Alternative Crops for Bedding, Feed and Fuel on Livestock Operations

Dr. Bill Deen – University of Guelph
Dr. Mahendra Thimmanagari – OMAF
Christoph Wand – OMAF

FarmSmart – January 18, 2014
Why Alternative (Forage) Crops?

- Multiple purposes, flexibility
- Emergency & opportunity feed
- High demand for straw as bedding
- Biomass to heat livestock facilities
- Compliment complex Ontario cropping systems for timing and equipment
## Four Categories, Three Purposes

<table>
<thead>
<tr>
<th></th>
<th>Energy (heat)</th>
<th>Feed</th>
<th>Bedding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residues</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Double-Crops</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annuals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perrenials</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Crop residues

- Corn stover
- Corn cobs
- Soybean residue
- Wheat straw
Sustainability and technical challenges associated with crop residues
Double crop forage trial

• Fall harvested - after winter wheat
  – fall rye, winter triticale, winter barley, winter wheat

• Spring harvested - after soybean or corn silage
  – oats, oats/peas, barley, wheat, triticale

• At various stages measuring
  – Yield, nutrient content, feed value
### Woodstock 2014 – forages after wheat

<table>
<thead>
<tr>
<th>Crop</th>
<th>N-rate kg/ha</th>
<th>Dry Yield (kg/ha)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Oct-08</td>
<td>Oct-23</td>
<td>Nov-24</td>
<td></td>
</tr>
<tr>
<td>Oats (70lb/ac)</td>
<td>0</td>
<td>1627</td>
<td>2420</td>
<td>3013</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>2187</td>
<td>3100</td>
<td>3920</td>
<td></td>
</tr>
<tr>
<td>Oats (105 lbs/acre)</td>
<td>0</td>
<td>1618</td>
<td>1527</td>
<td>2453</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>2107</td>
<td>2773</td>
<td>3720</td>
<td></td>
</tr>
<tr>
<td>Oats/Peas (110 lbs/acre)</td>
<td>0</td>
<td>1502</td>
<td>1933</td>
<td>2827</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>1951</td>
<td>2487</td>
<td>2960</td>
<td></td>
</tr>
<tr>
<td>Barley (100 lbs/acre)</td>
<td>0</td>
<td>507</td>
<td>713</td>
<td>947</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>622</td>
<td>967</td>
<td>1947</td>
<td></td>
</tr>
</tbody>
</table>
## Elora 2014 – forages after wheat

<table>
<thead>
<tr>
<th>Crop</th>
<th>N-rate kg/ha</th>
<th>Dry Yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Oct-25</td>
</tr>
<tr>
<td><strong>Oats (70lb/ac)</strong></td>
<td>0</td>
<td>1830</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>2710</td>
</tr>
<tr>
<td><strong>Oats (105 lbs/acre)</strong></td>
<td>0</td>
<td>1845</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>2745</td>
</tr>
<tr>
<td><strong>Oats/Peas (110 lbs/ac)</strong></td>
<td>0</td>
<td>1900</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>2540</td>
</tr>
<tr>
<td><strong>Barley (100 lbs/acre)</strong></td>
<td>0</td>
<td>580</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>830</td>
</tr>
</tbody>
</table>
Dedicated Biomass Crops: C4 perennial grasses

• Low energy input due to perennial
• Soil quality benefits
• High yield potential
• High nutrient use efficiency
• Utilizes existing equipment
• Adapted to marginal land
Miscanthus

NEF CEEDS™
Nagara, June 15, 2011, Elora

Nagara, June 30, 2011, Elora
Miscanthus – what we think we know

• High yield potential (15-25 t dm/ha), but dependent on location, stand age, variety, stand establishment success
• “Stitching” of poor stands does not work very well
• P and K removal rates are very low
• Cost effective establishment needs further assessment (rhizomes vs transplants vs stems vs CEEDS©)
• Good tolerance to a range of herbicides (atrazine, Dual, 2,4-D, ….) but no herbicides yet registered
• Excellent tolerance to pre-emergence (early post) glyphosate
Switchgrass - primer

- High yielding C4, perennial grass
- Upland and lowland varieties
- Propagated by seed, high diversity in population
- Native species
Switchgrass – what we think we know

• Senescence earlier in the fall than miscanthus
• Lodging is dependent on N rate – but significant yield impacts not observed
• Medium yield potential (7.5-12 t dm/ha) dependent on location, stand age, variety(?), stand establishment success, yield is surprisingly stable within a location
• K concentrations of spring harvested switchgrass is low (.2-.4%)
• Good tolerance to a range of broadleaf herbicides (2,4-D, bromoxynil, MCPA, Refine …..) but no herbicides yet registered
• In established stands, excellent tolerance to pre-emergence (early post) glyphosate
• No-till establishment following soybean works well.
• Good success companion seeding switchgrass with spring wheat
Potential Perennial Biomass Species for Ontario-2

Switchgrass
• Spring seeding at a rate around 8-10 kg/ha of pure live seed
• Fall harvested yields reported 8-12t/ha
• Spring harvest yields, 20 to 40% less, but better fuel quality for combustion

Miscanthus
• Giant Miscanthus, (Miscanthus x giganteus) vegetatively propagated from underground rhizomes or plugs
• Spring harvest and yields recorded up to 40 tonnes/ha from U of Illinois

Hybrid Willow
• Vegetative cuttings taken are planted at a density of 14,800 to 15,600 cutting/ha.
• After one year of growth, the plants are cut 2-4cm above the ground to produce more shoots.
• Yields range from 6-10 oven dried tonnes/ha

http://www.reap-canada.com/
http://www.omafra.gov.on.ca/english/busdev/bear2000/Budgets/Crops/Forages/switchgrass_static.htm
http://www.newenergyfarms.com/
Biomass feedstocks- conversion technologies for energy

Biomass crops:
Switchgrass, miscanthus

Ref. US DOE- State Bio_Energy Primer
## Heating demand and Fuel costs for different sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>Heat load factor/ year</th>
<th>Total cost GJ/m²/year</th>
<th>Natural gas @ $4.5/GJ</th>
<th>Heating oil @ $28.42/GJ</th>
<th>Propane @ $30.58/GJ</th>
<th>Miscanthus pellets @$9.32/GJ</th>
<th>Switchgrass pellets @$11.01/GJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broiler chicken</td>
<td>0.568 GJ/m²</td>
<td></td>
<td>2.56</td>
<td>16.14</td>
<td>17.37</td>
<td>5.29</td>
<td>6.25</td>
</tr>
<tr>
<td>Greenhouse</td>
<td>2.5 GJ/m²</td>
<td></td>
<td>11.25</td>
<td>71.05</td>
<td>76.45</td>
<td>2.33</td>
<td>27.5</td>
</tr>
<tr>
<td>Community Centre</td>
<td>0.9 GJ/m²</td>
<td></td>
<td>4.05</td>
<td>25.58</td>
<td>27.52</td>
<td>8.39</td>
<td>9.91</td>
</tr>
<tr>
<td>School</td>
<td>0.74 GJ/m²</td>
<td></td>
<td>3.33</td>
<td>21.03</td>
<td>22.62</td>
<td>6.90</td>
<td>8.15</td>
</tr>
</tbody>
</table>

Ref. 1. Steve Clark, OMAF
2. Assessment of the Business Case for Purpose-Grown Biomass in Ontario,
Cost comparison of Biomass crops and Other Energy Sources

OMAF COP- 2009: for switchgrass, based on 3.1 tonne average/tonne for fall cut, spring harvest system- $73.07

2012 study: Assessment of Business case for purpose grown biomass crops in Ontario

Miscanthus
- Total establishment cost of miscanthus is estimated at $1,179/acre which include the land fixed cost, ($100/tonne)
- Acceptable price of miscanthus bales at farm gate is $104.4/tonne
- Mature yield of miscanthus estimated at 7.5tonnes/acre

Switchgrass
- Establishment cost of switchgrass estimated at $425/acre, which includes the land fixed cost ($100/tonne)
- Acceptable price of switchgrass bales at farm gate is $135.7/tonne
- Mature yield of switchgrass estimated at 4.3tonnes/acre

Processing:
- Total cost of processing for pellets estimated at $38.88/tonne, which includes the processing cost of $23/tonne and the pellet mill financing cost of $15.88/tonne

Transportation
- Average $29.17/tonne

Pellet cost:
- Miscanthus- $172.45/tonne (104.4+38.88+29.17)
- Switchgrass- $202.75/tonne (135.7+38.88+28.17)
## Results

<table>
<thead>
<tr>
<th>For All Sectors</th>
<th>Broiler Chicken</th>
<th>Greenhouse</th>
<th>MUSH</th>
<th>Grain Drying (21,850 Tonnes)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total GJ</td>
<td>21,200</td>
<td>9,120</td>
<td>10,230</td>
<td>6,720</td>
<td>47,270</td>
</tr>
<tr>
<td>Total Propane Cost</td>
<td>($0.60/L)</td>
<td>$476,470</td>
<td>$205,050</td>
<td>$229,930</td>
<td>$1,062,420</td>
</tr>
<tr>
<td>Total Natural Gas Cost</td>
<td>($0.28/m³)</td>
<td>$159,030</td>
<td>$68,440</td>
<td>$76,740</td>
<td>$354,600</td>
</tr>
<tr>
<td>Total Oil Cost</td>
<td>($0.61/L)</td>
<td>$333,940</td>
<td>$143,710</td>
<td>$161,150</td>
<td>$744,610</td>
</tr>
<tr>
<td>Total Biomass Cost</td>
<td>50% Efficiency</td>
<td>$351,600</td>
<td>$150,370</td>
<td>$169,670</td>
<td>$783,050</td>
</tr>
<tr>
<td></td>
<td>85% Efficiency</td>
<td>$206,820</td>
<td>$88,450</td>
<td>$72,110</td>
<td>$433,010</td>
</tr>
</tbody>
</table>

Ref. Steve Clark, Jennifer Birchmore, OMAF and Emily Hope, U of Guelph
Based on 2012 study

**For the grower**
- conservative estimate at farm gate
  - Miscanthus- $104.4/tonne
  - Switchgrass- $135.7/tonne
  - Tall grass prairie- $148.7/tonne

**For the consumer:**
- 2012- estimated cost of miscanthus and switchgrass pellets in 2012 to end users are $172.45/tonne and $203.75/tonne
- Agricultural biomass is 1/3 the cost of propane and heating oil.
  - estimated costs of heating oil and propane to end users are approximately $28.42/GJ and $30.58/GJ
  - Miscanthus and switchgrass pellets would cost $9.32/GJ and $11.01/GJ

Ref. Assessment of the Business Case for Purpose-Grown Biomass in Ontario,
## Chemical composition of biomass feedstock's

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Switchgrass</th>
<th>Miscanthus</th>
<th>Corn stover</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall harvest (Ash %)</td>
<td>3.93 - 5.17</td>
<td>2.68 – 3.39</td>
<td>5.7 - 13.1</td>
</tr>
<tr>
<td>Spring harvest (Ash %)</td>
<td>3.19 - 4.41</td>
<td>1.45 - 2.35</td>
<td></td>
</tr>
<tr>
<td>Fall harvest (Calorific value MJ kg⁻¹)</td>
<td>18.49 - 18.91</td>
<td>18.93- 19.13</td>
<td>16.6-18.40</td>
</tr>
<tr>
<td>Spring harvest (Calorific value MJ kg⁻¹)</td>
<td>18.44 – 18.89</td>
<td>18.88- 19.13</td>
<td></td>
</tr>
<tr>
<td>Cellulose %</td>
<td>37</td>
<td>43</td>
<td>38</td>
</tr>
<tr>
<td>Hemicellulose %</td>
<td>27</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>Lignin %</td>
<td>19</td>
<td>19</td>
<td>19</td>
</tr>
</tbody>
</table>

Ref. 1. Impact of agronomic treatments on fuel characteristics of herbaceous biomass for combustion- Fuel processing technology, 109 (2013) 96-102
2. Composition of Herbaceous biomass feedstocks
Densified agricultural biomass - energy markets

- Residential- heat and hot water
- Greenhouses-heat
- Industrial/commercial- heat and hot water
- Ontario Power Generation
- Independent Power Generators
- Export

Feed-in tariff/ micro FIT price, as on Jan. 1, 2014

| Renewable biomass | ≤ 100 kW to ≤ 500 kW | 15.6 to 25.6 ¢/kWh |

Biomass energy provides significant cost savings and markets for space heating especially in areas without access to natural gas; estimated, agricultural biomass is 1/3 the cost of propane and heating oil.

There is significant global market opportunity for biomass crops for high value biobased chemicals and materials.

Greater focus on developing for integration of biomass supply chains with traditional manufacturing and petroleum supply chains and around the entire supply chain from feedstock to processing and end product.

Emerging Bioeconomy has potential opportunities for purpose grown biomass industry in Ontario for manufacture of diverse bioproducts in the rural communities.
Switchgrass as Forage

- Switchgrass has good nutritional value to cattle and has been used pasture or used for hay (Mitchell & Anderson, 2008)
- The crop should be grazed at the boot stage, as it is high quality and has good palatability (Mitchell & Anderson, 2008)
- Once the seed-heads begin to emerge, the nutrient and protein levels begin to drop, and should no longer be used as pasture (Bates et al, unknown)
- When grazing, it is important to not over graze as 8 inches of residual height needs to be left to ensure rapid regrowth (Bates et al, unknown)
- Yields tend to vary between 1 to 4 tons per acre in one cut systems
Miscanthus as Forage

- Miscanthus is harvested as very mature for biofuel, and cannot be digested very well in the rumen (Norman & Murphy)
- Miscanthus is native to Japan, is commonly used as forage there (University of Minnesota, 2008)
- Research on nutritional value is very scarce, however Carver (2001) stated there is little to no nutritional value
Miscanthus as Bedding

• Miscanthus is also becoming more commonly used for bedding as it is very absorbent, absorbing up to 3 times its weight (Miscanthus Bedding)

• Miscanthus is also used as bedding as it is a low allergen bedding (OMAF, 2012)
Discover the new alternative for horses and poultry

Miscanthus horse and animal bedding

Miscanthus bedding (Elephant Grass) is the modern alternative to straw and wood shavings for use as horse, poultry and cattle bedding. It can be used the same way as any other bedding either deep litter or a shallow covering on rubber mats, all depending on the preferences of the owners. Once you try miscanthus bedding you will never go back to shavings.

Miscanthus is Bio-degradable, as soon as the droppings and wet patches are removed from the stable or animal pens it will compost quicker than other beddings. It has high levels of absorbency, being able to absorb up to three times its own weight in moisture and

Miscanthus Bedding Benefits

- 100% Miscanthus
- Dust extracted
- Bio-degradable
- No chemicals or fertilizer
- Easily maintained
- Extremely absorbant
- Economical
- Carbon neutral
- Beneficial to wildlife
- No known diseases or bugs
- Top bedding in Equi-Ads Equestrian Magazine 2007

http://www.miscanthusbedding.co.uk/
Miscanthus/Switchgrass for Bedding

• Fall harvest for bedding unlikely
• Later winter - spring harvest
  – Bale or chop using existing commercial equipment
• High quality hemp is cultivated throughout Canada

• Hemp can be cultivated organically with very few implications to yield

• Its stem contains 2 separate fibre layers (AAFC, 2007)

• It is possible to cut hemp for silage to mix with corn silage (Mosjidis et al, 2012). By mixing hemp in with corn silage, cows had improved weight gains.

• Hemp is common forage in the Netherlands as it is an alternative to straw. Researchers have found that cows fed hemp give a little more milk and seem to be healthy (Dutch Daily News, 2011)
• When selecting hemp for silage, it is very important to choose the variety carefully as some hemp is toxic to cattle (Mosjidis et al, 2012)

• Hemp does still contain small levels of THC, a study in Europe has discovered that the THC can be transferred into milk (European Food Safety Authority, 2011) at very low levels

• Great potential for bedding; low in dust and very absorbent (Small & Marcus, 2002; Agrisorb, 2010)

• Hemp growers licenced by government of Canada
Bottom Line:

- Numerous alternative crops have potential for livestock operations
- They exist as double-crops, annuals and perennials
- Track record and data on those in biomass use
- Individual crops can and have served as fuel (heat), feed and bedding
- Agronomics becoming clearer
- More analysis required on economics of perennials relative to straw as bedding
- More details analysis of crops for nutritional parameters required, and is underway
Thank You