Purpose-Grown Biomass Crops: Efficient Production, Yield Modelling and Real-world Verification

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• Partners:

[Logos of various organizations]

ADECO
BioResources Inc.
Project Goals

• This research will:
  – determine the yield potential of four purpose-grown biomass crops on marginal agricultural lands in Nova Scotia;
  – identify locally-source biological inputs to enhance the growth of these crops;
  – demonstrate the suitability of these crops in different agricultural areas;
  – create models to predict the yield of these crops under NS growing conditions.
The Problem/Opportunity

• Uncertainties about Nova Scotia’s biomass feedstock basket

• Limited volume of woody biomass
• High costs of wood
• Potential for insecure supplies
• Changes in forestry policy
• Lack of data on alternative biomass sources
The Problem/Opportunity

- Nova Scotia has an “abundance” of underutilized, marginal agricultural land which could grow purpose-grown biomass crops.
- For example, there is 418,166 ha of “Class 4” land in the Province\(^1\).

\(^1\)NSDA (2020) Profile of Agricultural Land Resources in Nova Scotia
Advantages of Purpose-Grown Biomass Crops

- Can be grown on marginal agricultural lands (CLI Class 3 and less)
- No “food versus fuel” debate
- Perennial crops – once established, crops can be harvested from 15 to 30 years
- High yields (12 – 18 Dt/ha/yr) with very little to no inputs (fertilizer, pesticides, etc.)
- Increase the carbon/organic matters content of soil
The Problem/Opportunity

- **Agricultural Producer:**
  “I will not grow these crops unless I have a market for the biomass.”

- **Biorefiner/Investors:**
  “I will not invest in a biorefinery until I am sure of a supply chain of biomass to my plant’s gate.”
Approach – Field Studies

- Test four biomass crops at seven locations across Nova Scotia with three biological inputs (pulp-mill residue, aerobic digestate, and seaweed extract) plus untreated control plots. Monitored until 2023.
Approach – Field Studies

• Five sites were established in the summer of 2019. An additional two sites will be established in 2021.
What are we measuring?

• Mid-season:
  – Survival rates
  – Maximum plant height
  – Leaf number
  – Leaf area
  – Stem or tiller number
  – Soil sampling from each treatment
What are we measuring?

• End-of-season:
  – Survival rate
  – Dry weight (grasses annually; trees every 3 yrs)
  – Maximum plant height
  – Stem number, diameter and height (trees only)

• Biomass harvested from the Miscanthus plots is also analyzed for nutrient content

• Meteorological data
Progress to date – Field Studies
Mean above-ground biomass dry weight (g) as influenced by soil treatment from Nappan, Nova Scotia, in 2019. CT = Control, DG = liquid digestate, PS = pulp mill sludge and SE = seaweed extract. Different letters indicate significant difference at $P < 0.05$. Bars indicate standard error. (NB: Dry weights are per sample and given that the sampling procedure was different for each grass, the dry weights between switchgrass and Miscanthus in the figures are not directly comparable.)
Lessons learned about establishing the crops

- The presence of deer can be a serious issue for establishing the tree species.
Lessons learned about establishing the crops

- Weed control is extremely important in the first couple of years.
  - Grasses: Weed pressure in the Miscanthus plots was much less than in the switchgrass plots due to Miscanthus’s remarkable growth. A herbicide application in year 2 was necessary in the switchgrass plots.
Lessons learned about establishing the crops

• Frost heaving at sites with heavy soils can be a problem for tree establishment:
  – Tree survival over the first winter (2019-20) was very poor at one site. Due to frost-heaving of the stem cuttings planted the previous season.
Lessons learned about establishing the crops

• In general, Miscanthus is doing amazing well!
  – We have almost 100% establishment and over-wintering survival rates in our Miscanthus plots.
  – This maybe largely be due to our use of Miscanthus transplants, rather than rhizomes, to establish the stands.

Miscanthus plots at the East Skye Glen site in mid-August.
Lessons learned about establishing the crops

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Approach – Yield Modelling

• There too few studies of purpose-grown biomass crops in Nova Scotia to confidently inform industry of their potential yield in the Province.

• We are creating models of yield potential based upon studies of growth of biomass crops from around the world in areas with comparable climates to Nova Scotia.
Progress on Yield Modelling

- After analysing over 50 soil and meteorological factors from hundreds of site-years of data from published studies on switchgrass yield potential, two factors (growing-degree days and seasonal precipitation) were identified as highly predictive of switchgrass yield.
Switchgrass yield model

Scatterplot of measured switchgrass biomass yield (Mg ha\(^{-1}\)) against predicted switchgrass biomass yield (Mg ha\(^{-1}\)). Dotted lines indicate the 95 % prediction interval, while the grey shaded area represents the 95 % confidence interval. The bold line represents the 1:1 fit (\(y = 0.5191x + 5.183\), \(R^2 = 0.6222\), \(n = 153\)). Blue dots represent data collected from Nova Scotia.

Bar plot of predicted switchgrass biomass yield (Mg ha\(^{-1}\)) based on growing degree days (GDD) and precipitation (mm) over a typical growing season in Nappan and Kentville, Nova Scotia. The growing season was measured from 15 April – 15 October for 9 years (2011 – 2019).
Miscanthus yield model

Scatterplot of measured *Miscanthus* biomass yield (Mg ha\(^{-1}\)) against predicted *Miscanthus* biomass yield (Mg ha\(^{-1}\)). Dotted lines indicate the 95% prediction interval, while the grey shaded area represents the 95% confidence interval. The bold line represents the 1:1 fit (\(y = 0.7534x + 5.8192\), \(R^2 = 0.8143\), \(n = 40\)).

Bar plot of predicted *Miscanthus* biomass yield (Mg ha\(^{-1}\)) based on growing degree days (GDD) and precipitation (mm) over a typical growing season in Nappan and Kentville, Nova Scotia. The growing season was measured from 15 April – 15 October for 9 years (2011 – 2019).

Mean yield = 21.3 ± 2.0 Mg ha\(^{-1}\)
Relevance and Success Outcomes

• This research will determine the yield potential and identify best-practices for production of biomass crops in different agricultural areas within Nova Scotia, thereby reducing the financial risk to potential producers and users of these crops.

• This research may help create new revenue streams for agricultural producers from underutilized, marginal lands.

• This research may help diversify the biomass feedstock base to help attract more biomass processing facilities to Nova Scotia.

• This research may help create new markets for the three biological inputs (pulp-mill residue, aerobic digestate, and seaweed extract) being tested.
Will the yield potential be high enough, and the cost of production low enough, to convince agricultural producers to grow these crops and to attract more biomass processing facilities to Nova Scotia?

Will government policy decision be made to help grow this aspect of the bioeconomy in Nova Scotia?
Future Work

• Continue maintenance and data collection data on the five established sites.
• Establishment of two additional sites in 2021.
• Continue to refine databases and yield prediction models for switchgrass and Miscanthus, finalize the model for willow, and develop the same for poplar.

Planned field site at Chegoggin Point, near Yarmouth, NS.
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Adapted and Productive Cultivars for Dedicated Perennial Bioenergy Crops in Eastern Canada

Yousef A. Papadopoulos
Dedicated perennial bioenergy Grass Species:

– **Switchgrass** (*Panicum virgatum*)

– **Miscanthus** (*Miscanthus giganteus*)
Outline

• **Switchgrass** (*Panicum virgatum*)

  – Breeding efforts to develop productive bioenergy feedstock switchgrass cultivars.

  – Adaptation and productivity of bioenergy feedstock switchgrass and Miscanthis cultivars in Canada:
    • Results from Current Cultivar Evaluation Trials
Adaptability and Productivity Evaluation of Perennial Grass Species and Cultivars for Dedicated Bioenergy Cropping
Establishment of Perennial Grass Species and Cultivars
(Evaluation Trial Seeded at Nappan Research Farm in 2011)
Long Term Adaptability and Productivity Evaluation of Switchgrass Cultivars for Dedicated Bioenergy Cropping
(Evaluation Trial Seeded at Nappan Research Farm in 2011)

September 1st 2020

October 2nd 2020
Long Term Adaptability and Productivity Evaluation of Switchgrass Cultivars for Dedicated Bioenergy Cropping
(Evaluation Trial Seeded at Nappan Research Farm in 2011)
Current Studies on Adaptation and Productivity of Bioenergy Switchgrass Cultivars

Sites of Evaluation Trials
Long Term Adaptability and Productivity Evaluation of Switchgrass Cultivars for Dedicated Bioenergy Cropping
Switchgrass Cultivars Establishment - Average 1st Production Year (2019) Nappan, NS, Indian Head, SK, Lethbridge, AB and Agassiz, BC

(Evaluation Trial Seeded at Nappan Research Farm in 2018)
Effective Management Strategy
4 Miscanthus cultivars (BNC, Ryerse, Gildale and Riverside) Established in 2018 at Nappan, NS, Indian Head, SK, Lethbridge, AB and Agassiz, BC
20 second summary

- Switchgrass is a productive and persistent bioenergy species in Canada.

- Based on long term switchgrass evaluation trials in the US and Canada, high yielding and winter hardy cultivars are commercially available for northern latitudes.

- AAFC breeding program is making good progress on enhancing the persistence and yield of Switchgrass for use as biofuel feedstocks.

- Limited number of Miscanthus cultivars currently available with adequate adaption to Canadian growing conditions.