Establishment and Yield Potential of Four Biomass Crops on Marginal Lands in Nova Scotia

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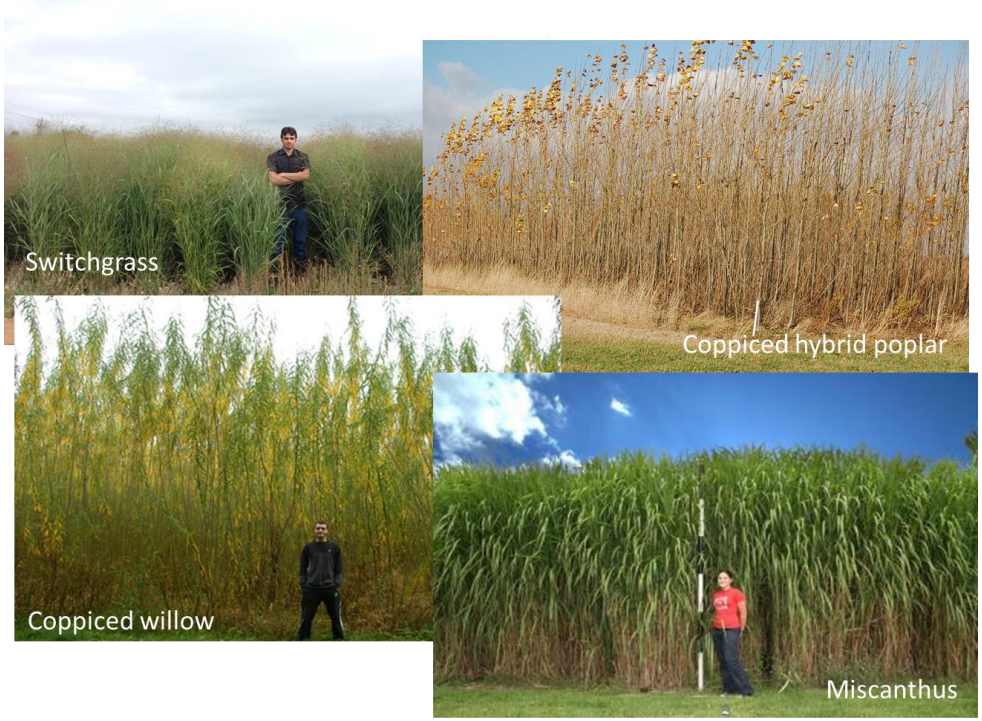
Project Goals

To assess the potential of biomass crops as a major feedstock supply for bioprocessing in NS by:

- determining the yield potential of four biomass crops on marginal agricultural lands across NS;
- identifying locally-source biological inputs to enhance the growth of these crops;
- creating models to predict the yield of these crops under NS growing conditions;
- testing adaptivity of Miscanthus and switchgrass cultivars to NS growing conditions



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Project Overview

- 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

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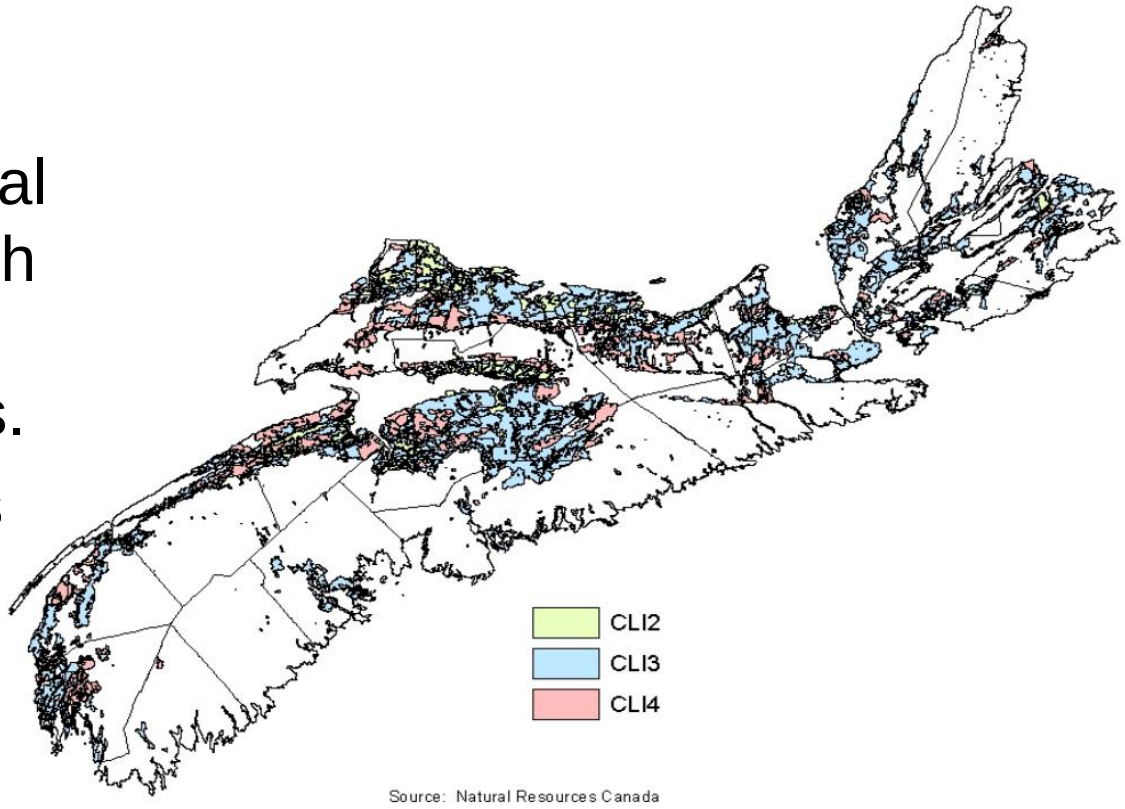
Project Overview

- 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
- No forest harvesting 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

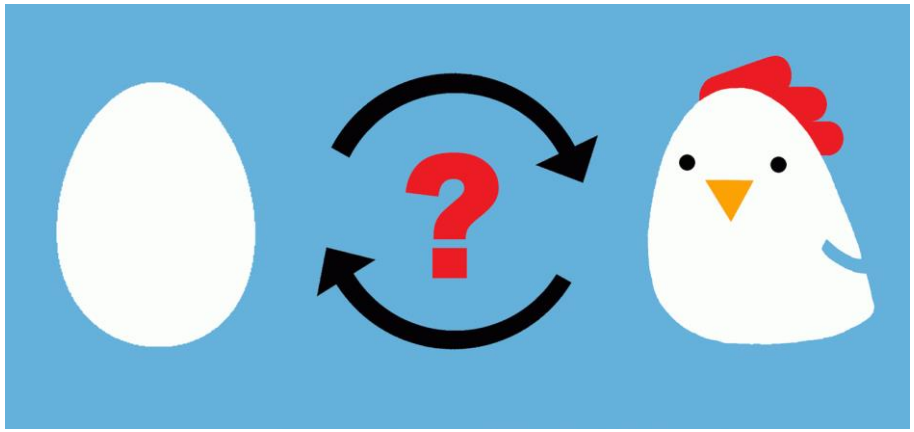
Project Overview

- Agricultural Producer:

  "I will not grow these crops unless I have a market for the biomass."

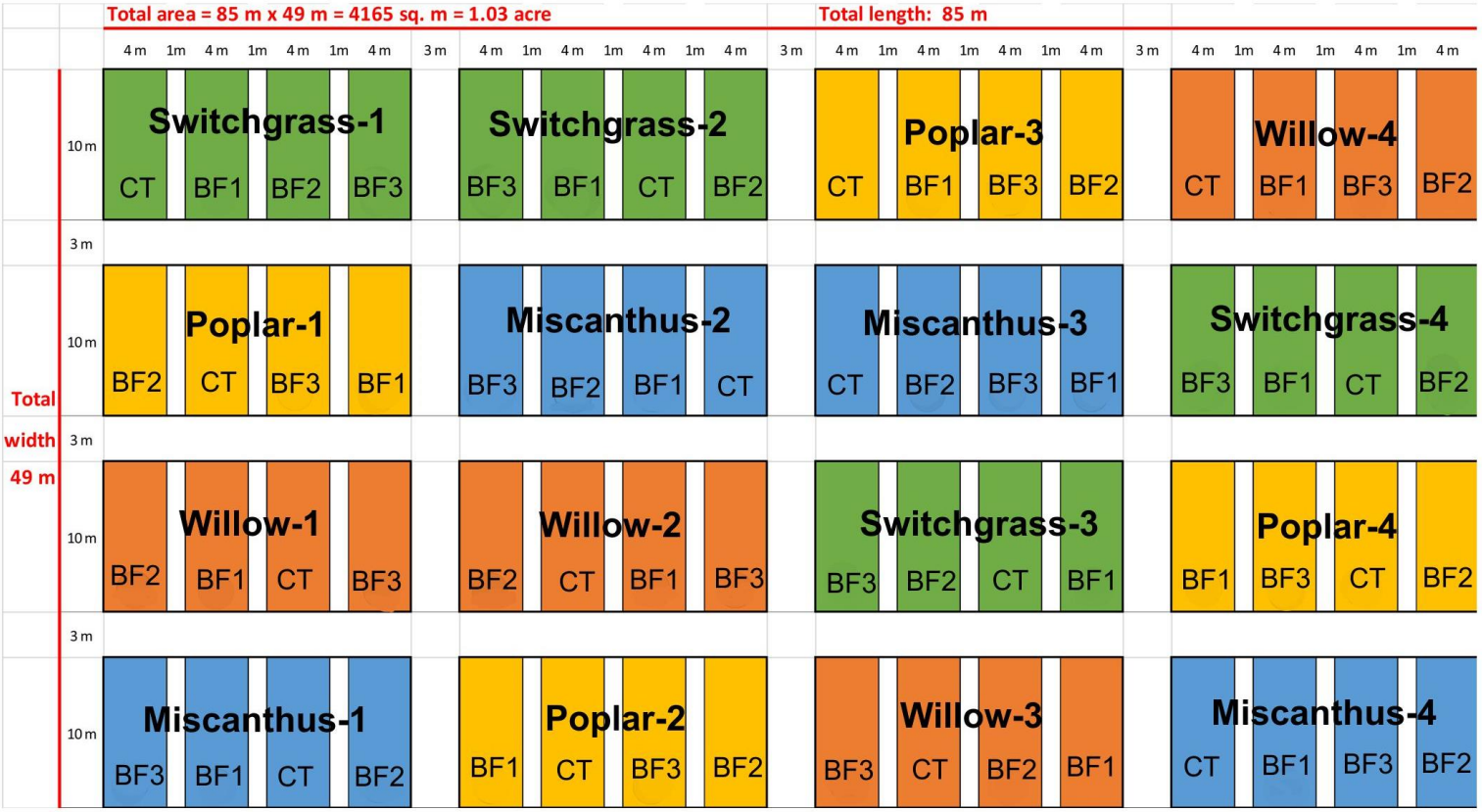
- Biorefiner/Investors:

  "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 and two sites in 2021.

What are we measuring?

- Crop performance data:
  - E.g., survival rates, plant height, leaf area, stem/tiller number
- Yield
- Soil and tissue nutrients
- Meteorological data
- Biomass quality characteristics

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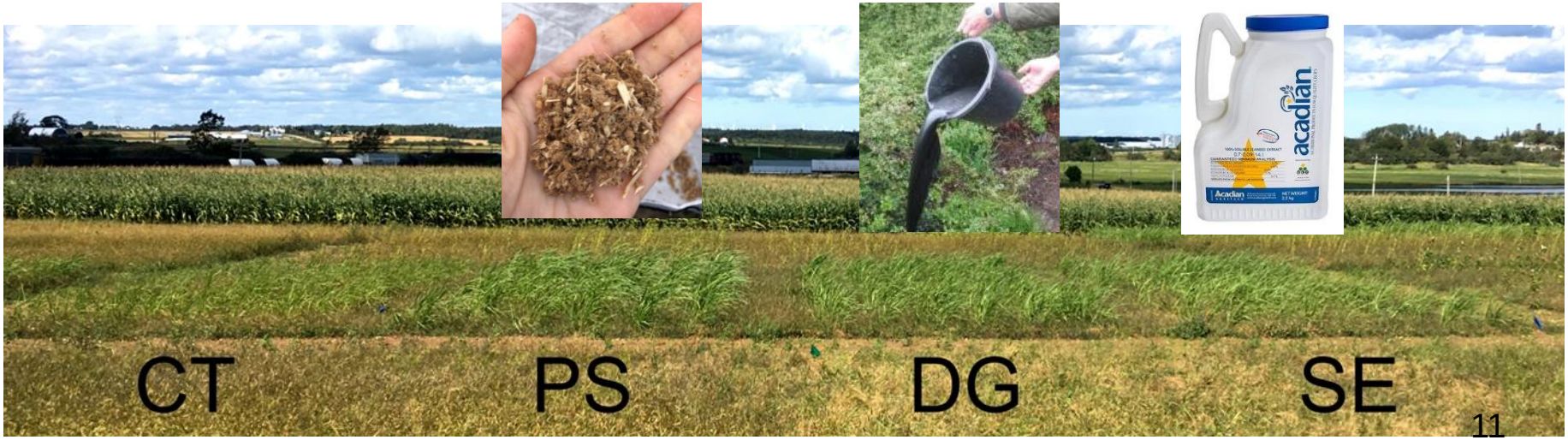
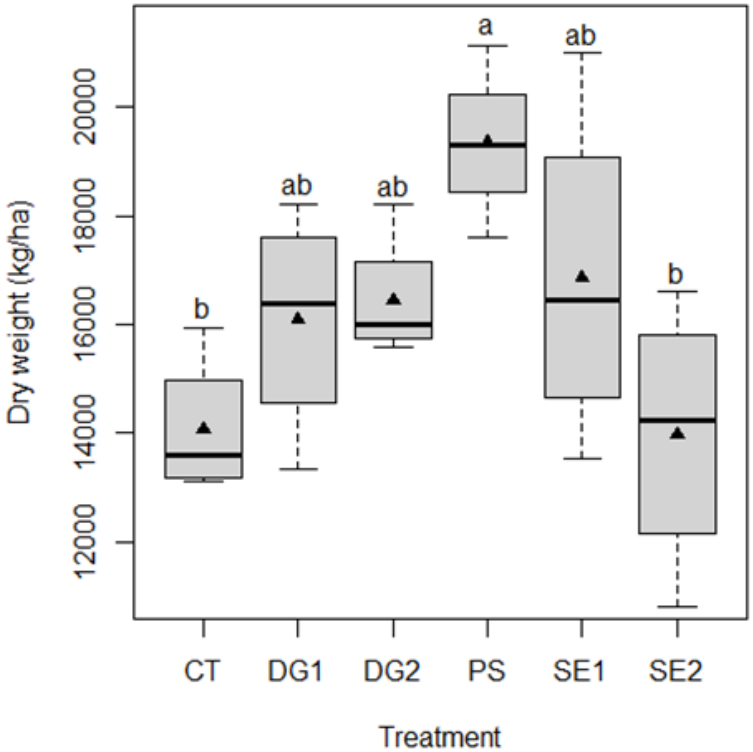
Progress to Date



Progress to Date

Examples of crop growth. Miscanthus (on left) and hybrid poplar (on right) subplots at the East Skye Glen Site on 2 Sept. 2021.



Effects of soil amendments on Miscanthus dry weight accumulation at the Skye Glen site in the fall of 2021.

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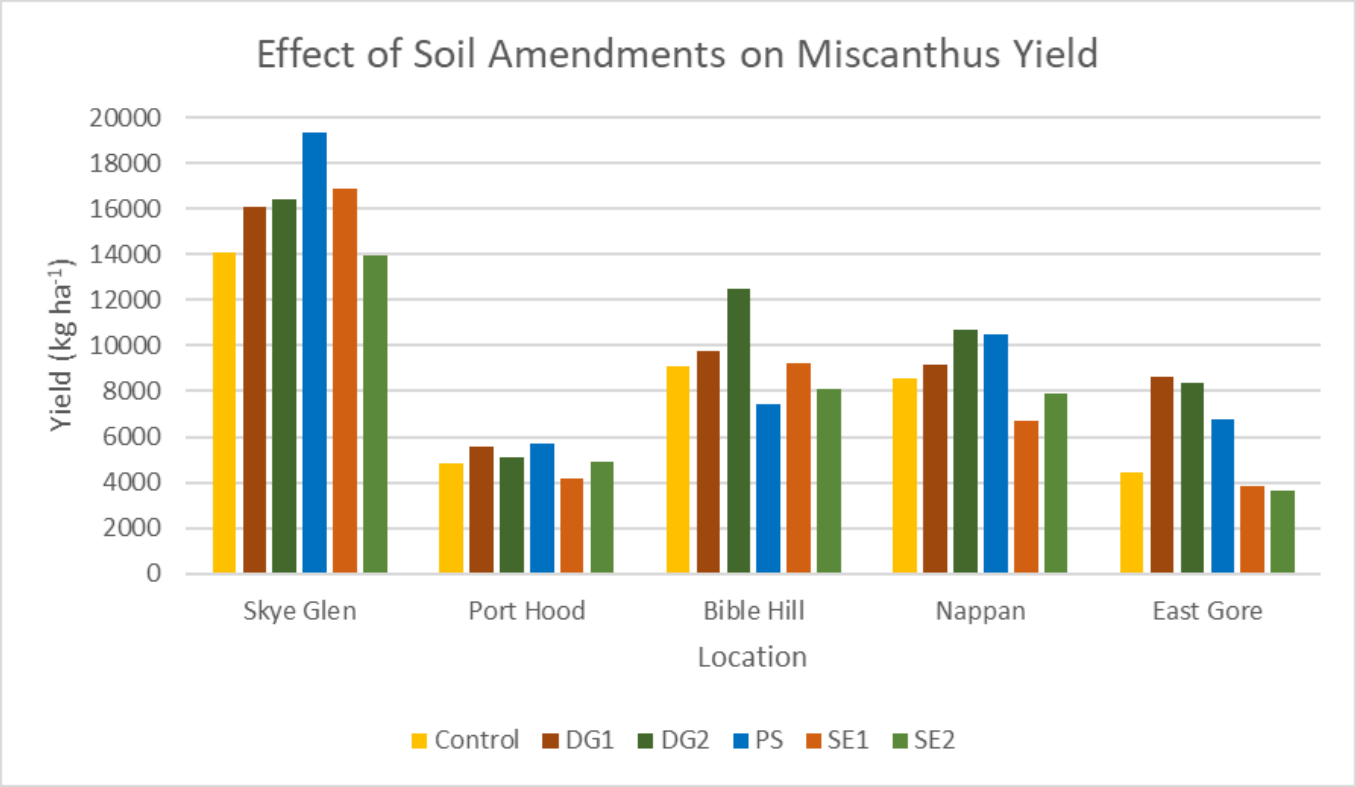
Effects of soil amendments are visible on crop growth

Effects of soil amendments on Miscanthus dry weight accumulation at the Nappan site on 9 Sept. 2021. CT = control; DG1 = single application of anaerobic digestate; DG2 = double application of anaerobic digestate; PS = pulp mill residue; SE1 = single application of seaweed extract; and SE2 = double application of seaweed extract.

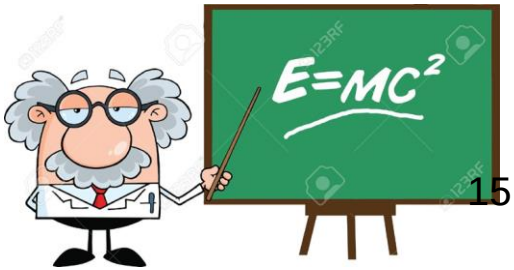
Yield potential varies among sites



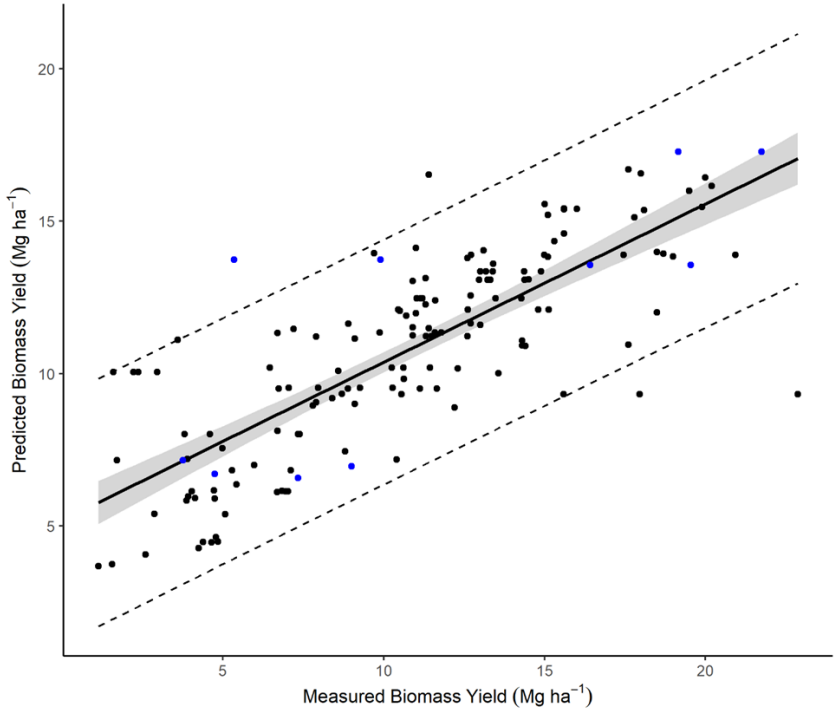
Effect of soil amendments on Miscanthus yield at five locations in Nova Scotia in 2021. CT = control; DG1 = single application of anaerobic digestate; DG2 = double application of anaerobic digestate; PS = pulp mill residue; SE1 = single application of seaweed extract; and SE2 = double application of seaweed extract.

Approach – Yield Modelling

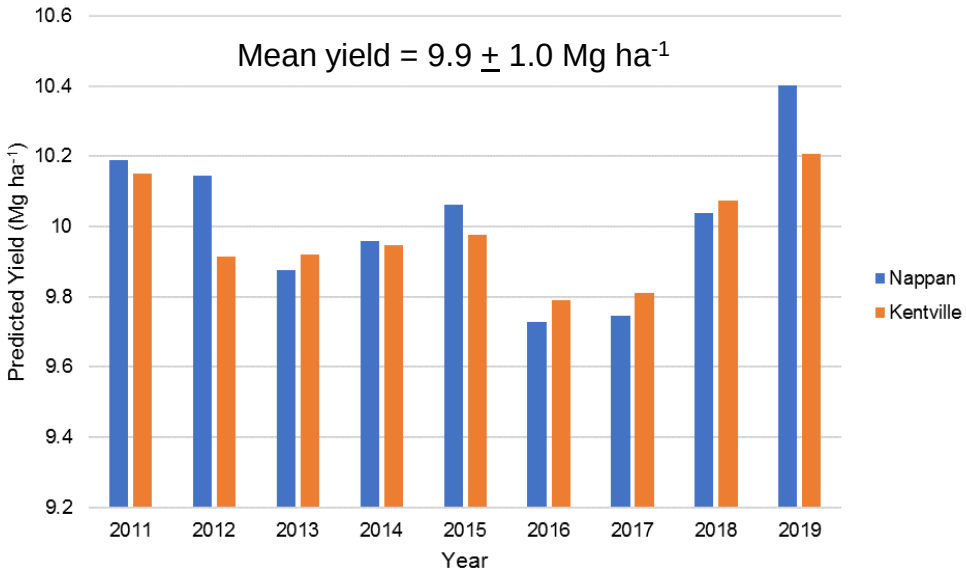
- There are too few studies of purpose-grown biomass crops in Nova Scotia to confidently inform industry of their potential yield in the Province.
- We are creating models of yield potential based upon studies of growth of biomass crops from around the world in areas with comparable climates to Nova Scotia.
- 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.

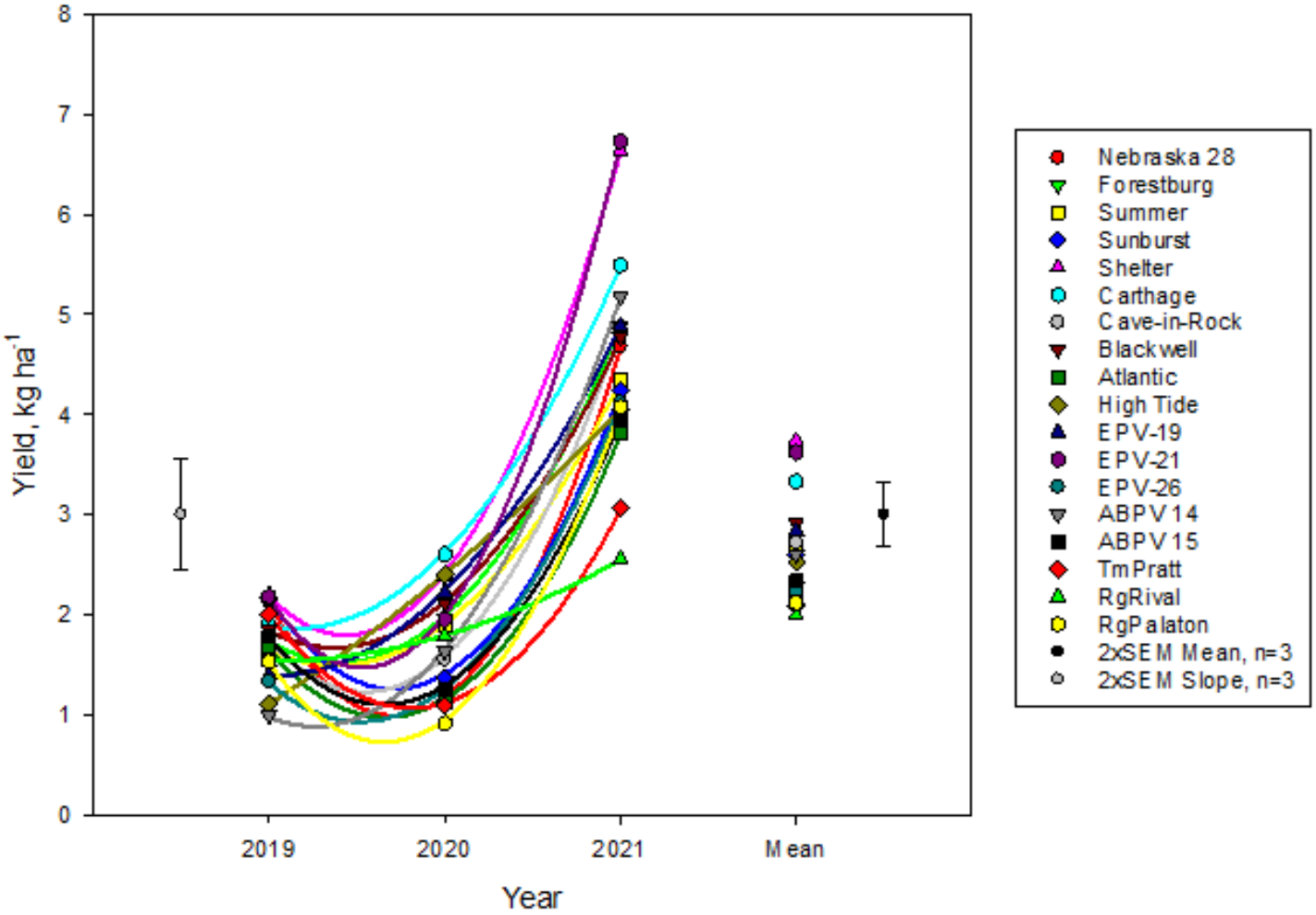


Bar plot of predicted switchgrass biomass yield (Mg ha^{-1}) based on growing degree days (GDD) and precipitation (mm) over a typical growing season in Nappan and Kentville, Nova Scotia. The growing season was measured from 15 April – 15 October for 9 years (2011 – 2019).

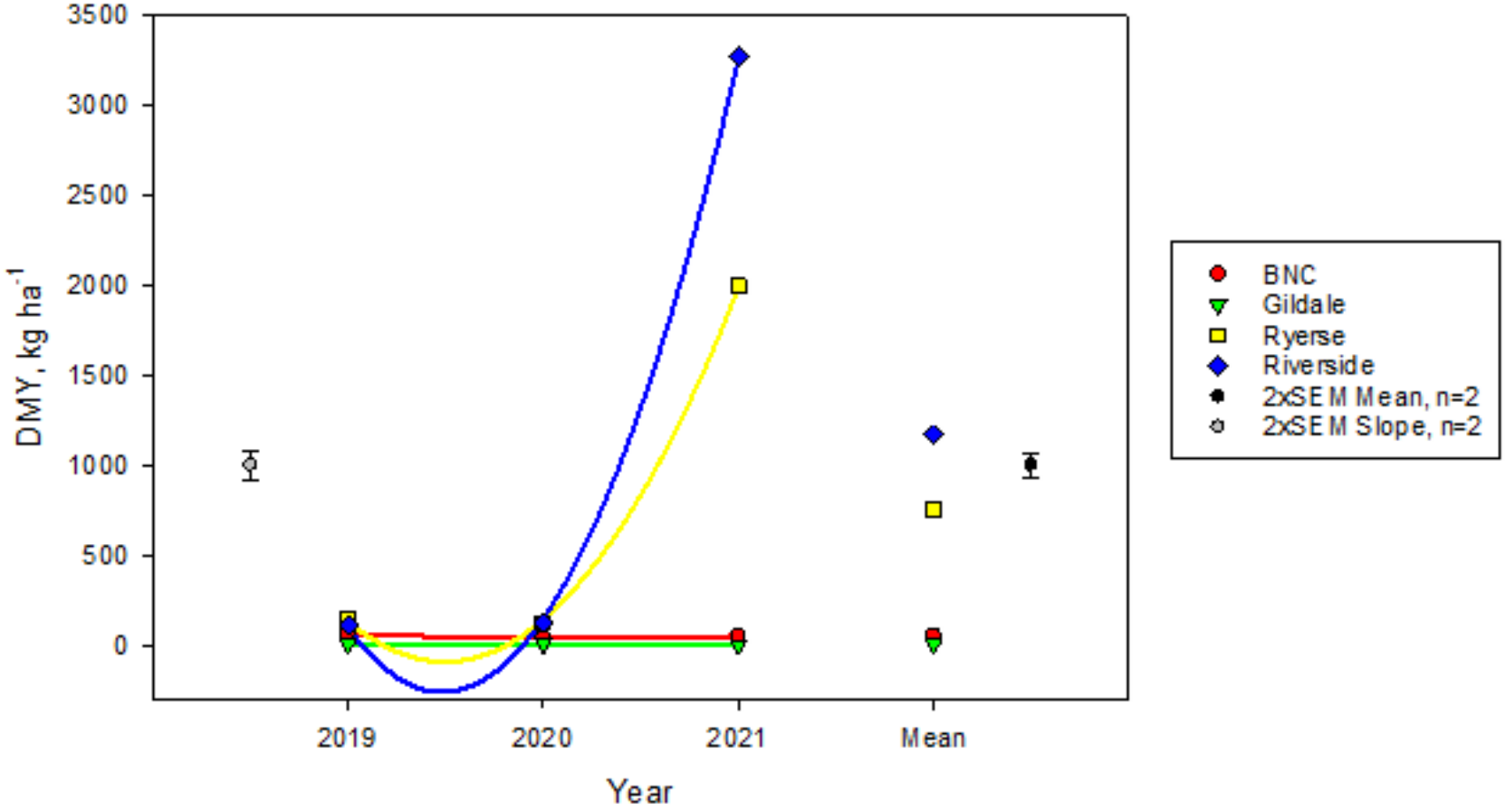
Approach - Testing switchgrass and Miscanthus cvs under NS growing conditions

- 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.
- The AAFC breeding program is making good progress on enhancing the persistence and yield of Switchgrass for use as biofuel feedstocks
- There are only a limited number of Miscanthus cultivars currently available with adequate adaption to Canadian growing conditions.

Biomass DW accumulation of switchgrass cultivars at Nappan in the fall of 2019, 2020 and 2021



Biomass DW accumulation of Miscanthus cultivars at Nappan in the fall of 2019, 2020 and 2021



Relevance: Lessons learned about establishing the crops

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

Relevance: Lessons learned about establishing the crops

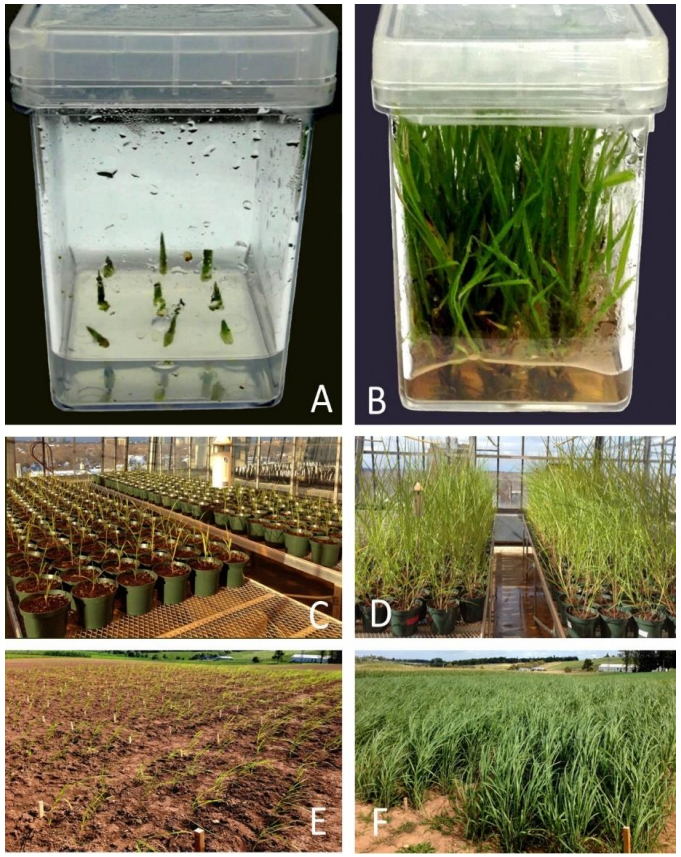
- Weed control is extremely important in the first couple of years.
  - Grasses: Weed pressure in the Miscanthus plots was much less than in the switchgrass plots due to Miscanthus's remarkable growth. A herbicide application in year 2 was necessary in the switchgrass plots.

Relevance: 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.

Relevance: 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.



Success Outcomes

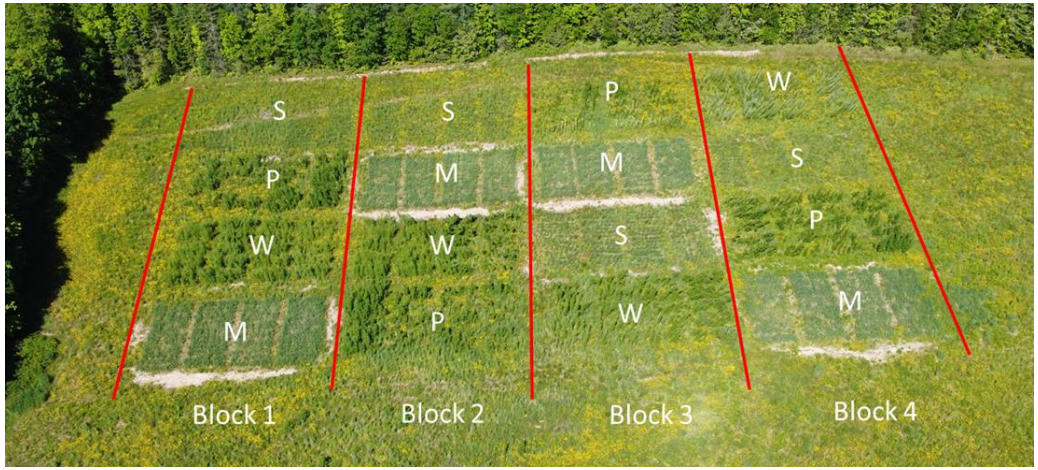
- This research will:
  - determine the yield potential and identify best-practices for the production of biomass crops in different agricultural areas within Nova Scotia, thereby reducing the financial risk to potential producers and users of the biomass.
  - may help create new revenue streams for agricultural producers from underutilized, marginal lands.
  - may help diversify the biomass feedstock base to help attract more biomass processing facilities to Nova Scotia.
  - may help create new markets for the biological inputs (i.e., the pulp-mill residue and aerobic digestate) being tested.

Critical Success Factors

- 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 seven established sites.
- Continue to refine databases and yield prediction models for switchgrass, Miscanthus, and willow, and finalize the model for poplar.
- Complete an economic analysis of the production of Miscanthus from tissue culture and transplants
- Test biomass tissues for quality characteristics
- Continue the testing of the switchgrass and Miscanthus cultivars under NS growing conditions.



Summary

- Using on-farm field trials, yield modelling, and the testing of biomass-grass cultivars, we will develop a good understanding of the yield potential of these four biomass crops grown on marginal lands in NS.
- We have shown that these crops can be established and have significant yield potential in their first few years of growth.
- The outcomes of this research should reduce the investment risks of both biomass producers and biomass users.

Summary

- While we have demonstrated that these crops can be established and produce significant biomass on marginal lands in NS, the commercial success of the use of these crops will be dependent on the development of transport systems and markets for the biomass.
- The next year of work will better characterize the value of these crops through an economic analysis of the Miscanthus plantlet production and determination of quality characteristics of the biomass produced from the sites across NS.

With special thanks to . . .

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