intended that Phase III will look more broadly at the supply chain (harvest, storage, handling and logistics) and devise a system that connects producers of biomass with the end user (processor).
Officials from Detroit Metro and Willow Run Airports are interested in producing “drop in” fuel for their jets and diesel operated ground support vehicles. They have about 1900 acres of land, some of which could be used to produce biomass and some of which could be used to build processing facilities to convert biomass into transportation fuel. There is a network of highways and a significant amount of urban vacant land surrounding the airports that could be used to produce biomass. Supporters and potential partners of this project could include Wayne County Airport Authority (WCAA), Delta and Southwest Airlines, Boeing Commercial Airplanes, Air Transport Association of America (ATA), UOP Honeywell, and Commercial Aviation Alternative Fuels Initiative (CAAFI). Drop in fuels could be created in this zone and piped directly to the airport tank farms. Air transportation leaders also recognize the importance of sustainability and embracing alternative energy and energy efficiency. In embracing sustainability and alternative energy, WCAA can be a living laboratory for addressing our dependence on foreign oil and will help to open up new markets for Michigan-made products.

Michigan State University is working on a project that would develop a sustainable biomass production and logistics system to support a processing facility. This project could be the foundation for Phase III. Funding for this project is being sought through the Sustainable Bioenergy RFA from the Agriculture Food and Research Initiative (AFRI). The primary objective of the project is to develop a regional system for the sustainable production and distribution of bioenergy and biobased products with net positive social, environmental, and economic effects. The MSU led project could bring the expertise to the table to develop the supply chain.

B. Bioenergy crop economics

There are several areas in need of additional focus. The most important area is determining the actual cost of production along limited access highways and public lands (e.g. state-owned game land and airports). Determining the propensity of bioenergy crops to attract wildlife should be included in this study. Another area of focus needs to be analyzing potential supply chains and markets for these crops.

Objective 8. Dissemination of project information

This report will be posted on the Michigan Department of Energy, Labor and Economic Growth web site. An article summarizing the final report will be drafted for distribution to the press through ANR Communications. A poster will be developed for the NACAA AM/PIC in Oklahoma and a presentation will be developed for use when speaking to groups.

IV. Conclusions

It is clear that there is ample non-traditional cropland available in Michigan to grow bioenergy crops. It is also clear that there are bioenergy crops capable of growing under Michigan climatic conditions on marginal soils. To fully utilize the production potential of this land requires rethinking the way non-traditional cropland is managed by government entities. Growing bioenergy crops on state land has several desirable attributes. First, bioenergy crops do not compete with the production of food. Second, the potential exists to generate economic activity and jobs on land that currently does not generate income or jobs. And third, growing bioenergy crops can reduce the cost of some annual maintenance operations such as mowing.

The crops analyzed in this study are currently grown on few, if any, acres in Michigan. One reason is that these crops are not as profitable to grow in Michigan as corn. Getting solid economic data that increases our understanding of how bioenergy crop production can be profitable on non-traditional cropland is the most critical next step. A closely related critical next step is to set in place the infrastructure necessary to move biomass and oilseed from the grower to the processor. For example, Michigan lacks the capacity to crush small oilseeds, which means Michigan-grown small oilseeds must be shipped out of state for processing. This is a deterrent to growing the food grade oil and biodiesel production industries in Michigan.

V. Bibliography

Gould, M. Charles. 2010. Personal email dated October 27th and 28th from Jordan Burroughs, Wildlife Outreach Specialist in the Department of Fisheries and Wildlife at Michigan State University.

Harper, Craig A. 2008. A Guide to Successful Wildlife Food Plots: Blending Science with Common Sense. PB 1769. University of Tennessee Extension, Institute of Agriculture. Knoxville, TN.

Tarr, Matt. Date unknown. Brassicas for deer food plots. Whitetail Stewards, Inc.

Williams, R. and T. Baxley. 2006. Comparing Fall Food Plot Blends for Deer: 2006 Update. FOR 113. The School of Forest Resources and Conservation, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Gainesville, FL.

VI. Glossary

Centerline of the highway - A line equidistant from the edges of the median separating the main-traveled ways of a divided highway, or the center-line of the main-traveled way of a nondivided highway.

Freeway - A freeway is an access-controlled, divided highway designed for the unimpeded movement of large volumes of traffic. Characteristics of a freeway include controlled access through the use of interchanges, and use of underpasses or overpasses at intersections. (Source: http://www.michigan.gov/mdot/0,1607,7-151-9620_11154_39107-131251--,00.html)

Highway - A main road that provides direct access to buildings and intersections. Unlike a limited access freeway, a highway has intersections at grade level and signs and signals to control traffic.

Interchange - An interchange is the junction of a freeway and another road. Interchanges keep the traffic flowing on the freeway, but there may be some restrictions on the connecting routes. A complete interchange provides for movements in all directions; a partial interchange has some missing connections.

Limited Access - A highway or section of highway designed for travel by registered motor vehicles. Access is limited to intersections, and driveways are generally not allowed. Freeways are a common type of limited access highway.

Median - A barrier, constructed of concrete, asphalt, or landscaping, that separates two directions of traffic.

Right-of-Way (ROW) - Land and/or property acquired for or devoted to transportation purposes. Right-of-way is also a project phase.

Appendix A

Freeways to Fuels Literature Search
Apr-10

		Switchgrass	Camelina	Penneycress	Canola	Oriental Mustard	Existing Biomass
One	Yield (units)	9.0 MG/HA	1/2 - 1 1/4 ton/acre	2200 - 2500 lbs/acre	2.2 MG/HA	1200 lbs/acre	From Utah? Kentucky?
	Reference	James, LK, Swinton, SM, Thelen, KD. 2010. Profitability Analysis of Cellulosic Energy Crops with Corn. Agron. J. 102: 675-687.	Ehrensing, DT, SO Guy. 2008. Camelina. Oilseed crops, Oregon State University Extension Service	Ampong-Nyarko, K. 2010. Pennycress - up and coming low break-even cost crop for the Prairies	James, LK, Swinton, SM, Thelen, KD. 2010. Profitability Analysis of Cellulosic Energy Crops with Corn. Agron. J. 102: 675-687.	Golz, Theresa. 1993. Mustard. North Dakota State University.	KBS successional plots?
	Cost of Production (units)	$167/acre (annualized)			$285/acre	91.46/acre (economic)	Need to identify potential pollutants - sulfur, lead, heavy metals
	Reference	James, LK, Swinton, SM, Pennigton, DR. 2010. Profitability of Converting to Biofuel Crops. MSU Extension Bulletin E-3084.	There is only one good reference available and it is listed below.		University of Kentucky Cooperative Extension Service. 2002 (Revised 2008).	Golz, Theresa. 1993. Mustard. North Dakota State University.	Kurt Thelen - Rose Lake
Two	Yield (units)	8.96 ton/HA	1100 - 1200 kg/HA	292 lbs/acre	1200 - 1800 lbs/acre	1,000 - 1100 lbs/acre	
	Reference	Duffy, MD, VY Nanhou. 2002 Cost of Producing Switchgrass in Southern Iowa.	Putnam, DH, JT Budin, LA Field, WM Breene. 1993. CamelinaL A promising low-input oilseed.	ARS 2006 Annual Report for Industrial Products from New Crops Project	Dumler, TJ, D Shoup, KL Martin. 2009. Canola Cost-Return Bedget in South Central Kansas. Kansas State University Agricultural Experiment Station and Cooperative Extension Service	Oplinger, ES, EA Oelke, DH Putnam, KA Kelling, AR Kaminsid, TM Teynor, JD Doll, BR Durgan. 1991. Mustard. Alternative Field Crops Manual.	
	Cost of Production (units)	$65.41/ton, $518.75			$200 - 234/acre	$56.00/acre (cash)	
	Reference	Duffy, MD, VY Nanhou. 2002 Cost of Producing Switchgrass in Southern Iowa.			Dumler, TJ, D Shoup, KL Martin. 2009. Canola Cost-Return Bedget in South Central Kansas. Kansas State University Agricultural Experiment Station and Cooperative Extension Service	Oplinger, ES, EA Oelke, DH Putnam, KA Kelling, AR Kaminsid, TM Teynor, JD Doll, BR Durgan. 1991. Mustard. Alternative Field Crops Manual.	
Three	Yield (units)	4.39 - 5.41 ton/acre	670 - 2240 lb/acre	75-100 gallons/acre			
	Cost of Production (units)		$45-$68/acre				
	Reference	Nyoka B, P Jeranyama, V Owens, A Boe, M Moechnig. 2007. Management Guide for Biomass Feedstock Production from Switchgrass in the Northern Great Plains	Stratton, A, J Kleinschmit, D Keeney. 2007. Camelina. Institute for Agriculture and Trade Policy.	Suszkiw, J. 2008. Experimental Plots of Pennycress Tested for Biodiesel Production. USDA ARS.			
Four	Yield (units)						
	Reference				http://www.uky.edu/Ag/NewCrops/introsheets/canola.pdf		
	Cost of Production (units)						
	Reference						

A Methodology for Quantifying the Amount of Land in Highway Right of Ways and Other Non-traditional Agricultural Lands for Biofuel Production

In support of a project funded by an AgriEnergy Technology Demonstration Grant
(Grant No. BES-10-160) from the Michigan Department of Energy, Labor and Economic Growth

Michigan State University Extension

Edward H. Schools, Rebecca L. Rogers, M. Charles Gould,
Dennis Pennington, Lasantha Rathnayake

MICHIGAN STATE
UNIVERSITY
EXTENSION

Background

In this analysis we present a methodology to quantify the area of Michigan Department of Transportation (MDOT) Right of Way (ROW) that could be utilized for biofuel production. This spatial analysis is part of a larger study that will utilize this analysis as well as other factors such as soil productivity and market conditions to determine the economic feasibility of ROW biofuel production.

Methodology

Quantifying highway median area

The overall process consisted of converting limited access highway centerlines to a polygon dataset, manually assessing each polygon for potential useable area, removing restricted areas and mapped wetlands, and then using field testing to adjust the initial results. Spatial analysis was performed using ESRI ArcGIS ver 9.3 software. Datasets utilized in the analysis include the Michigan Framework version 9b (Michigan Center for Geographic Information 2009), National Wetland Inventory (NWI) (U.S. Fish and Wildlife Service 1980), Michigan Department of Transportation Managed Areas (Michigan Department of Transportation 2008), and National Agriculture Imagery Program (NAIP) imagery (U.S. Department of Agriculture 2005).

Procedure

The analysis started with the limited access highway centerlines from the Michigan Framework version 9b dataset. This dataset is a line dataset consisting of the centerlines of highway segments, overpasses, interchanges, and highway exits. The dataset also includes line segments for crossovers between opposing directional lanes. The dataset contains 4992 miles of centerlines. Figure 1 shows an example of the framework dataset in Clinton County, Michigan.

Determining the available area of highway medians, exits, and interchanges, required converting the line dataset into polygons. Open ended highway exits required adding lines to make closed polygons. New line segments were also added wherever the limited access highway intersected another road, stream, or river

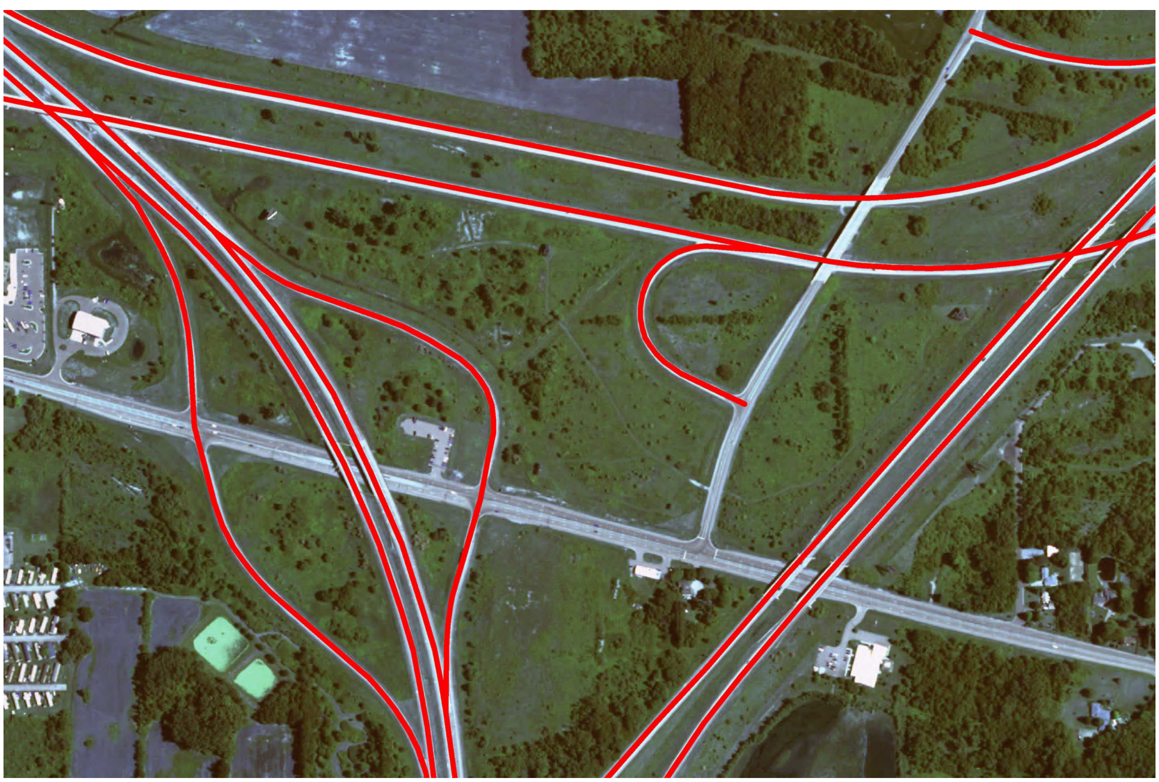


Figure 1. Highway centerlines in red overlaying the 2005 NAIP imagery.

(Figure 2). Highway centerline segments with no obviously useable median areas were eliminated from the dataset before conversion to polygons. Typically this would be where there was no median or the median in the NAIP imagery was obviously non-vegetated. Line segments were also added to delineate obviously forested areas within the highway medians. All line editing was completed using the 2005 NAIP imagery as a backdrop.

vious features such as parking areas. Table 1 shows the designation and the thresholds for each designation.

Table 1. Polygon designations based on the percentage of useable area observed in 2005 NAIP imagery and the thresholds used for the designation.

Designation	Description
N	Less than 20% of polygon is useable
P2	20% - 50% of polygon is useable
P	50% - 80% of polygon is useable
U	Greater than 80% of polygon is useable

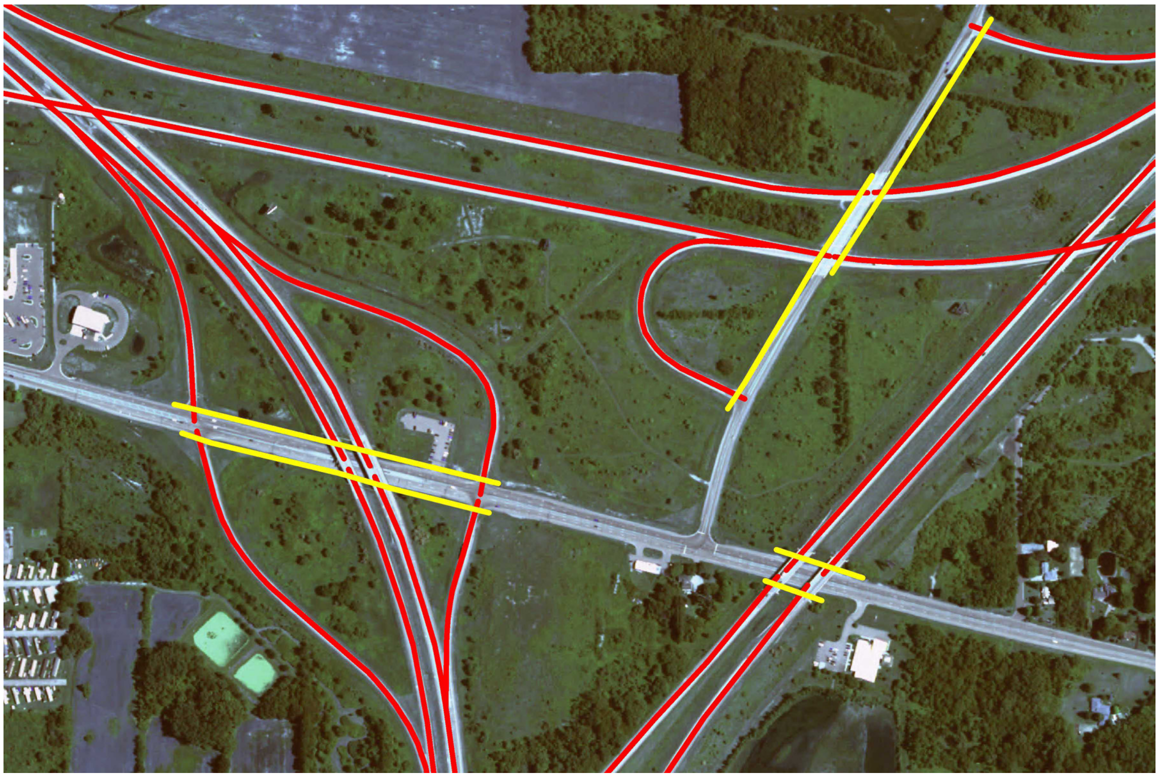


Figure 2. Line segments in yellow added to highway centerlines to create closed polygons.

The line dataset was then converted to polygons using the ESRI ArcGIS Feature to Polygon tool. This tool converted areas bounded by line segments into individual polygons (Figure 3). The process created a total of 6874 individual polygons. The polygons were then buffered inward a distance of 35 feet from the centerline to remove highway lanes and the highway shoulder from area calculations (Figure 4). The distance of 35 feet was based on a series of field measurements made on Interstate 69 between Lansing and the Southern Michigan border. Measurements were taken from the highway centerline past any berms or ditches to the point in the median that appeared to be useable.

Each polygon was then inspected against the 2005 NAIP imagery and classified according to the area potentially suitable for biofuel production. The factors assessed in the visual inspection were the amount of tree and shrub cover within each polygon or other ob-

After manually coding the polygons two types of restrictive areas, Michigan Department of Transportation managed areas and NWI wetland areas, were removed from the polygons. Removing the restrictive areas was accomplished using the ESRI ArcGIS Erase tool. This tool removes the area of coincidence between the overlay polygons, e.g. wetlands, and the target polygons (Figures 5.a, 5.b, 5.c). Removing the wetlands and managed areas after coding the polygons meant that some portions of polygons coded as useable would be impacted. We chose this sequence of operations so that if the wetland or managed areas datasets change, or other datasets are to be incorporated, the analysis could be redone without manually recoding the polygons for usability.

The MDOT managed areas are right of way areas known to contain rare species or examples of high quality natural communities. The managed area data-

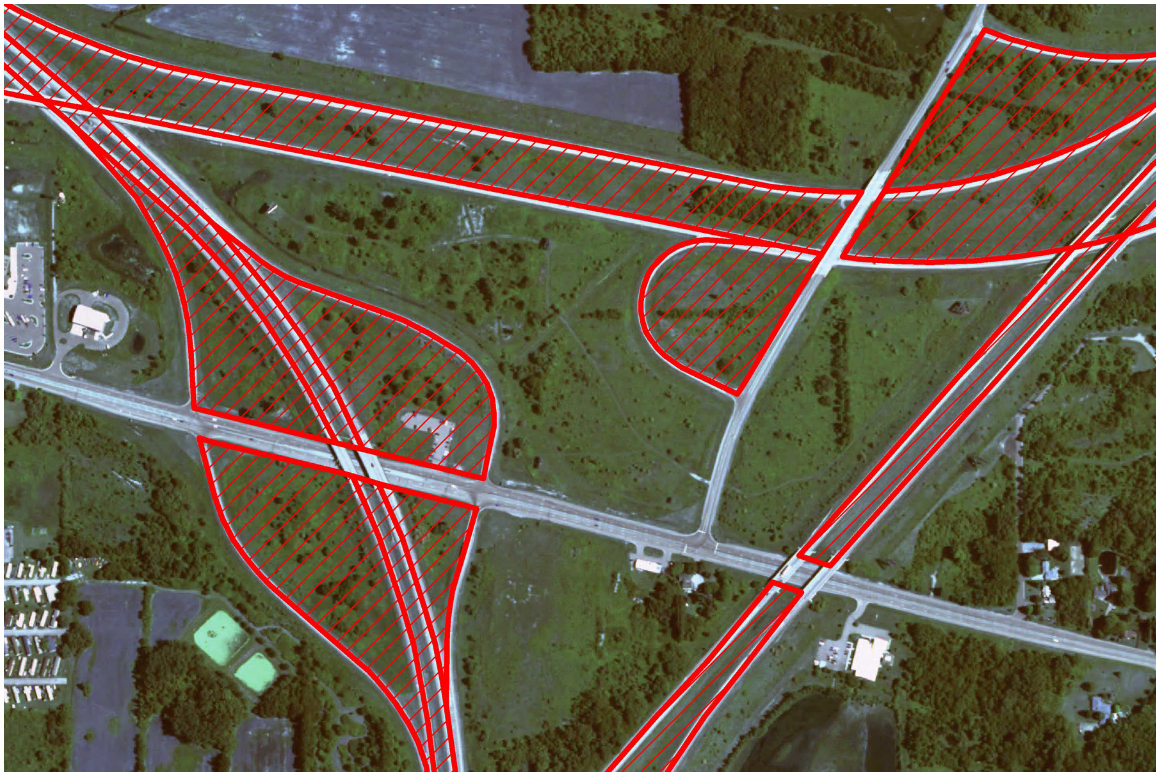


Figure 3. Initial polygons created by converting edited centerline dataset to polygons.

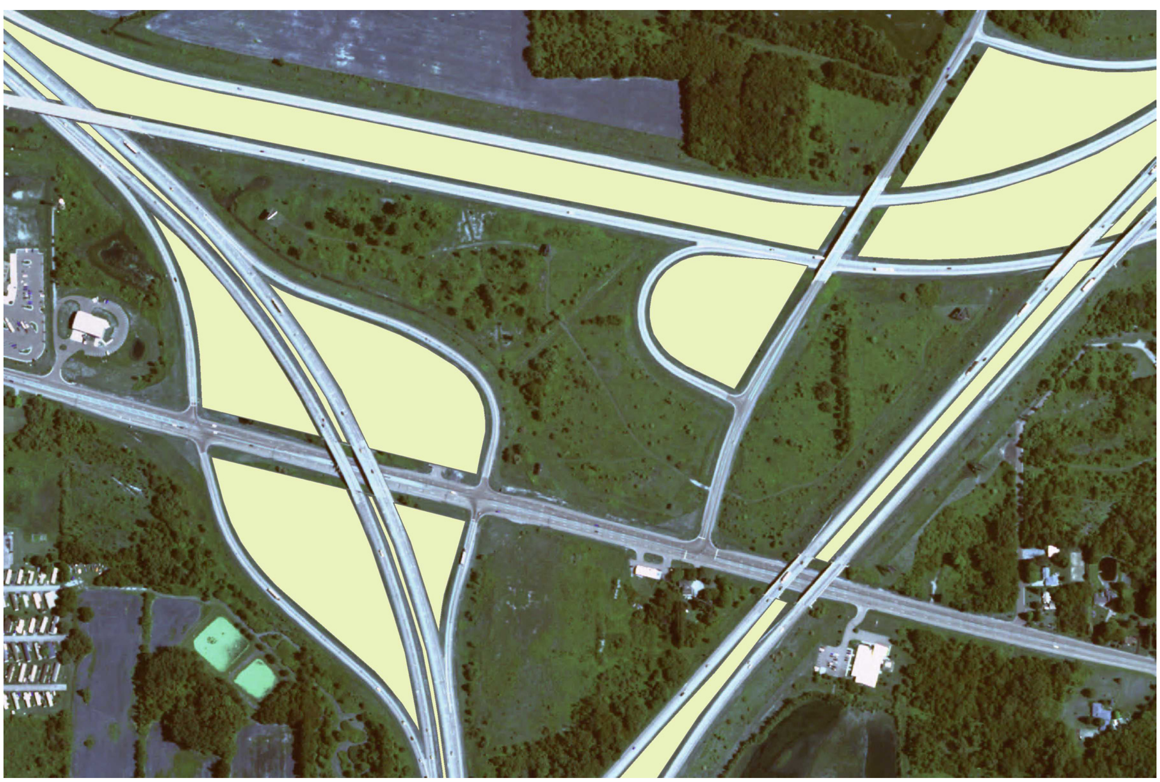


Figure 4. Polygons buffered inward 35 feet.

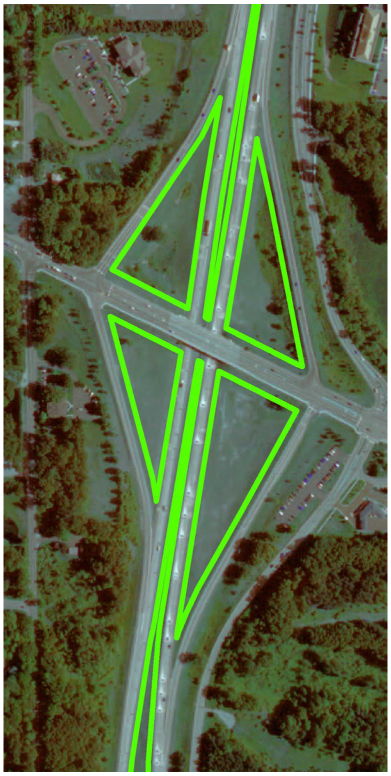


Figure 5.a. Polygons around a highway interchange.

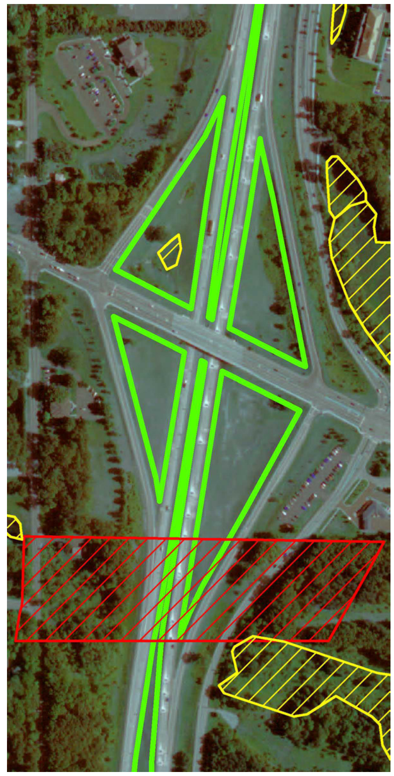


Figure 5.b. MDOT managed areas in red and NWI wetlands in yellow overlaying the polyogns.

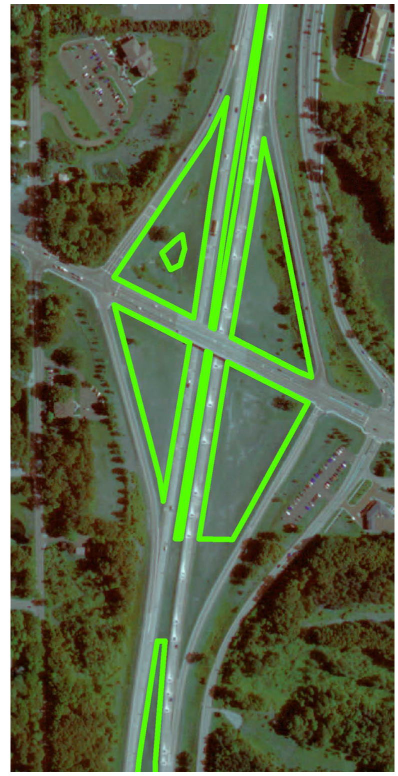


Figure 5.c. The result of erasing the MDOT managed areas and NWI wetlands from the highway polygons.

set was produced for MDOT utilizing the Michigan Natural Features Inventory natural heritage database of rare species and high quality natural communities. These areas have management restrictions placed on them and are unlikely to be available for biofuel production in the near future.

The NWI is a circa 1980 dataset consisting of photo interpreted wetlands delineated using the Cowardin classification system (Cowardin, et al 1979). The dataset does not represent regulated wetlands under the State of Michigan regulations (State of Michigan 1994). The NWI dataset used for this study consists of a combination of the original wetland polygons delineated circa 1980 and polygons that have been updated utilizing 2005 aerial photography.

Field evaluation

A selection of polygons was evaluated for factors that would limit polygon utility for biofuel production but were not detectable in the 2005 NAIP imagery. Such factors include safe access, slope, wetness, and changes in vegetation or human alterations since the date of the NAIP imagery.

An initial group of 160 polygons, from the subset of polygons considered at least 80% useable, were randomly selected for field evaluation. In some cases evaluators also assessed other polygons in proximity to the designated polygons and a total of 316 polygons were eventually assessed. While only the original 160 polygons were randomly selected, we included all the tested polygons in our analysis, feeling the larger sample size was more important than any possible error induced by sampling bias.

Several different evaluators, distributed across the Lower Peninsula, performed the evaluations. Evaluators were given maps of specific polygons to visit. Appendix A is a typical example of a map used for polygon evaluation. Evaluators either completely eliminated a polygon from consideration or determined the percentage of the polygon area useable for biofuel production. A training session utilizing test sites was held to ensure that all evaluators assessed polygons in approximately the same manner.

Results and Discussion

The polygon creation process created a total of 6,874 polygons. Polygon size ranges from slivers less than 0.01 acre to 112.5 acres. The total polygon acreage is 26,472 acres. After examining the polygons in relation to the 2005 NAIP aerial photographs, 5,961 polygons were coded as usable (Greater than 80% of polygon is useable). The usable polygons had a total area of 17,973 acres.

To characterize the polygon size distribution, polygons were placed into groups based on their size. The groups consist of polygons less than one acre in size, one to two acres, two to three acres, etc… up to five acres. All polygons larger than five acres are grouped together. Table 2 shows the results for all polygons and Table 3 shows the results for the polygons coded as useable. The tables show that smaller polygons represent a large percentage of the total number of polygons but do not represent a proportionally share of the total area.

When examining the area of the useable polygons, two factors reduce the 17,973 acres potentially available to a smaller area actually usable for production; the number of polygons rejected by field evaluators and the percentage of polygon area deemed useable during field evaluation. Evaluators outright rejected 76 of the 316 polygons, a rejection rate of 24%. The amount of useable area within the accepted polygons varied from 10% to 100% with an average of 73% of the polygon area estimated as usable.

To account for the proportion of polygons rejected during field evaluation, we randomly selected and rejected from the set of useable polygons the same percentage of polygons rejected during field testing. We performed 100 iterations of random selections, rejecting the selected polygons and summing the area of the remaining polygons. This process resulted in 100 different area calculations, ranging from a minimum area where a greater number of larger polygons were rejected to a maximum area where mostly smaller polygons were rejected.

While the randomization process accounts for the percentage of polygons rejected by evaluators, it does not account for the portion of the polygon area deemed suitable for biofuel production. To account for the reduction in usable area we multiplied the minimum and maximum areas produced by the randomization process by the mean percentage (73%) of polygon area determined usable by evaluators.

Table 2. Size distribution of all polygons in the dataset, including useable, partly useable, and not useable polygons.

Polygon area	# of polygons	% of total polygons	Area (ac)	% of total area
< 1.0 acre	2531	36.82%	871.16	3.29%
1.0 ≤ acre, < 2.0 acres	1113	16.19%	1644.92	6.21%
2.0 ≤ acres, < 3.0 acres	701	10.20%	1725.51	6.52%
3.0 ≤ acres, < 4.0 acres	575	8.36%	1981.00	7.48%
4.0 ≤ acres, < 5.0 acres	417	6.07%	1861.52	7.03%
≥ 5.0 acres	1537	22.36%	18388.33	69.46%
Total	6874		26472.44	

Table 3. Size distribution of the polygons coded as useable based on the NAIP imagery.

Polygon area	# of polygons	% of total polygons	Area (ac)	% of total area
< 1.0 acre	2405	40.35%	833.57	4.64%
1.0 ≤ acre, < 2.0 acres	1046	17.55%	1542.86	8.58%
2.0 ≤ acres, < 3.0 acres	630	10.57%	1551.22	8.63%
3.0 ≤ acres, < 4.0 acres	479	8.04%	1652.42	9.19%
4.0 ≤ acres, < 5.0 acres	347	5.82%	1548.71	8.62%
≥ 5.0 acres	1054	17.68%	10844.21	60.34%
Total	5961		17973.00	

Table 4 presents the results of the randomization process to adjust for unusable polygons and adjusting for the polygon usable area. The results in Table 4 are presented using different minimum sized polygons. This allows the user to select a minimum size polygon practical to consider for potential production. In our analysis we use a minimum size of one acre. When using a one acre minimum size threshold, and accounting for rejected polygons and polygon useable area, the total area available for biofuel production in highway medians ranges between 9,292 and 9,756 acres. The mean area available is 9,516 acres. While a one acre polygon may be too small for production by itself, almost all occur in close proximity to other polygons. The aggregate area of the smaller polygons in close proximity to each other is likely to be of sufficient size to be feasible for production. If needs dictate that a user consider only polygons of a larger area, e.g. five acres, the total area available would drop from a mean value of 9,516 acres to 6,017 acres.

The above analysis quantifies the area available within the highway medians or in exits and interchanges. It does not quantify the area from the centerline of the highway out to the edge of the MDOT right of way (ROW). Quantifying this area is complicated by the fact that MDOT does not have a consistent ROW width which would allow a single standard sized buffer to be applied to the centerlines. During field visits the outer ROW edge was coarsely assessed for usability. A conservative estimate of the ROW area suitable for biofuel production is in the 10% - 25% range of the total median area. The results of applying 10% and 25% additions to the adjusted mean areas are shown in Table 5.

An estimate of highway right of way area that could be utilized for biofuel production, including only highway medians and interchange polygons larger than one acre, and after accounting for some areas not being useable or only partially useable, is 9,516 acres. Because other parts of the highway right of way have the potential to be utilized, 9,516 acres should be considered a very conservative estimate. A better estimate would include other parts of the highway right of way that have the potential to be utilized.

If one includes other parts of the limited access highway rights of way, the estimate of available land ranges from 10,468 acres, assuming 10% additional right of way is available, to 11,895 acres, assuming 25%

Table 4. Area available for biofuel production after accounting for rejected polygons and the productive area of useable polygons. Area calculations are provided using different using minimun sized polygon thresholds.

Minimum polygon size threshold (ac)	Number of randomly selected polygons above the size threshold	Range of area available after accounting for rejected polygons (ac)	Mean area available after accounting for rejected polygons (ac)	Range of area available after accounting for the usable percentage of polygons (ac)	Adjusted mean area after accounting for the usable percentage of polygons (ac)
1	2,703	12,729 – 13,365	13,036	9,292 – 9,756	9,516
2	1,909	11,618 – 12,028	11,853	8,481 – 8,780	8,653
3	1,434	10.410 – 10,882	10,688	7,599 – 7,944	7,802
4	1,069	9,018 – 9,663	9,427	6,583 – 7,054	6,882
5	801	7,963 – 8,422	8,242	5,813 – 6,148	6,017

Table 5. Area available for production calculated using two estimates of potentially useable adjoining ROW area. Area calculations are provided using different using minimun sized polygon thresholds.

Minimum polygon size threshold (ac)	Adjusted mean polygon area (ac)	Mean polygon area plus 10% of adjoining ROW (ac)	Mean polygon area plus 25% of adjoining ROW (ac)	Average of mean polygon area plus 10% and 25% of adjoining ROW (ac)
1	9,516	10,468	11,895	11,182
2	8,653	9,518	10,816	10,167
3	7,802	8,583	9,753	9,168
4	6,882	7,570	8,602	8,086
5	6,017	6,618	7,521	7,070

additional right of way is available. The true value lies somewhere between these two estimates. A reasonable estimate of the limited access highway medians and other rights of way potentially available for biofuel production is 11,182 acres, which is the average of the 10,468 acre estimate and the 11,895 acre estimate.

Limitations of the spatial analysis

The above analysis provides a total acreage potentially available for biofuel production. The total acreage does not take into account the spatial distribution of the available acreage. The nature of the medians and highway exchanges tend to be a group of smaller polygons in close proximity to each other at interchanges connected together by long narrow medians. While any one polygon may be too small to be viable, in aggregate there is likely enough area to be viable. In this analysis it is possible there are polygons sufficiently isolated from others that may not be cost effective for biofuel production even though they contribute to the total available acreage.

The amount of land ultimately available for production will depend to some extent on MDOT policies. One factor determining the usability of any given polygon was the amount of trees and shrubs detected within the polygon. In this analysis, the working assumption was that the removal of trees and shrubbery would not be permitted. Allowing the removal of trees or shrubs will increase the amount of acreage available for production. Conversely, in the interval between this analysis and the time any biofuel production is initiated, more area could ecologically succeed from grass to shrubs and trees. This succession will decrease the amount of land available unless removal is permitted.

In this analysis we utilized only limited access highways. Other State of Michigan divided highways may contain useable median areas that would contribute to the total acreage available for production.

Other potential land sources

In addition to highway right of ways, other underutilized land may be available for biofuel production. We examined three different types of non-traditional agricultural lands, airports, State Game Areas and Genesee County Land Bank properties, for potential biofuel production.

Michigan has over 200 municipal airports. Informal discussions with personnel from Metro Detroit Airport and Willow Run Airport show approximately 1,169 acres of potentially useable land at Detroit Metro and 814 acres at Willow Run. Appendences B and C show approximate locations of potentially useable land at these two airports. A more in depth analysis is required to determine the amount of land viable for biofuel production at these and other airports. Quantifying the biofuel production potential of Michigan airports will require one on one interface with each airport and is beyond the scope of this analysis and report. It does, however, have the potential to greatly add to the amount of land available for biofuel production.

We also examined the amount of land currently under some form of cultivation in State Game Areas (SGA). Utilizing the remotely sensed Cropland Data Layer (U.S. Department of Agriculture 2008), approximately 17,000 acres of land within SGAs are in cultivation or pasture. Appendix D shows the acreage by SGA. The primary purpose of the SGAs is wildlife restoration. All management activities on these properties must meet this objective to fulfill the requirements of the federal funding used to purchase them. Biofuel production as an end to itself is likely not an allowed activity. Biofuel production as part of wildlife restoration activities could be allowed. Utilization of SGA land for biofuel production will require that the biofuel production be compatible with, and help meet, the management objectives for the SGAs. Close coordination with the Michigan Department of Natural Resources and Environment Wildlife Division will be required to determine the likelihood of biofuel production and to quantify the actual area available for biofuel production.

As part of this analysis we briefly examined the utility of property owned by the Genesee County Land Bank (Genesee County Land Bank 2010) for biofuel production. The Genesee County Land Bank ownership tends to be properties that have been abandoned or foreclosed on because of unpaid taxes. Other Michigan Counties also have land banks that operate similar to the Genesee County Land Bank. At the time of this analysis, after dissolving adjoining parcels together, the Genesee County Land Bank owned 3,221 separate parcels that ranged in size from less than 0.001 acres up to 153 acres with a total of 1,242 acres. Figure 6 shows a sample of Genesee County Land Bank properties.

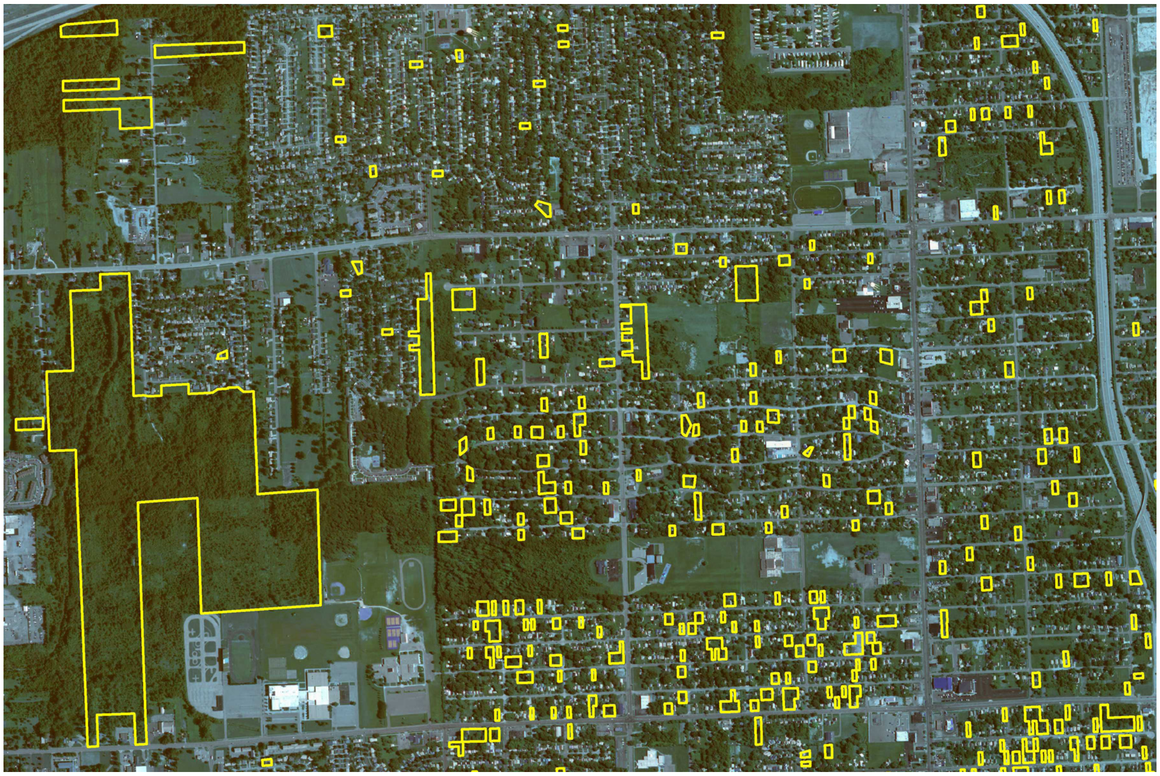


Figure 6. Distribution of Genesee County Land Bank properties.

In general, the Genesee County Land Bank properties tend to be smaller parcels disjunct from each other. The properties also tend to be urban in nature, some with buildings on them. There are, however, some larger land holdings. These larger holdings, in particular those close to other areas utilized for biofuel production, could add to total area useable for biofuel production. Further analysis will be required to determine the utility and potential of land bank properties

Conclusions

There are non-traditional agricultural lands within Michigan that could be potentially utilized for biofuel production. We estimate that within the highway medians 9,516 acres could be potentially utilized. Including other right of way areas brings the total acreage available up to approximately 11,182 acres. Favorable policies, such as shrub and small tree removal, could increase these acreages.

Other nontraditional agricultural lands such as airports, land bank properties, and State Game Areas could potentially support biofuel production. Of these three, airports are the most promising, with approximately 2,000 acres available at Willow Run and Detroit Metro airports alone. Airport lands also have an advantage in that the acreage is relatively compact compared to the acreages in highway rights of way. Further quantification of the potential for airports to support biofuel production is highly recommended.

Citations

Cowardin, L.M., Carter, V., Golet, F.C., LaRoe, E.T,. 1979. CLASSIFICATION OF WETLANDS AND DEEPWATER HABITATS OF THE UNITED STATES. FWS/OBS-79/31
DECEMBER 1979.

Genesee County Land Bank. 2010. Digital data. (http://www.thelandbank.org/)

Michigan Center for Geographic Information. 2009. Framework ver.9. Digital Data. www.michigan.gov/cgi.

Michigan Department of Transportation 2008 MDOT managed Areas, unpublished digital data

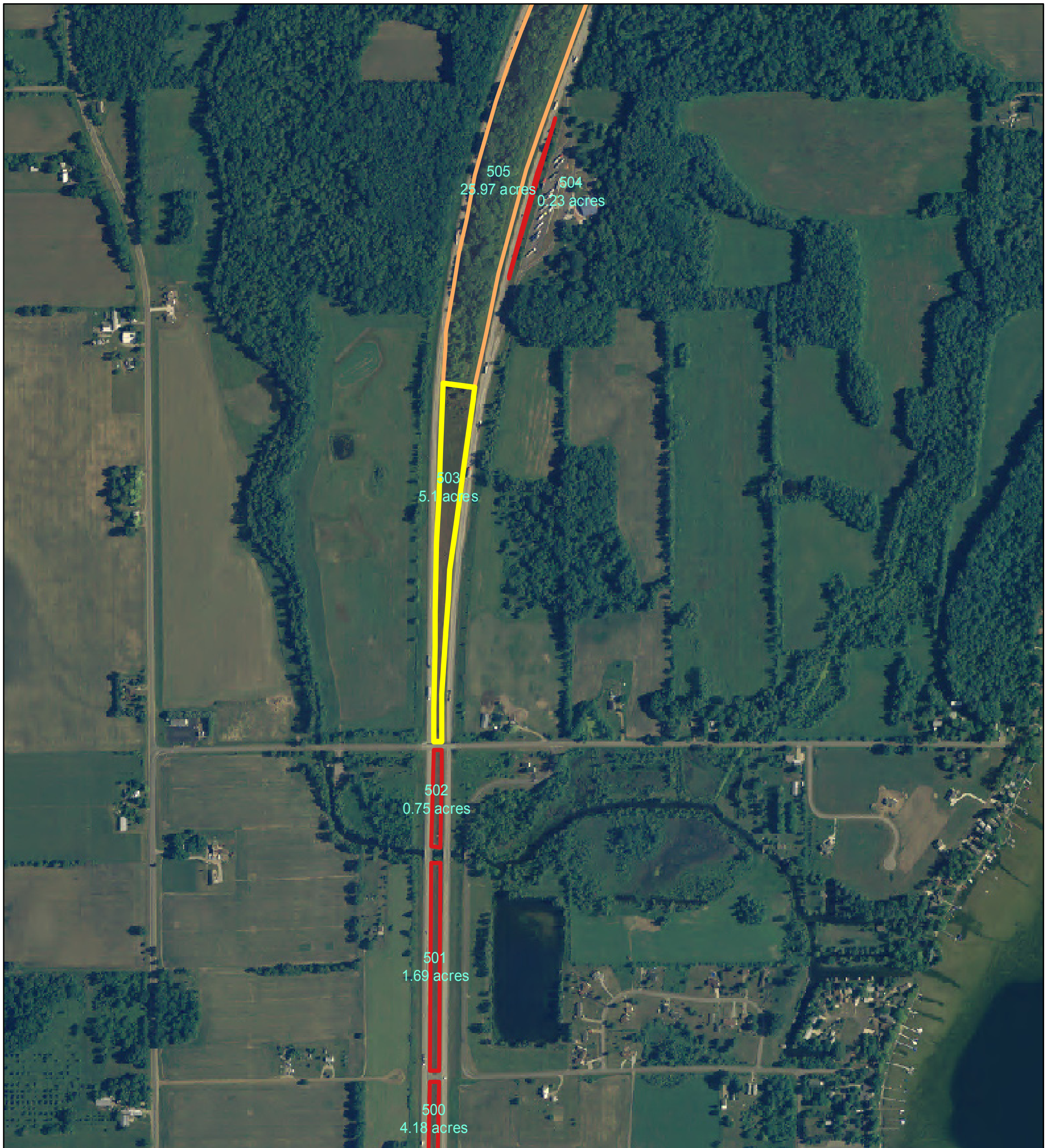
State of Michigan. 1994. Natural Resources and Environmental Protection Act, Act 451of 1994.

U.S. Department of Agriculture. 2005. National Agriculture Imagery Program. (www.fsa.usda.gov/FSA).

U.S. Department of Agriculture 2008. National Agricultural Statistics Service Cropland Data Layer. (http://www.nass.usda.gov/research/Cropland/SARS1a.htm).

U.S. Fish and Wildlife Service. circa 1980. National Wetland Inventory (NWI) database for Michigan. Scale 1:24,000. Data and metadata available online from the Michigan Center for Geographic Information (www.michigan.gov\cgi).

Appendix A
Typical map used by evaluators



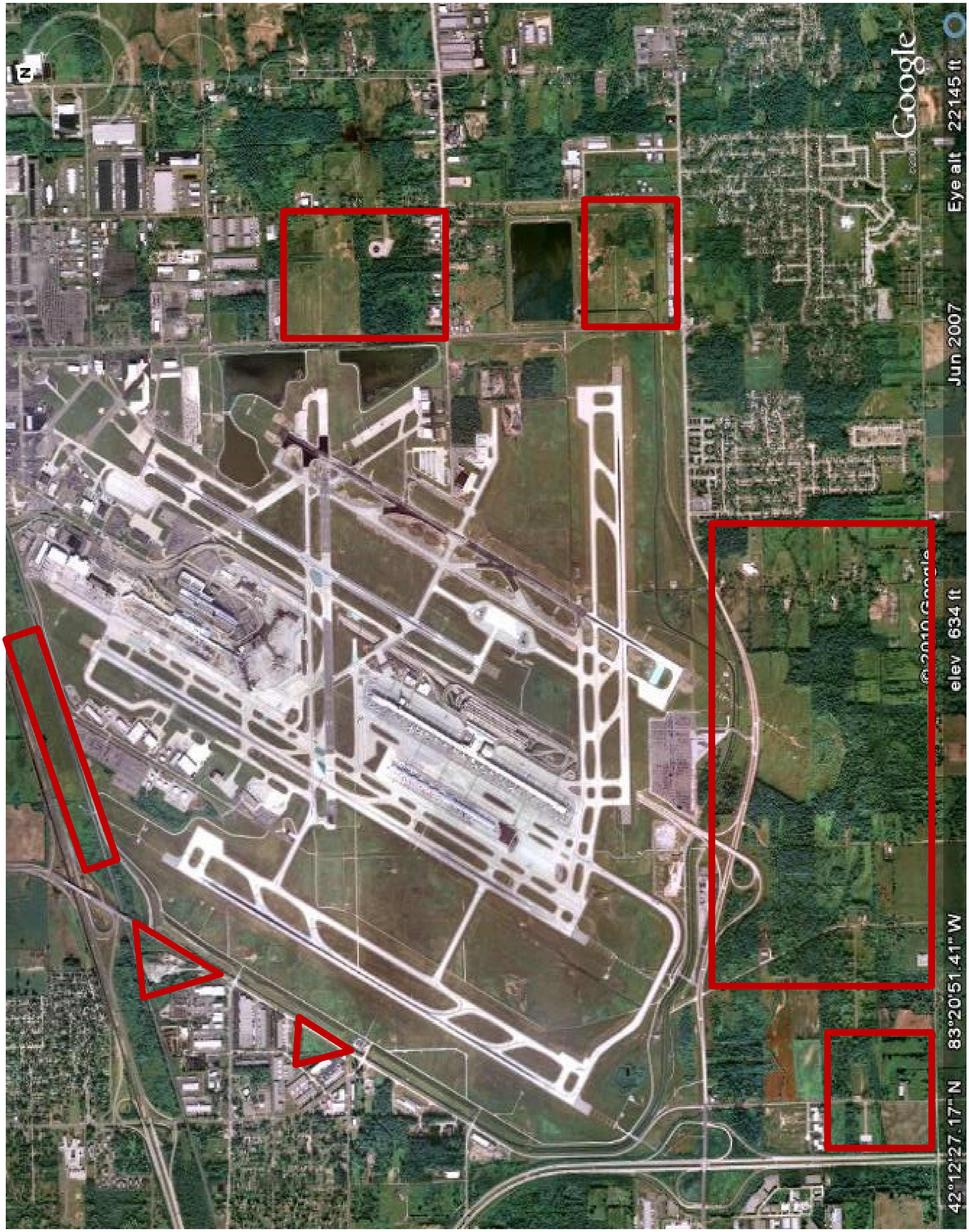
One site located south of EXIT 10 off 69

Is the site an automatic rejection? Yes No
Too small
Too narow
Ingress/egress

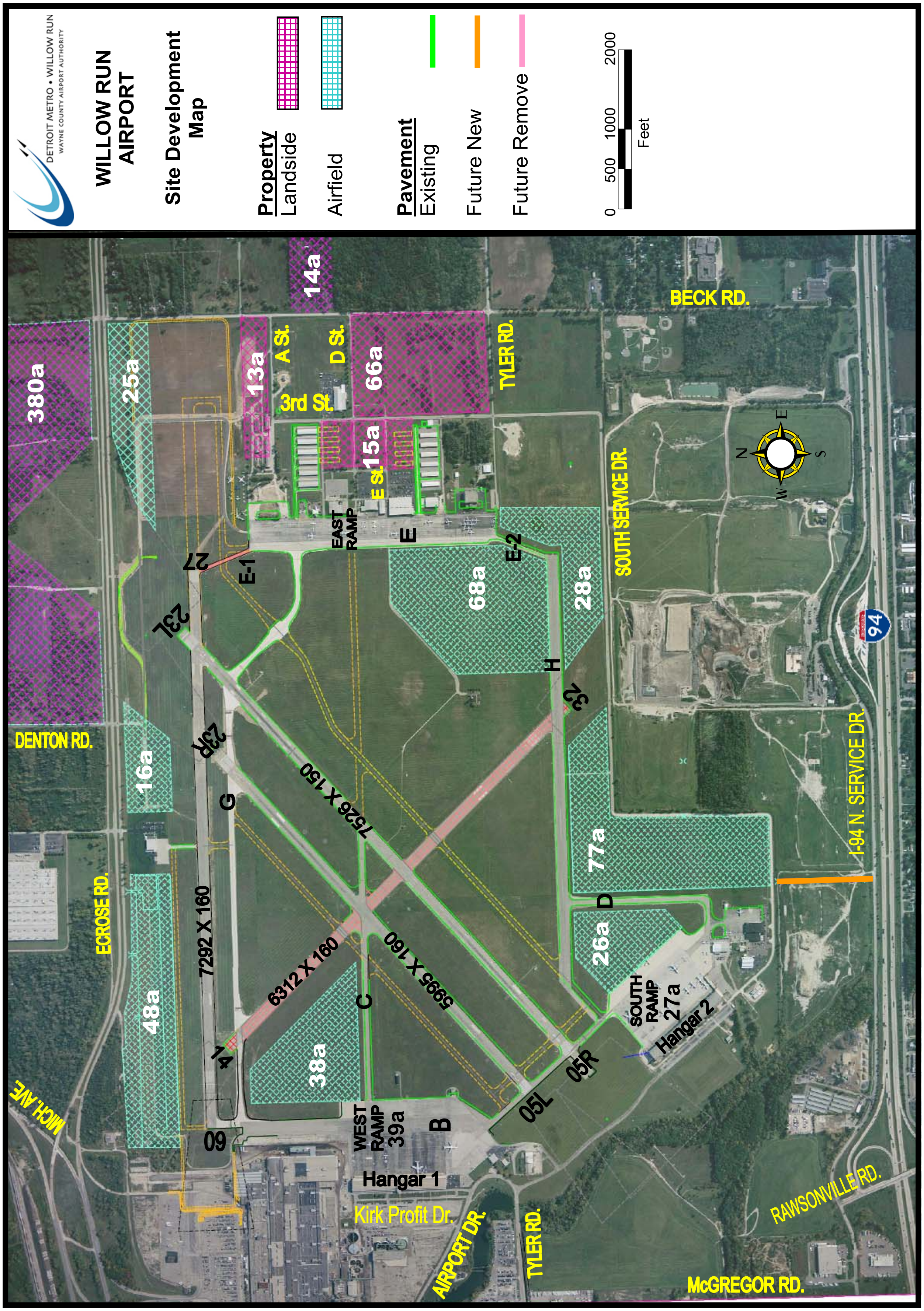
Approx. % usable at site?

Limits to area?
Moisture
Slope/topology
Other:

Appendix B
Potential biofuel production areas at Detroit Metro Airport



Appendix C
Potential biofuel production areas at Willow Run Airport



Appendix D
State Game Area acreage currently in agriculture

State Game Area	Acreage in agriculture	State Game Area	Acreage in agriculture
Leidy Lake State Game Area	78	Martiny Lake State Game Area	25
Somerset State Game Area	108	Deford State Game Area	135
Onsted State Game Area	67	Lowell State Game Area	43
Allegan State Game Area	2658	Rouge River State Game Area	100
Muskrat Lake State Game Area	126	Maple River State Game Area	704
Grand River State Mini Game Area	89	Haymarsh Lake State Game Area	48
Flat River State Game Area	90	Sharonville State Game Area	770
Langston State Game Area	15	Dansville State Game Area	433
Murphy Lake State Game Area	7	Edmore State Game Area	143
Tuscola State Game Area	55	Fish Point State Game Area	688
Gagetown State Game Area	162	Verona State Game Area	2924
Rush Lake State Game Area	204	Rogue River State Game Area	119
Petobego State Game Area	88	Shiawassee River State Game Area	2405
Vassar State Game Area	54	Barry State Game Area	462
Stanton State Game Area	82	Betsie River State Game Area	1
Lost Nation State Game Area	139	Cannonsburg State Game Area	2
Vestaburg State Game Area	269	Crane Pond State Game Area	238
Portland State Game Area	473	Crow Island State Game Area	256
Gourdneck State Game Area	112	Middleville State Game Area	272
Three Rivers State Game Area	115	Minden City State Game Area	41
Tobico Marsh State Game Area	28	Ottawa State Mini Game Area	181
Cass City State Game Area	6	Port Huron State Game Area	46
Muskegon State Game Area	613	Oak Grove State Game Area	40
Sanilac State Game Area	7	Gregory State Game Area	175
Pentwater State Game Area	2	Chelsea State Game Area	88
Manistee River State Game Area	9	Pointe Mouillee State Game Area	95
Lapeer State Game Area	311	Petersburg State Game Area	19
Gratiot-Saginaw State Game Area	507	Erie State Game Area	70

2459 SPECIAL CONDITIONS FOR HARVESTING HAY

The following conditions shall be followed to comply with Section 15b of P.A. 51 of 1951, which mandates vegetation mowing and control of brush within the Right of Way of all public roads, except those within the limits of a city or village and designated Federal-aid urban boundaries.

1. The hay cannot be sold or traded; it must be for the harvester's own use.
2. Hay harvesting equipment needs to stay out of areas of phragmites plants.
3. The applicant is responsible for securing the permission of any underlying property owner where easement or statutory Right-of-Way is involved.
4. No other type of farming shall be allowed such as plowing and planting of a crop.
5. Traffic Volumes – sites chosen shall be areas with reasonably low traffic volumes to minimize the possibility of causing congestion or hazards.
6. Roadside Cross-Section the person requesting the permit shall carefully go over the area requested to make sure that the roadside slopes are not too steep for the operation of hay baling equipment. Also, many areas of Right-of-Way that look fairly flat have not been mowed in years and are deeply rutted from erosion, which shall prohibit the operation of typical farm equipment.
7. Soil Type- a determination shall be made to make sure that the roadside soils shall support the weight of the farm equipment without causing rutting, or other damage to the turf.
8. Condition of Sod - in some areas, we are depending on the existing vegetation going to seed and thereby supplementing the existing turf. Removal of the existing grass may cause thinning of the Right-of-Way vegetation.
9. On limited access highways, only areas that are accessible from an interchange or entry points other than the highway or highway shoulder shall be considered. Equipment shall not be driven on the highway or the shoulder of the highway when traveling from one harvest area to another.
10. Hay harvesting shall not be allowed in median areas or any roadside area routinely mowed. In general, hay harvesting on freeways shall normally not be allowed closer than 15-20 feet to the shoulder of the road.
11. Hay harvesting shall not be allowed in areas where planted or desirable volunteer woody vegetation might be destroyed or damaged.
12. Equipment shall not be parked on the highway right-of-way overnight. However, in the event that it is necessary to leave equipment overnight, it shall be left only in approved areas.
13. Signing may be necessary in which case special signs shall be developed and erected by MDOT.
14. To give a clean-cut and uniform appearance, all vegetation within and approved area shall be cut even if it is not raked and baled. Jumping around and skipping areas shall not be allowed.
15. Undesirable material may be left on the roadside, but once the hay is raked or baled, it shall be removed from the Right-of-Way.
16. The requirements of the Michigan Farmers Transportation Guidebook need to be followed, as well as applicable MIOSHA safety regulations.

Information

MDOT may receive requests from adjacent property owners who are willing to cut grass and require a breach in the Limited Access Right-of-Way. When a permit applicant requests to mow grass outside the limits of their adjacent property, Adopt-a-Landscape, (Procedure 1506.01) shall be followed.

Harvesting hay is allowed in Limited Access Right-of-Way in extreme cases, such as when an economical shortage of hay occurs.

Procedure

TSC Construction Permit Staff

1. Receive the standard permit application package from the permit applicant.

2. Review the permit application package.

3. Send the permit application package to the Region Resource Specialist for Review.

Region Resource Specialist

4. Receive the permit application package from the TSC Construction Permit Staff.

5. Review the permit application package.

6. Coordinate a meeting with the permit applicant to review the area.

7. Approve or deny the permit application package.

8. Return the permit application package with approval or denial to the TSC Construction Permit Staff.

TSC Construction Permit Staff

9. Receive the permit application package and approval or denial from the Region Resource Specialist.

10. Complete Limited Access Right-of-Way Requirements, (Procedure 1502.21) due to necessity of an access gate.

11. Process permit according to the Individual Permit Process, (Procedure 1502.01). If issued, attach either Special Conditions for Mowing and Brush Cutting, (Form 2279) or Special Conditions for Harvesting Hay, (Form 2459).

Appendix D

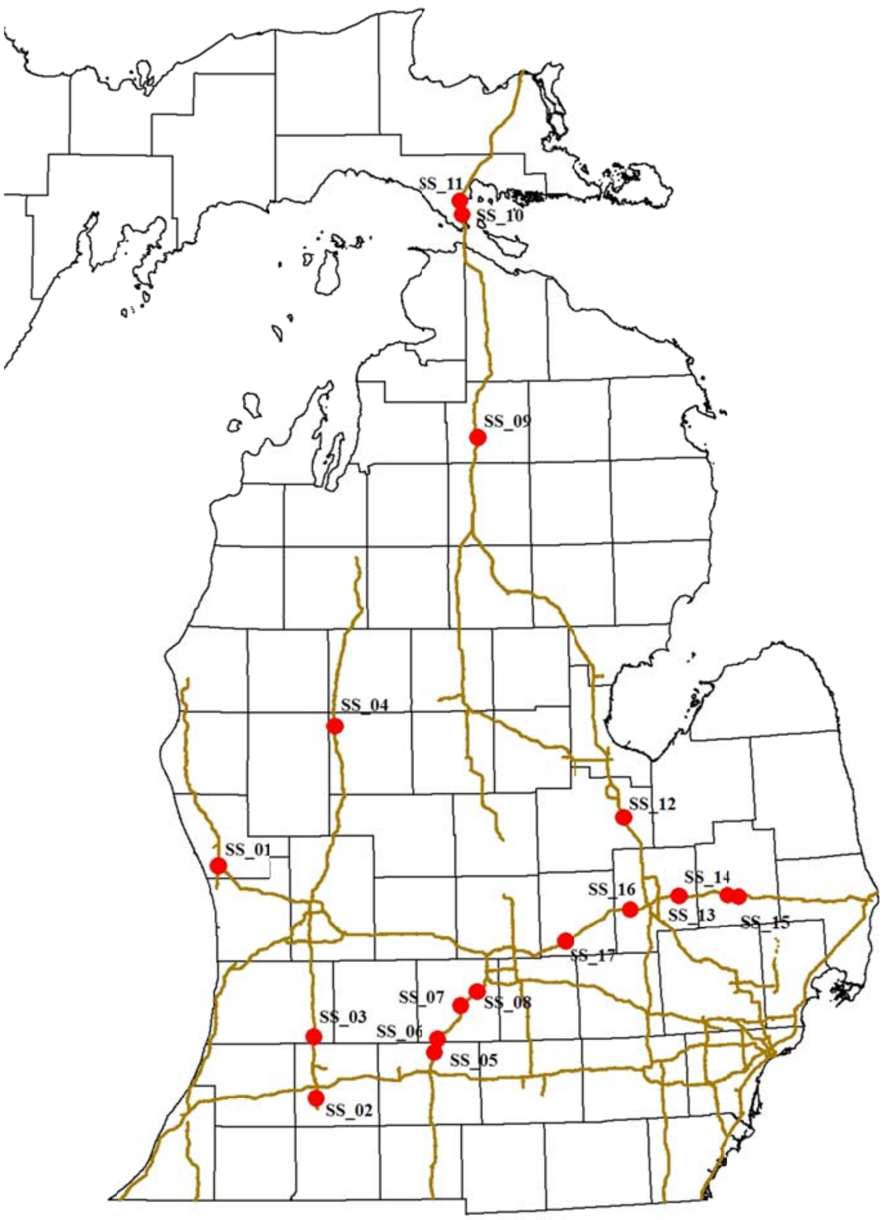
Soil sample test results from 18 median and limited access highway sites across Michigan [2010 F2F Project]

				ppm					meq/100 g	%
Soil Sample #	Location	pH	Lime Index	Phosphorus (P)	Potassium (K)	Magnesium (Mg)	Calcium (Ca)	Sodium (Na)	CEC	Organic Matter
SS_01	Polygon 1467 Exit 10 off of US 31	5.7	69.0	42	24	52	337	18	3.4	2.3
SS_02	Median US 31 South of Exit 31 Ele. 909 ft. N 42° 11.410' HO 85° 38.783'	6.8		47	38	88	475	7	3.2	1.9
SS_03	Site 915 US 131 Exit 49	7.7		14	96	213	1391	9	9.0	4.5
SS_04	US 131 median North of Exit 149	7.7		36	43	117	748	42	4.8	1.9
SS_05	I-69 Median MM 44 (SB I-69)	8.2		7	32	73	992	76	5.7	1.9
SS_06	I-69 NB Exit 48 Polygon	7.9		34	50	116	1191	17	7.0	2.8
SS_07	I-69 SB Exit 61 Polygon	7.7		49	118	156	1425	37	8.7	3.4
SS_08	I-69 SB MM 67 Median	8.1		42	68	138	1490	184	8.8	3.3
SS_09	Median of I-75 at rest area ~ 1.5 miles south of Exit 279	7.0		33	26	37	428	36	2.5	1.9
SS_10	I-75 Exit 348, Junction of I-75 and I-75 BL, SE quadrant	7.5		8	86	340	1364	21	9.9	5.4
SS_11	I-75 Exit 352, Junction of I-75 and M 123, SE quadrant	7.8		6	44	176	1833	13	10.7	4.3
SS_12	I-75 exit 143 NW quadrant	7.9		25	67	159	1480	291	8.9	3.1
SS_13	Median I-69 mile marker 157 1/2 mi W of Morris Rd	8.4		10	35	101	1396	104	7.9	1.6
SS_14	I-69 mile marker 161 rest area E bound side	7.5		8	50	112	1008	9	6.1	2.0
SS_15	Median I-69 W of exit 143	8.1		5	59	133	2110	391	11.8	3.0
SS_16	Median I-69 W of exit 128	7.9		6	52	124	1619	198	9.3	2.6
SS_17	I-69 at M-52 NW quadrant	8.1		15	71	159	1720	36	10.1	2.3
SS_18	Site location lost	8.2		15	89	135	2623	210	14.5	3.0

Notes:

Appendix E

Red dots signify soil sample locations.



Estimates for the Production Bioenergy Crops on Land Adjacent to Roads

By

William A. Knudson

Introduction

The purpose of this paper is to provide rough estimates on the cost of production and the breakeven price and yields of selected bioenergy crops on state land that is adjacent to roads. Using this land has several desirable attributes. This land does not compete with the production of food. Also using the land to produce bioenergy crops creates a potential to generate economic activity and jobs on land that currently does not generate income or jobs.

This paper will analyze the following bioenergy crops: canola, switchgrass, pennycress and camelina. Some of the positive and negative attributes of each of these crops will also be identified. A spreadsheet showing the cost of production, and breakeven prices and yields will be generated.

It should be noted that no discount rate is explicitly used for this analysis. This is due to two reasons. A discount rate is imputed in the 5 and 10 percent rate of return break even prices. An alternative way of interpreting these figures is what the breakeven price is assuming a discount rate of 5 and 10 percent. Secondly, the land currently is not generating any income and given current interest rates on government bonds the foregone income on interest earning is virtually zero.

It is very important to note that these will be very rough estimates. Some of the data is several years old. Adjustments for inflation are attempted to make the estimates more accurate, but the reality is that production practices have changed over time. More accurate estimates can be generated when data from test plots becomes available. A cost and viability issue with some of these crops is in some cases the need to apply herbicides. In some cases there are no herbicides that are registered for these crops. Good management practices may be necessary to minimize competition from weeds. These issues present some of the many additional opportunities for additional research.

Growing crops on state land has several cost advantages over the private sector. The state does not pay property taxes or have to pay rent on land. Interest expenses are also small or zero. As a result of this it makes sense for the state to produce crops that do not compete directly against private sector farmers. The crops analyzed in this study are currently grown on few, if any, acres in Michigan. One reason for this is that these crops are currently not as profitable to grow in Michigan as corn (James, Swinton, and Thelen, p.684). Given current prices and costs of production the private sector is not likely to produce bioenergy crops.

Canola

There are several aspects of canola that make it a possible crop to be grown near roadways. It has a higher oil content than many crops especially compared to soybeans. While it has a comparatively low amount of meal the meal that it does produce can be used for animal feed. There is also a well-established market for canola; it can be sold no matter the state of the biofuels market. There is also a futures market for canola which could allow the state to lock in a price. While perhaps less important than other attributes canola is a very attractive crop that has the potential to enhance the attractiveness of the state's roadways. Canola can grow in a wide variety of soil textures (University of Kentucky).

One potential problem with canola is that it might attract wildlife. This could increase the number of vehicle-wildlife accidents. A major issue with canola is that the seeds are smaller than corn or soybeans as a result leaks in machines need to be sealed to minimize harvest loss (Ehrensing and Guy).

Tables 1 and 2 show the estimated cost of production for spring and winter canola as well as breakeven prices.

Table 1: Spring Canola

	High Yield (2,400 lbs. an acre)	Medium Yield (1,800 lbs. an acre)	Low Yield (1,200 lbs. an acre)
Costs			
Seed (5 lb at $2,80)	$14.00	$14.00	$14.00
Nitrogen (125 lbs at .75)	$93.75	$93.75	$93.75
Phosphate (80 lbs. at .75)	$60.00	$60.00	$60.00
Potash (150 lbs at .39)	$58.50	$58.50	$58.50
Weed Sprays	$18.22	$18.22	$18.22
Building Repairs	$2.55	$2.55	$2.55
Gasoline, Fuel, Oil	$21.30	$21.07	$20.77
Utilities, Phone	$2.25	$2.25	$2.25
Trucking/Freight	$48.16	$36.12	$24.08
Marketing	$1.20	$0.90	$0.60
Labor (3.80 hours at $10 an hour)	$38.00	$38.00	$38.00
Equipment Expenses	$28.35	$28.35	$28.35
Total Expenses	$386.28	$373.71	$361.07
Break Even Price (cents per lb.)	16	21	30
Price 5% rate of Return	17	22	32
Price 10% rate of return	18	23	33
Note: In June, the November Futures Price Winnipeg was 17.1 cents			

Source: Nott et al.

Table 2: Winter Canola			
	High Yield (2,900 lbs. an acre)	Medium Yield (2,200 lbs. an acre)	Low Yield (1,500 lbs. an acre)
Costs			
Seed (5 lb at $2.80)	$14.00	$14.00	$14.00
Nitrogen (125 lbs at .75)	$93.75	$93.75	$93.75
Phosphate (80 lbs. at .75)	$60.00	$60.00	$60.00
Potash (150 lbs at .39)	$58.50	$58.50	$58.50
Weed Sprays	$0.00	$0.00	$0.00
Building Repairs	$2.55	$2.55	$2.55
Gasoline, Fuel, Oil	$21.30	$21.07	$20.77
Utilities, Phone	$2.25	$2.25	$2.25
Trucking/Freight	$57.19	$45.15	$30.10
Marketing	$1.20	$0.90	$0.60
Labor (3.80 hours at $10 an hour)	$38.00	$38.00	$38.00
Equipment Expenses	$28.35	$28.35	$28.35
Total Expenses	$377.09	$364.52	$348.87
Break Even Price (cents per lb.)	13	17	23
Price 5% rate of Return	14	17	25
Price 10% rate of return	14	18	26
Note: In June, the November Futures Price Winnipeg was 17.1 cents			

Source: Nott et al

The important conclusion from these tables is that winter canola is preferable to spring canola. The yields tend to be higher and the costs are slightly lower due to the reduced need to spray for weeds for winter canola. As a result, the breakeven prices are lower for winter canola than spring canola. Breakeven prices vary from 16 cents a pound to 30 cents a pound for spring canola and from 13 cents a pound to 26 cents a pound for winter canola.

Switchgrass

Switchgrass has several desirable attributes. The most important desirable attribute is the fact that it does not have to be replanted every year. A well established and managed stand of switchgrass can be productive for more than 10 years (Nyoka et al. p. 4). Another desirable attribute is that when harvested, switchgrass is baled; many other energy crops are small seeds that need to be harvested carefully. Switchgrass can also be applied using no-till techniques, although weeds should be cleared through the use of a nonselective herbicide such as Roundup before seeding. The best time to plant switchgrass is when there is sufficient soil moisture and when the soil temperature is ideally between 59 and 68 degrees (Nyoka et al, p.5).

Shortcomings of switchgrass production include the fact that a crop often cannot be harvested in the year it is planted and that yields in the first year could be less than succeeding years. The second and third full years have good yields. Another potential shortcoming of growing switchgrass especially as it applies to crops grown near roadways is that it could attract wildlife, and has been grown specifically for that purpose (James, Swinton, and Thelen, p.678). Unlike canola there is no well-established market or price discovery mechanism neither for switchgrass nor for other crops that can be used to produce cellulosic ethanol (James, Swinton and Thelen, p.680).

Tables 3 and 4 provide an estimate of the cost of establishing and maintaining a switchgrass field.

Table 3: Switchgrass Establishment Year

	Cost per acre
Costs	
Seed (5 lb at $11.33)	$57.00
Nitrogen	$0.00
Phosphate	$32.00
Potash	$60.00
Weed Sprays	$21.00
Building Repairs	$2.55
Gasoline, Fuel, Oil	$10.65
Utilities, Phone	$2.25
Trucking/Freight	$0.00
Marketing	$0.00
Labor (.44 hours at $10 an hour)	$4.40
Equipment Expenses	$16.77
Total Expenses	$206.62

Sources: Nott et al., University of Tennessee

Table 4: Switchgrass After Establishment			
	4 tons an acre	**6 tons an acre**	**8 tons an acre**
Costs			
Seed (5 lb at $11.33)	$0.00	$0.00	$0.00
Nitrogen	$45.60	$45.60	$45.60
Phosphate	$32.00	$32.00	$32.00
Potash	$60.00	$60.00	$60.00
Weed Sprays	$8.00	$8.00	$8.00
Building Repairs	$2.55	$2.55	$2.55
Gasoline, Fuel, Oil	$10.65	$10.65	$10.65
Utilities, Phone	$2.25	$2.55	$2.55
Trucking/Freight	$12.00	$18.00	$24.00
Marketing	$8.00	$12.00	$16.00
Labor (2.54 hours at $10 an hour)	$25.40	$25.40	$24.50
Equipment Expenses	$64.21	$64.21	$64.21
Total Expenses	$270.66	$280.96	$290.06
Break Even Price (dollars per ton)	$72.83	$50.26	$38.84
5% Rate of Return (dollars per ton)	$76.47	$52.78	$40.78
10% Rate of Return (dollars per ton)	$80.11	$55.29	$42.72

Source: Nott et al., University of Tennessee

The break even prices are based on 10 years (year 1, planting and establishment and 9 years of harvest). Three different yields are estimated 4 tons, 6 tons and 8 tons an acre. The breakeven price varies from $30.07 a ton for the high yield estimate to $72.83 a ton for the low yield estimate. Total costs are divided by the number of years to determine the breakeven price. For a 5 percent rate of return the price varies from $40.78 a ton for the high yield estimate to $76.47 a ton for the low yield estimate. To obtain a 10 percent rate of return the price varies from $42.72 a ton for the high yield estimate to $80.11 a ton for the low yield estimate.

Camelina

Camelina is a member of the mustard family. It has a high oil content and has an especially high level of omega-3 acid (Institute for Agriculture and Trade Policy), which creates potential for the food market as well as the biodiesel market.

Camelina has several desirable aspects. It requires little seedbed preparation and can be broadcast sown. It is also tolerant to cold and has some drought tolerance. However, the seeds are very small and harvesting equipment needs to be able to handle the seeds without losing them through the combine (Institute for Agriculture and Trade Policy). Post-harvest handling of the crop is important for the same reason.

Table 5 shows the estimated cost of production and breakeven prices for camelina. There is an estimate of $10 an acre for weed sprays. However, it may be possible to grow camelina without using herbicides (Ehrensing and Guy). If that is the case, cost per acre will decline by $10.

Table 5: Camelina

Costs	**Cost per acre (1,000 lbs. per acre)**	**(1,250 lbs. per acre)**	**(1,500 lbs. per acre)**
Seed	$3.00	$3.00	$3.00
Fertilizer	$16.50	$16.50	$16.50
Weed Sprays	$10.00	$10.00	$10.00
Building Repairs	$2.55	$2.55	$2.55
Gasoline, Fuel, Oil	$10.65	$10.65	$10.65
Utilities, Phone	$2.25	$2.25	$2.25
Trucking/Freight	$12.00	$15.00	$18.00
Marketing	$4.00	$5.00	$6.00
Labor (.44 hours at $10 an hour)	$4.40	$4.40	$4.40
Equipment Expenses	$19.08	$19.08	$19.08
Total Expenses	$84.43	$88.43	92.43
Brekeven Price (dollars per pound)	$0.08	$0.07	$0.06
5 Percent Rate of Return	$0.09	$0.07	$0.06
10 Percent Rate of Return	$0.10	$0.08	$0.07

Sources: Nott et al., Economics of Oilseeds for Biofuels in Montana

It should be noted that camelina has the potential to be extremely profitable. In 2008, a Montana based company offered contracts for the 2009 crop at 20 cents a pound (Economics of Oilseeds for Biofuels in Montana), far in excess of the figures listed in the table. If herbicides are avoided the breakeven prices decline by about ½ a cent per pound. Most of these costs are based on figures in Montana; the experience in Michigan may be different. Also, the yield figures may be optimistic, if actual yields are lower, the break even prices will be higher. Furthermore, camelina is a minor crop, small changes in output and acres planted could lead to a large decline in prices. Finding a market and locking in a price is very important.

Pennycress

Pennycress, also known as stinkweed is generally considered a weed but is a potential crop with a high oil content well suited to produce biodiesel (Moser et al, p.4149, 4150). Like camelina it is a member of the mustard family (Ampong-Nyarko). It can grow in a wide range of soils and requires minimal agricultural inputs. It has the potential to produce more oil per acre than camelina and soybeans and it has excellent cold weather operating characteristics (Moser et al. p.4150, 4153).

A shortcoming of pennycress is that its oil cannot be used for food although it can be used has a fumigant. Unlike canola there is no firm market for pennycress oil. Pennycress also has the same harvesting and handling issues facing canola and camelina.

There is also little cost of production data for pennycress. Most of the research is being done in Alberta. Given that it is in the same family as camelina the cost of production is likely to be similar to camelina. Yields are in the 2,200 to 2,500 lbs per acre (Ampong-Nyarko) range; however, this might be on the high side. Given these assumptions table 6 gives the break even prices for pennycress.

Table 6: Pennycress

	Cost per acre		
Costs	**(2,000 lbs per acre)**	**(2,250 lbs. per acre)**	**(2,500 lbs. per acre)**
Seed	$3.00	$3.00	$3.00
Fertilizer	$16.50	$16.50	$16.50
Weed Sprays	$10.00	$10.00	$10.00
Building Repairs	$2.55	$2.55	$2.55
Gasoline, Fuel, Oil	$10.65	$10.65	$10.65
Utilities, Phone	$2.25	$2.25	$2.25
Trucking/Freight	$24.00	$27.00	$30.00
Marketing	$8.00	$9.00	$10.00
Labor (.44 hours at $10 an hour)	$4.40	$4.40	$4.40
Equipment Expenses	$19.08	$19.08	$19.08
Total Expenses	$100.43	$104.43	108.43
Brekeven Price (dollars per pound)	$0.05	$0.05	$0.04
5 Percent Rate of Return	$0.05	$0.05	$0.05
10 Percent Rate of Return	$0.06	$0.05	$0.05

Sources: Nott et al., Economics of Oilseeds for Biofuels in Montana, Ampong-Nyarko

Given the lack of hard data on pennycress these figures should be considered very rough estimates. The yield estimates are for Alberta and the cost estimates are based primarily on Montana figures. The experience in Michigan could be very different. Due to potentially higher yields the breakeven prices are lower for pennycress than they are for camelina, and are generally in the 4 to 6 cents a pound range (the breakeven prices are rounded to the nearest cent).

Areas for Further Research

There are several areas for further research. The most important issue is to develop test plots to determine the actual cost of production along road right of ways. Another important area for research is to analyze potential supply chains and markets for these crops. This includes determining potential buyers of the biomass produced along right of ways.
A third area of research is to analyze the potential for bioenergy crop production on other public lands. Examples include game land owned by the Department of Natural Resources and the

Environment and land controlled by airports. In the case of game land bioenergy crops that attract wildlife could be analyzed.

References

Ampong-Nyarko, K. *Pennycress – Up – and – Coming Low Break-Even Cost Crop for the Prairies*.

Economics of Oilseeds for Biofuels in Montana. http://thebioenergysite.com/articles/460.

Ehrensing, D.T. and S.O. Guy. *Camelina*, EM8953-E. Corvallis: Oregon State University Extension Service, 2008.

Institute for Agriculture and Trade Policy. *Camelina: Camelina Sativa*.

James, L., S. Swinton, and K. Thelen. "Profitability Analysis of Cellulosic Energy Crops Compared with Corn." *Agronomy Journal* (2010) Vol. 102, Issue 2 (675-687).

Moser, B., G. Knothe, S. Vaughn, and T. Isbell. "Production and Evaluation of Biodiesel from Field Pennycress (*Thlaspi arvense* L.)Oil." *Energy and Fuels* (2009) Vol. 23 (4149-4155).

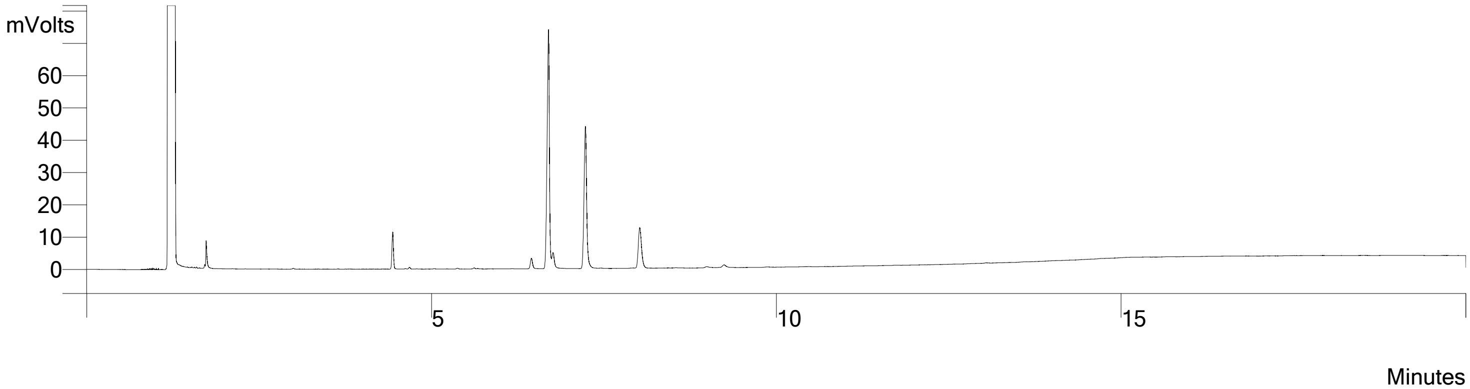
Nott, S., G. Schwab, J. Jones, J. Hilker and L. Copeland. *1995 Crops and Livestock Budgets Estimates for Michigan*, Agricultural Economics Report No. 581. East Lansing: Department of Agricultural Economics, Michigan State University, May 1995.

Nyoka, B., P. Jeranyama, V. Owens, A. Boe, M. Moechning. *Management Guide for Biomass Feedstock Production from Switchgrass in the Northern Great Plains*. Brookings: North Central Sun Grant Center.

University of Kentucky Cooperative Extension Service. *Canola*.

University of Tennessee. *Guideline Switchgrass Establishment and Annual Production Budgets Over Three Year Planning Horizon*, E12-4115-00-001-08. Knoxville: University of Tennessee Extension.

Data File:	c:\research\fames mustard\fames	Operator (Calc):	lars
Channel:	Middle = FID RESULTS	Calc Date:	08/25/2010 04:23:26 PM
Sample ID:	fames mustard	Times Calculated:	8
Operator (Inj):	lars	Calculation Method:	c:\research\lars\lars\4-15-2010 4-15-39
Injection Date:	08/25/2010 01:20:09 PM	Instrument (Calc):	Varian GC/MS #1
Injection Method:	c:\research\lars\gc methods\fames mega	Run Mode:	Analysis
Run Time (min):	20.003	Peak Measurement:	Peak Area
Workstation:	SPARTY	Calculation Type:	Percent
Instrument (Inj):	Varian GC/MS #1	Calibration Level:	N/A
		Verification Tolerance:	N/A



Peak No	Peak Name	Result ()	Ret. Time (min)	Time Offset (min)	Area (counts)	Rel Ret Time	Sep. Code	Width 1/2 (sec)	Status Codes	Group
1	C14:0	0.10	2.99	-0.006	372	0.00	BB	1.2		0
2	C16	4.66	4.44	-0.062	17619	0.00	BB	1.4		0
3		0.05	4.62	0.000	194	0.00	BV	1.4		0
4		0.23	4.68	0.000	861	0.00	VB	1.4		0
5		0.05	5.04	0.000	200	0.00	BB	1.6		0
6		0.10	5.37	0.000	392	0.00	BB	1.6		0
7		0.16	5.62	0.000	596	0.00	BV	1.6		0
8		0.08	5.67	0.000	311	0.00	VB	1.8		0
9	C18:0	1.92	6.45	-0.024	7265	0.00	BB	2.0		0
10	C18:1 cis+tran	47.79	6.69	-0.001	180828	0.00	BB	2.2		0
11		1.33	6.76	0.000	5023	0.00	TS	0.0		0
12	C18:2 cis+tran	31.25	7.23	-0.005	118257	0.00	BB	2.4		0
13	C18:3	10.88	8.02	0.002	41155	0.00	BB	3.0		0
14	C20:0	0.43	8.99	-0.042	1613	0.00	BB	4.1		0
15		0.82	9.24	0.000	3102	0.00	BB	3.4		0
16	C22:0	0.06	11.73	-0.006	227	0.00	BB	0.0		0
17		0.10	13.05	0.000	377	0.00	BB	0.0		0
	Totals	**100.01**		**-0.144**	**378392**					