Ensuring Sufficient Water Supply for the Emerging Bioeconomy

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Purpose of Presentation

- Review water supply requirements for biofuel in Canada
- Assess where water supply might be a limiting factor
- Review nature of water availability
- Discuss options for the bioeconomy in water stressed regions
- Anticipate sensitivity of water supplies to
  - land use change,
  - drought and
  - climate change
Intensive Plant Growth for Biofuels

- Despite having much of the world’s freshwater, Canada has water limitations to biofuel growth.
- Highly productive crops will tend to use most or all available soil water in drier parts of Canada and reduce streamflow everywhere:
  Evaporation (incl. transpiration) \( \approx \) Rainfall
  - Prairies
  - Interior BC valleys
  - SW Ontario
- Afforestation will reduce streamflow because of interception of rainfall and snowfall and increased infiltrability of soils.
  - Interception evaporation is not due to transpiration – water loss not related to biomass production.
- **Reduced streamflow is not necessarily consistent with improved water quality claims of biofuel industry.**
Biodiesel Processing

- Active Ion Purification (ion resin catalyst)
- No water added for wash process
- Able to process vegetable oils with acid values < 5%
- Example: Milligan’s Biodiesel, Foam Lake, SK
- BIODIESEL PRODUCTION HAS LITTLE WATER SUPPLY LIMITATION
Ethanol Processing

- Ground, sometimes steeped, grain ‘meal’ slurried with water to form ‘mash’
- Mash is processed and fermented
- Distillation: ethanol is concentrated to 190 proof ethyl alcohol then dehydrated to 200 proof.
- Water use from 3 to 10 litres water per 1 litre ethanol.
- Carbon use is smaller when water use is higher
- 80 million litres ethanol/year = 800 million litres water use/year for average plant.
Ethanol Plant Water Requirements

- One ethanol plant uses 800 million litres/year =
- 800,000 m³/year =
- 2,200 m³/day =
- 0.025 m³/s per plant.
- If plant density is 1 plant per 100 km², then ~100 km² gross basin area draining to plant
- Equivalent to 8 mm/year of runoff via streamflow for plant water use.
- This is easily accomplished across Canada except for parts of the Prairies – the ‘Palliser Triangle’. 
- However, the Prairies are an excellent source of grain for ethanol and so the water supply for Prairie ethanol plants must also be considered........
Case Study: THE CANADIAN PRAIRIES

Landcover tied to climate & soils with distinctive land atmosphere interactions

Water flows west to northeast through major ‘exotic’ rivers that derive most water from mountain runoff
Distinctiveness of Prairie Hydrology

- **Dry** – relatively small precipitation, water deficit, low moisture reserves
- **Cold** – long frozen season, snow cover, frozen soils
- **Flat** – gentle topography, poorly defined drainage
- **Extreme** –
  - Inter-annual – sequences of drought and floods
  - Intra-annual – dry and wet years
  - Episodic – intense snowstorms, snowmelt and rainfall, intense heat, rapid growing season, unreliable streamflow
"Saskatchewan, Saskatchewan, there's no place like Saskatchewan; we sit and gaze across the plain and wonder why it never rains…"

These words from the song *Saskatchewan* were written during the 1930s.
Localized hydrology affected by poor drainage, storage in small depressions.

Non-contributing areas for streamflow extensive in Canadian Prairies.
Water Use in Southern Prairies

- Precipitation on average 350 mm
- Grain Growing
  - 125 mm soil water reserves needed
  - 175 mm spring rainfall needed
  - Roughly 300 kg/ha increased wheat yield for each extra 25 mm of water added
- Agricultural, municipal, industrial & aquatic use – require surface and groundwater in excess of crop use
- South Saskatchewan River: <1% of flow originates from Saskatchewan, but 70% of population use the river
What About Locally Produced Water Supplies?

- Because of frozen soils and rapidly melting snowcovers in the spring, 80% - 90% of prairie runoff is produced from snowmelt.
- Snowmelt runoff is strongly controlled by snow drift location and size, soil moisture and mid winter thaws.
- In wet years, there is often excess water to dryland cereal grain growing needs – this water could potentially be used for ethanol production, but how reliable is it?
- Hydrological computer simulations may tell us something about the reliability of local prairie water supplies.
Creighton Tributary, Bad Lake as a typical Prairie Basin

Moderately well drained plateau of grains and fallow drains into a coulee
Semi-arid to sub-humid climate
Typical drainage and landcover for much of southern prairies
Prairie Basin Water Balance
Creighton Tributary, Bad Lake early 1970s
30% Summer Fallow
15% Grassland Coulee

-500 -400 -300 -200 -100 0 100 200 300 400 500
Fallow Stubble Coulee Basin

Snowfall Rainfall Runoff Sublimation Drifting Snow Evaporation

30% Summer Fallow
15% Grassland Coulee
2006: Continuous Grain Cropping

Graph showing water equivalent in mm for Stubble, Coulee, and Basin categories.
Implications of Land Use Changes

- *By making agriculture more effective at using rainfall and snowmelt we have substantially reduced the ‘excess’ water that formed runoff.*

- Local runoff feeds streams, fills small lakes, recharges groundwater

- Can we have both optimised dryland agriculture for biofuels and local water supply for ethanol plants???
Drought Restricts Spring Runoff Generation

Local Prairie water supplies inherently unreliable during drought

Unlikely to support sustainable biofuel processing industry

Competition between agricultural production and water runoff for streamflow and biofuel processing

Implication is that little is left for wetlands, ecosystem services
Rocky Mountains, source of most Canadian Prairie surface water
Decline of ~1.5 billion m$^3$ over ~90 years (~-15%) in natural flow
Decline of ~1.1 billion m$^3$ over ~30 years (~-15%) in actual flow
Upstream consumption of naturalized flows up to 7%-42% in last 15 years
What is Reducing Natural River Flow?

- Not glaciers: glacier melt contribution to Bow River at Calgary ~ 0.6%, or less.
- Lowest snowfall years associated with lowest river flows – mountain snowpack
- 15% flow decline likely a climate change effect.

What is Reducing Actual River Flow?

- Irrigation – responsible for most water use (75%)
- Municipal/industrial – relatively small effect (17%)
- Alberta water use consumes 25% of natural flows, but up to 42% in drought years
Conclusions

- Biofuel economy will affect and be limited by the hydrological cycle
  - Reduced streamflow in afforested basins
  - Reduced soil moisture and streamflow in intensive agricultural basins
- Low streamflow and water storage potential in southern Prairies will limit ethanol plant size and number
- Droughts cause cessation of prairie runoff – unreliable water source for biofuel processing
- Prairie biofuel production must rely on Saskatchewan River system – Rocky Mountain water
- Rocky Mountain waters are declining: example SSR flow is down ~40% since settlement due to consumption and climate change.
- Consumption of water for biofuel primary production, forest interception loss & ethanol processing will reduce water availability for ecosystem services and human use and may degrade water quality in some cases
Thank You!

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- Centre for Hydrology information: [http://www.usask.ca/hydrology](http://www.usask.ca/hydrology)
- Support for research from
  - Canada Research Chairs Programme
  - Province of Saskatchewan
  - Drought Research Initiative, DRI – Canadian Foundation for Climate and Atmospheric Science
    [http://www.drinetwork.ca/](http://www.drinetwork.ca/)