SCBD/STTM/JM/RH/64589

Request for submission of information on experiences on the development and application of tools relevant to the sustainable production and use of biofuels

Throughout its history, Canada's agriculture, energy and forest sectors have been closely linked. Renewed interest in biofuels has reinforced these links between food, fuel and fibre for environmental, economic, food and political security. As part of its commitment to produce and use renewable transportation fuels which can diversify the energy mix, contribute to reductions in greenhouse gas (GHG) emissions and provide new opportunities for the agriculture and forestry sectors particularly in local communities, the government of Canada has developed a strategy for renewable fuels. The strategy includes the following four components: i) increasing the retail availability of renewable fuels through regulation; ii) supporting the expansion of Canadian production of renewable fuels; iii) assisting farmers to seize new opportunities; and, iv) accelerating the commercialization of new technologies.

Canada is actively working with stakeholders to better understand issues pertaining to improved sustainability in the production, use and development of biofuels. The GH Genius model, developed by Natural Resources Canada, is one of several models in the world, capable of estimating life-cycle emissions from both conventional and alternative fuels. This model estimates that, under typical Canadian conditions, the life-cycle GHG emissions from grain-based ethanol are on average 40 percent lower compared to gasoline, and that the energy provided by the ethanol is over 50 percent greater than the fossil energy used to create it. Similarly, under typical Canadian conditions, oilseed-based biodiesel production and use can reduce life-cycle fossil energy use by approximately 80 percent and life-cycle GHG emissions by more than 60 percent compared to crude oil-based diesel. These figures consider all factors such as feedstock production and transportation and assume the fuel is produced in a modern, efficient plant.

AGRICULTURE

One of the key drivers for supporting renewable fuels production and use is the benefit that it can bring to the agriculture sector and rural Canada. Increased renewable fuels production in Canada will result in increased demand for feedstocks and new markets for Canadian agricultural producers' crops. In addition, agricultural producers could achieve economic benefits through equity investment in renewable fuels production facilities, further encouraging an approach that goes beyond simple commodity production to focus on new ways to add value to biomass produced on farms and to contribute to the economic and socio-economic sustainability of rural communities.

Farm and rural communities face special challenges in mobilizing the effort and equity required to develop renewable fuels production facilities using agricultural products as inputs. The first challenge is in realistically assessing the opportunity and developing the

business and technical capacity required to build facilities which cost more than $100 million. The second challenge is the capital formation hurdle to raising equity to finance these facilities.

Agriculture and Agri-Food Canada (AAFC) announced the $20 million Biofuels Opportunities for Producers Initiative (BOPI) in July 2006 to address the first challenge. BOPI ended in March 2008 and was well received by the agriculture community. BOPI helped about 120 potential biofuels projects led by farmers and rural communities to develop business plans and feasibility studies.

AAFC developed the ecoAgriculture Biofuels Capital Initiative (ecoABC) to address the second challenge. The ecoABC Initiative is a federal $200 million four-year program ending on March 31, 2011 that provides repayable contributions for the construction or expansion of transportation biofuel production facilities. Funding is conditional upon agricultural producer investment in the biofuel projects, and the use of agricultural feedstock to produce the biofuel. So far, ecoABC has helped support seven projects in which approximately 500 farmers have invested about $42 million.

The bioeconomy presents an opportunity to diversify farm incomes by creating market opportunities through the development of new products, or new processes, to produce products from biomass. Canada has a natural advantage in this emerging economy, with a wealth of natural resources and landmass to produce agricultural and forestry biomass. Canada is a world leader in developing next-generation biofuels technologies that produce cleaner fuels from wheat straw and wood residue. These new technologies have the potential to generate even greater environmental benefits than traditional renewable fuels.

To help, the Agricultural Bioproducts Innovation Program (ABIP) was designed to support new and existing research networks and encourage the development of clusters for the advancement of a sustainable and profitable Canadian bioeconomy.

The ABIP funds networks and clusters of highly qualified researchers that have the capacity to conduct scientific research and development projects, and accelerate commercialization and technology transfer activities focused on: the development of crop platforms and cropping systems suitable to conversion of feedstocks to agricultural bioproducts; developing effective and efficient technologies for agricultural biomass conversion; and product diversification through technologies such as agricultural and industrial chemicals, biomaterials and health products.

A number of biofuels related research networks were launched in early 2009 under ABIP, including the Cellulosic Biofuels Network, The Feed Opportunities from the Biofuels Industries network, The Canadian Triticale Biofinery Iniative, and the Sustainable Cropping System Platforms for Biodiesel Feedstock Quantity and the Quality Research Network. Research is just beginning and results will be available in the coming years.

As these programs are implemented, monitoring the indicators for soil, water and biodiversity under the National Agri-Environmental Health Analysis and Reporting Program (NAHARP) will generate science-based information to track environmental performance and play a critical role in guiding policy and program design.

FORESTRY

Wood has several advantages as a feedstock for biofuels production with respect to its sugar content, bulk density, transportation and storage costs and cultivation and harvesting systems. Canada's forests, representing about 10 percent of the world's forested area, are a potential huge resource for forest-based renewable energy and are expected to play an important role in future development of biofuels and other bioproducts. The Canadian forest sector already uses biomass residues generated at mill sites for cogeneration of heat and electricity. The pulp and paper industry derives 57% of its energy needs from forest biomass and about 6% of Canada's total secondary energy use comes from forest biomass. The primary areas of activity are: direct use of residues from forestry and production processes for forest products; cultivation of dedicated energy crops; and, production of second generation biofuels using bioconversion systems. Activities on second generation biofuels are in various stages of development. Results from research on the use of enzymatic and other processes to isolate the basic components of lignocellulose have been very promising. Pilot scale projects have been established for further refinement of the technology. Studies are underway to demonstrate the potential for lignin-based bioenergy and other bioproducts to reduce greenhouse gas emissions, improve environmental performance, increase sector employment and encourage regional development.

Biomass for bioenergy may be considered as a by-product of timber production systems since forest residues constitute 25-45% of harvested wood. Many types of forestry operations such as thinning in young stands, harvesting tops and branches in older stands or urban silviculture treatments can yield biomass suitable for energy production. Studies on availability indicate that between 1.5 to 13% of Canada's primary energy source could be supplied by woody biomass, depending on region, harvesting techniques, inclusion of urban waste wood, historic residues and salvage wood from pest epidemics. For example, the recent outbreak of mountain pine beetle in western Canada, is estimated to have killed 500 million m^3 of trees over 13.5 million hectares. The use of this salvage pine is being investigated as a source of bioenergy and for associated potential social and environmental benefits such as increasing income in Aboriginal and local communities, and reducing fire risk and greenhouse gas production. The Ouje-Bougoumou Cree's biomass district heating system is an example where a rural community, using sawmill wood waste, was able to reduce costs approximately 96% less than with hydroelectricity and also reduce the production of nitrogen oxides by approximately 35% in comparison to an oil-fired system. It is estimated that during the first year, more than 200 tons of carbon dioxide emissions were avoided.

Short rotation woody biomass crops, selected for their rapid growth, tolerance to pests or toxics and for specific traits suited to particular growing conditions, are starting to be grown as dedicated energy crops. Such crops are managed through agricultural

approaches with objectives for carbon, solid wood products and biomass for energy. Cultivation techniques for silver maple and several varieties of fast-growing poplars, willows and alder have been developed and assessments of their suitability and sustainability as bioenergy crops have been carried out at various sites across Canada. Agro-forestry projects planting willows in riparian areas have demonstrated the capacity to improve water quality by removal of nutrients (nitrogen, phosphorous) in run-off from the surrounding agricultural lands. In addition to the economic gain to be had through managed harvesting of these willow buffers, other demonstrated positive impacts were creation of nesting habitat and enhanced biodiversity, groundwater replenishment, snow trapping, retention and removal of nutrients, and sediment interception.

Biomass production from residues and dedicated crops is dependent on conservation requirements for soil, water and biodiversity. As a forest nation and a founding member of the Montréal Process, established to formulate an international framework of criteria and indicators for sustainable forest management, Canada is committed to sustainable development. In 1995, the Canadian Council of Forest Ministers (CCFM) developed a framework of six criteria and associated indicators to guide and report on sustainable forest management. The framework includes criteria on soil and water protection, maintenance of ecosystem condition and productivity and conservation of biodiversity. From this national policy framework, linking international, provincial/territorial, regional and local processes, community initiatives and a certification scheme, goals and targets for conservation of biodiversity and ecosystem condition (soil and water) have been developed at sub-national levels. Forest management plans provide the vehicle and process whereby policy, planning, inventory and management practices are formulated by forest harvesting companies into detailed plans for harvesting forest areas and ensuring ecosystem/landscape sustainability. Third-party certification is a tool used by governments to demonstrate the rigour of Canada's forest management laws and to document the country's sustainable forest management record, including biodiversity stewardship. The voluntary adoption of one of the three main processes for certification of sustainable forest management used in Canada, on more than 87% of the productive forest land, provides a tool for consumers to identify wood products originating from sustainable managed forests

Over the past 30 years Canadian researchers have investigated the relationship between biomass removal and forest soil quality; tree nutrition, long term site productivity; and, habitat suitability for several indicator species (mammals, birds, arthropods and other wood dependant organisms). Improved understanding of the relationships between biomass removal and forest condition, productivity and biodiversity has led to the development of various tools including guidelines, monitoring protocols and decision support systems, to assist with sustainable management of biomass as part of forest planning and certification processes. Work is currently underway by Natural Resources Canada and the Forest Engineering Research Council of Canada to develop an index of site suitability for forest residue removal.

Research has facilitated the application of monitoring information to the development of models. A steady state mass balance model was developed to simulate potentially

sustainable levels of tree biomass growth and related nutrient uptake dynamics. The development of a carbon budget model has allowed calculation of the effects of site level management practices on local and national carbon budgets. Using volume to biomass models, the National Forest Inventory, Canada's national plot-based monitoring system, is now able to undertake periodic monitoring of biomass. The Ontario NEBIE plot network is an example of a regional program designed to track environmental effects of biomass removals in various different forest types. Researchers at the Canadian Forest Service have recently initiated a Canada-wide long-term study, which invites all stakeholders who undertake forest biomass harvesting projects, to monitor several ecological parameters associated with intensification of biomass removal including potential impacts on biodiversity.

The New Brunswick Forest Biomass Decision Support System is another example the application of research results to improve decision-making processes and advance policy development. This integrated, sustainable forest biomass allocation tool allows the impact of harvesting on sustainability and forest growth to be assessed and provides a set of guidelines for selecting eligible areas for biomass harvesting on public land. The province of New Brunswick uses this tool to assist with implementation of the Crown Land Forest Biomass Harvesting Policy, within its framework of sustainable forest management.

Annex 1 provides a listing of selected references about sustainable use of forest and agricultural biomass for bioenergy in Canada, (including the impacts on biodiversity) tools, research, monitoring , protocols and policy development.

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Annex 1: Selected references from Canada for SCBD/STTM/JM/RH/64589

Table 1 Tools relevant to the sustainable production and use of bioenergy/biofuels: Examples from Canada

Title of Project	Description	Reference(s)
Earth Observation for Sustainable Development of Forest (EOSD)'s Biomass Mapping through remote sensing	**Objective(s):** To apply and demonstrate methods for mapping forest biomass over several ecologically-diverse regions in Canada. **Results**: Development of tools for mapping and scaling up biomass at a national level using EO data. These tools will contribute to national reporting on carbon and to the National Forest Carbon Accounting Framework. Depending on the availability of forest maps and/or inventory plots, these methods map forest biomass i) from forest structure (e.g., BioCLUST, Luther et al. 2006; BioSTRUCT, Hall et al. 2006b) or ii) directly from inventory plot biomass data using a k-nearest neighbour approach (kNN, Guindon et al. 2005). In the case where inventory data are unavailable or non-existent, such as in northern boreal regions, a shadow fraction method (BioSF) is applied to high resolution imagery such as QuickBird or Ikonos that can be used to derive surrogate plots (Leboeuf et al. 2007).	http://cfs.nrcan.gc.ca/subsite/eosd/biomass
What impact does forest biomass harvesting have on soils? Join the research effort!	**Objective(s)**: - to predict the ecological consequences of removing logging residues from the forest; - to establish a Canada-wide project involving a long-term study that encompasses a number of ecozones and a range of sites and stands. **Result(s)**: -a guide that describes the procedure for establishing plots that can be used to monitor the effects of the removal of forest biomass.	http://scf.rncan.gc.ca/news/612
New Brunswich Forest Biomass Decision Support System (FBDSS)	**Application(s)**: The FBDSS was developed to identify areas that are ineligible for biomass harvesting due to “high risk” areas - those site conditions that are sensitive to biomass removal resulting in a significant loss of nutrients and	http://www.gnb.ca/0078/policies/FMB0192008E.pdf

	expected growth rates of the future forest.	http://www.sfmnetwork.ca/docs/e/Biomass15-4Moorehouse_Policyup-dateforNB.pdf http://www.sfmnetwork.ca/docs/e/Biomass06-4_1of2_Arp_Siteproductivityup-dateforAtlanticprov.pdf
Effects of harvest intensity on long-term site productivity in boreal conifer ecosystems	**Objective(s):** To evaluate the impact of harvest intensity (biomass removal) on long-term site productivity in conifer-dominated boreal ecosystems in Ontario. **Results: 1)** A steady state mass balance model (ForSust), developed to simulate potentially sustainable levels of tree biomass growth and related nutrient uptake dynamics, was applied to 17 jack pine sites across Canada. Specifically, the model simulates sustainable annual increment (SAI)of biomass growth for stem-only and whole-tree (aboveground biomass) harvesting, and for recurring forest fire conditions.	1)J.S. Bhatti, N.W. Foster, T. Oja, M.H. Moayeri, and P.A. Arp. 1998. Modeling potentially sustainable biomass productivity in jack pine forest stands.
	2) Evaluating the sustainability of forest production when jack pine stems and logging residues are used for energy production:	Bhatti, J.S.; Foster; Arp, P.A. 1997.Evaluating the sustainability of forest productionwhen jack pine stems and logging residues are used for energy production. P. 9-13 in Richardson. J. (ed.) Proc. Bioenergy and Boreal Forest Management Workshop, Timmins, Ontario, 23 Sept. 1997. International Energy Agency Task XII: Biomass Production, Harvesting and Supply Forest Management Activity. Canadian Forest Service, Ottawa, ON.
	3) Impacts of various levels of biomass removals on the structure, function, and productivity of black spruce ecosystems: Research protocols.	Gordon, A.G.; Morris, D.M.; Balakrishnan, N. 1993. Impacts of various levels of biomass removals on the structure, function, and productivity of black spruce ecosystems: Research protocols. Ont. Min. Nat. Res., For. Res. Info. Paper No. 109. 21p.

Types of Wildlife Trees and Coarse Woody Debris Required by Wildlife of North-Central British Columbia	**Application**: To provide some of the necessary information by describing the habitat requirements of 133 vertebrate species of north-central British Columbia in relation to two special habitat elements: Wildlife Trees and Coarse Woody Debris.	http://www.for.gov.bc.ca/hfd/pubs/Docs/Wp/Wp50.pdf
A forest nutrient cycling and biomass model (ForNBM) based on year-round, monthly weather conditions	**Application(s):** The model can be applied (1) to predict sustainable forest nutrient harvesting rate in terms of the nutrient geochemical balance (the nutrient harvested in biomass=nutrient inputs from atmosphere deposition+fixation+mineral weathering–nutrient leaching); (2) to determine the limiting nutrients of forest growth (a limiting nutrient is expressed as the amount supplied by atmosphere deposition and mineral weathering is less than required by biomass growth at optimal site conditions); (3) to evaluate the effects of atmosphere acidic deposition on soil chemistry and forest growth; and (4) to evaluate the effects of forest harvesting on environmental issues, such as stream water quality in watersheds.	Zhu, Z.; Arp, P.A.; Meng, F.; Bourque, C. P.-A.; Foster, N.W. 2003. A forest nutrient cycling and biomass model (ForNBM) based on year-round, monthly weather conditions, part I: assumption, structure and processing. Ecol. Modell. 169: 347-360.
An Index of forest site sensitivity to intensive biomass removal for the commercial forest land of Quebec (Canada)	**Application(s):** To provide a provincial reference framework for assessment of site susceptibility to nutrient exportation resulting from forest harvesting.	http://www.sfmnetwork.ca/docs/e/Biomass24Thiffault_Indexofsitesensitivity.pdf
Improving Canada's National Forest Biomass Estimates through the National Forest Inventory	**Objective(s):** - Assign biomass data to every record in Canada's Forest Inventory (CanFI 2001) database; - Report on Canada's forest biomass resources on a periodic basis in conjunction with the National Forest Inventory (NFI) reporting; -report on the application of the methodology to the new plot-based NFI as well as provincial and industrial inventories. **Results**: The expanded and updated version of the CanFI 2001 database incorporates significant improvements to individual tree biomass equations	http://www.cbin.gc.ca/pro/gillis-eng.php

	(adoption of new national equations) and to the model development process (model fitting and selection), which result in more robust and accurate estimates of forest biomass in Canada. This database will be used to develop all summaries and reports on Canada's biomass resources. Work continues on the development of methodology to allow reporting on Canada's forest biomass resources on a periodic basis in conjunction with NFI reporting.	
		http://warehouse.pfc.forestry.ca/pfc/27434.pdf
Biomass Inventory Mapping and Analysis Tool (BIMAT)	Objectives: BIMAT is an Internet based Geographic Information System (GIS) product that provides the user with tools to undertake a GIS-based analysis of the location and amounts of selected agricultural crop residues, forest-based biomass sources, and sorted municipal woody wastes in a spatially explicit database. Users are able to calculate the amount of biomass of a specified type within a user-defined radius from a user-selected geographic point location, or identify the closest area required, to a user-selected geographic point location that meets a user-defined quantity of biomass of a specified type. The results of this query will be displayed on a map containing transportation and population information, and, once the user has acquired the information of interest, the maps and the summary data can be downloaded by the user for reports or further evaluation. The inventory of all biomass materials is developed using sustainability criteria for the preservation of soil, nutrients and	http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1226509218872&lang=eng

	system productivity.	
Agriculture Bioproducts Innovation Program (ABIP)	Objectives: The Agricultural Bioproducts Innovation Program (ABIP) is a multi-year program that seeks to mobilize Canada's creative talent in academia and in the private and public sectors and to integrate resources to build greater research capacity in agricultural bioproducts and bioprocesses.	
	Results: 1) The $19.9 million Cellulosic Biofuels Network will focus on the sustainable production of ethanol and associated bio-products from cellulosic material. The economics of crop production and the conversion of plants to ethanol will be assessed. Network researchers will also address larger issues such as the use of byproducts in cattle feedlots, the reduction of greenhouse gas emissions and optimal nutrient flow/balance.	http://www.agr.gc.ca/cb/index_e.php?s1=n&s2=2009&page=n90122
	2) The $6 million Feed Opportunities from the BioFuels Industries network aims to improve the economics of livestock operations through nutritional evaluation and development of feeding recommendations for wheat-based co-products. The network will work with the wheat-based ethanol industry to systematically evaluate the current steps in the ethanol process, their impact on the feed ingredients and how those ingredients fare on domestic and international markets	http://www.agr.gc.ca/cb/index_e.php?s1=n&s2=2009&page=n90123
	3) The $15.5 million Canadian Triticale Biorefinery Initiative network will develop new ways of making triticale plants a more valuable and renewable source of ethanol feedstock. The network will also find new ways of developing triticale plants for its biomaterials, which can be used in the Canadian manufacturing industry. The network's objective is to generate rapid economic growth in its respective industries, increase revenue for farmers, bring high quality jobs to rural Canada and help position Canada as an international leader in triticale production research.	http://www.agr.gc.ca/cb/index_e.php?s1=n&s2=2009&page=n90306
	4) In order to meet increased canola production demands, canola growers will need to grow more canola more often. To find out the most effective ways to	http://www.agr.gc.ca/cb/index_e.php?s1=n&s2=2009&page=n90319b

	increase canola production, the $1 million Sustainable Cropping System Platforms for Biodiesel Feedstock Quantity and Quality research network will carry out a series of five experiments conducted across the major soil zones and ecoregions of Western Canada.	
ecoAgriculture Biofuels Capital Initiative (ecoABC)	Objectives: The ecoABC Initiative is a federal $200 million four-year program ending on March 31, 2011 that provides repayable contributions for the construction or expansion of transportation biofuel production facilities. Funding is conditional upon agricultural producer investment in the biofuel projects, and the use of agricultural feedstock to produce the biofuel.	http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1195672401464&lang=eng
Biofuels Opportunities for Producers Initiative (BOPI)	Objectives: BOPI is designed to help farmers and rural communities hire experts who can assist in developing business proposals and undertake feasibility and other studies necessary to create and expand biofuels production capacity involving significant (greater than one-third) ownership by agricultural producers.	http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1200671799794&lang=eng
Integrated management of natural willow rings surrounding wetlands for nutrient management and biomass production	Objectives: Evaluating the impacts of willow coppice (removal of aboveground biomass allowing stems to regrow from the stump) on local biodiversity.	http://www.agr.gc.ca/cb/index_e.php?s1=tip-puce&s2=2008&page=08
Quantifying Straw Removal through Baling and Measuring the Long-Term Impact on Soil Quality and Wheat Production	Objectives: To quantify the proportion of total aboveground crop residues removed through baling and to evaluate the effects of 50 yr of straw removal with baling on soil quality and wheat (*Triticum aestivum* L.) production.	To be published in upcoming addition of Agronomy Journal Authors: G. P. Lafond, M. Stumborg, R. Lemke, W. E. May, C. B. Holzapfel, and C. A. Campbell
Canadian Agriculture, Bioproduction and Communities Research Initiative (CABCRI)	Objectives: To examine the impacts of the ecoAgriculture Biofuels Capital (ecoABC) Initiative and the Agri-Opportunities Program on farmers, communities and the agriculture sector and to explore the implications of an emerging and	Research is ongoing

growing bioeconomy for rural community development in Canada.

Specific questions to be addressed:
- What are the socio-economic impacts of the programs on program investors, primary producers and the agriculture sector?
- What capacities are required of program investors, primary producers and the agriculture sector to support biofuels production facilities and commercialization projects?
- What are the socio-economic impacts of biofuels facilities and commercialization projects on communities/regions in which they are located and on community development?
- What capacities are required of a community/region to support biofuels projects or commercialization projects?

Table 2 Research investigating the impacts of the production and use of bioenergy/biofuels on biodiversity and related socio-economic aspects: Examples from Canada.

Title of Project	Description	Reference(s)
Snag availability for cavity nesters across a chronosequence of post-harvest landscapes in western Newfoundland	**Objective(s):** To examine the availability and quality of standing dead trees (snags) for nesting habitat in a harvest chronosequence of boreal forests dominated by balsam fir (*Abies balsamea*) in western Newfoundland. **Results:** Managing for large-cavity excavators, such as Northern Flickers, and the associated range of secondary nesters would be greatly facilitated through the retention and/or creation of larger diameter white birch snags in Newfoundland. Current forestry guidelines in this jurisdiction suggest that ten snags/ha are to be left following harvest (following Cline et al., 1980). It would be more appropriate to leave ten high-quality snags/ha, i.e., snags with a large enough dbh to be potential cavity-nesting trees for the largest species in the region.	Smith, C.Y., Warkentin, I.G., and M.T. Moroni. 2008. Snag availability for cavity nesters across a chronosequence of post-harvest landscapes in western Newfoundland. Forest Ecology and Management 256 (4), pp. 641-647
Ontario's NEBIE (**n**atural disturbances and **e**xtensive, **b**asic**,i**ntensive and **e**lite level of silviculture) Plot Network	**Objective(s)**: Monitor the effects of silvicultural practices on microclimate, soil moisture and nutrient cycling, vegetation diversity, and wildlife habitat and compare with natural disturbances. **Results**: -evidence that the displacement of downed woody material and forest floor organic layers was the leading cause of changes in species richness and abundance on this site (Newmaster et al., 2007) -Survival of various species (e.g. marten, brown creeper) is strongly associated with coarse woody debris. -Intensification of biomass removal increases biodiversity impacts	http://www.mnr.gov.on.ca/en/Business/OFRI/2ColumnSubPage/STEL02_165647.html Newmaster, S.G., Parker, W.C., Bell, F.W.,and J.M. Paterson. 2007. Effects of forest floor disturbances by mechanical site preparation on floristic diversity in a central Ontario clearcut. Forest Ecology and Management 246 (2-3), pp. 196-207

The importance of coarse woody debris for insect biodiversity	**Objective(s):** Assess saproxylic beetles diversity across a gradient of management at EMEND sites. **Results**: - Snag age class was an important determinant of composition for saproxylic beetle assemblages; - saproxylic beetles are responding to changes in coarse woody debris, and not to the relative densities of canopy tree species, although these variables are strongly correlated; - Coarse woody debris management should be a primary concern in forest management plans seeking to conserve saproxylic organisms and the critical ecosystem functions (i.e. nutrient cycling) in which they participate.	Jacobs, J.M., J. R. Spence, D. W. Langor, 2007. Influence of boreal forest succession and dead wood qualities on saproxylic beetles. Agricultural and Forest Entomology 9: 2-15.
Arthropod Responses to Ecosystem Management and Changes in Deadwood in Boreal Forests of Abitibi-Temiscamingue	**Objective(s):** Assess responses of various groups of arthropods to alternative silvicultural approaches with emphasis on elements deemed to be impacted by additional recovery of biomass for bioenergy applications. **Results**: - Intensive harvesting and subsequent removal of deadwood had a strong negative effect on forest beetles; -loss of deadwood above ground had a significant negative effect on multiple species of soil microarthropod below ground; - saproxylic diptera species are associated with specific tree species and decay class.	http://www.sfmnetwork.ca/docs/e/Biomass28Work_Arthropodresponse.pdf

Effects of forest floor disturbances by mechanical site preparation on floristic diversity in a central Ontario clearcut	**Objective(s):** The effects of forest floor disturbance by six mechanical site preparation (MSP) treatments on structural and compositional diversity of early successional communities were examined in a clearcut in central Ontario. **Results:** Forest floor disturbance by different methods of MSP significantly affects structural and compositional diversity within secondary successional pathways in this and other related studies. The degree of mineral soil exposure, forest floor disturbance and abundance of downed woody material were significantly correlated with the species richness and abundance of spore- and seed-producing plants, as well as considerable changes in plant communities. The occurrence of five cryptogams found only in the slash piles (SLS), or uncut forests (UF) and SLS plots, indicates slash piles may provide substrate and a sheltered microhabitat for later successional forest species. Downed woody material, such as the larger diameter stems of fallen trees, appears to be important structural habitat that helps retain some of the cryptogam diversity (lichens, liverworts and mosses) following natural and anthropogenic disturbance. This suggests slash piles may contribute to the restoration of natural forest diversity by acting as refugia for cryptogams and other sensitive plant species, serving much the same function proposed for undisturbed residual forest patches, buffer strips along riparian areas and areas inadvertently left untreated during operational activity.	Newmaster, S.G., Parker, W.C., Bell, F.W., and J.M. Paterson. 2007. Effects of forest floor disturbances by mechanical site preparation on floristic diversity in a central Ontario clearcut. Forest Ecology and Management 246 (2-3), pp. 196-207
Future Bioenergy - A life cycle perspective on bioenergy options in North America	**Objective(s):** To investigate techno-economic and environmental aspects of bioenergy production. **Results**: -Development of Canadian and U.S. biomass supply estimates for forests, mill and agricultural residues, energy crops and municipal solid waste. Results indicate that in the near term, the biofuel industry could be profitably built around forestry and mill residues in Canada. - Investigation of the life cycle environmental and energy impacts of a set of emerging lignocellulosic ethanol conversion technologies.	http://www.bioresourcesjournal.com/index.php/BioRes/article/viewFile/BioRes_04_1_%23%23%23%23_Gronowska_JM_Review_US_Can_Biomass_Supply/335

Impact of nutrient removal through harvesting on the sustainability of the boreal forest.	**Objective(s)**: To investigate the cycling of base cations (K, Ca, Mg, Na) in boreal balsam fir forest. **Results**: - Whole tree harvesting may remove 44% of the K that is readily available for cycling in the short term.	Duchesne, L., and D. Houle. 2008. Ecol. Appl. 18(7) : 1642-1651
What impact does forest biomass harvesting have on soils? Join the research effort!	**Objective(s)**: - to predict the ecological consequences of removing logging residues from the forest; - to establish a Canada-wide project involving a long-term study that encompasses a number of ecozones and a range of sites and stands. **Result(s)**: -a guide that describes the procedure for establishing plots that can be used to monitor the effects of the removal of forest biomass.	http://scf.rncan.gc.ca/news/612
Harvesting intensity at clear-felling in the boreal forest: Impact on soil and foliar nutrient status	**Objective(s)**: The amount of logging residues left on site after clear-felling has been shown to influence the state of soil nutrient resources, but this effect may depend on soil conditions. In three regions of the boreal zone of Quebec, with contrasting soil characteristics, soil and foliar nutrient status of young (15-20 yr old) stands were compared among sites that were clear-felled at two harvesting intensities, that is, stem-only (SOH) and whole-tree harvesting (WTH). Balsam fir (*Abies balsamea*) stands were studied in the Forêt Montmorency and Gaspésie regions, while black spruce [Picea mariana (Mill.) B.S.P.] and jack pine (Pinus banksiana Lamb.) were studied in the Haute-Mauricie region. **Results:** Results suggested that the tree species regenerating the harvested sites, as well as the total Ca and Mg contents of the parent material are better indicators of a site's susceptibility to nutritional alteration by WTH than soil available nutrient status.	Thiffault, E., Paré, D., Bélanger, N., Munson, A., and F. Marquis. 2006. Harvesting intensity at clear-felling in the boreal forest: Impact on soil and foliar nutrient status. Soil Science Society of America Journal 70 (2), pp. 691-701

Effects of harvest intensity on long-term site productivity in boreal conifer ecosystems	**Objective(s):** To evaluate the impact of harvest intensity (biomass removal) on long-term site productivity in conifer-dominated boreal ecosystems in Ontario. **Results: 1)** A steady state mass balance model (ForSust), developed to simulate potentially sustainable levels of tree biomass growth and related nutrient uptake dynamics, was applied to 17 jack pine sites across Canada. Specifically, the model simulates sustainable annual increment (SAI)of biomass growth for stem-only and whole-tree (aboveground biomass) harvesting, and for recurring forest fire conditions.	1)J.S. Bhatti, N.W. Foster, T. Oja, M.H. Moayeri, and P.A. Arp. 1998. Modeling potentially sustainable biomass productivity in jack pine forest stands.
	2) Evaluating the sustainability of forest production when jack pine stems and logging residues are used for energy production:	Bhatti, J.S.; Foster; Arp, P.A. 1997.Evaluating the sustainability of forest production when jack pine stems and logging residues are used for energy production. P. 9-13 in Richardson. J. (ed.) Proc. Bioenergy and Boreal Forest Management Workshop, Timmins, Ontario, 23 Sept. 1997. International Energy Agency Task XII: Biomass Production, Harvesting and Supply Forest Management Activity. Canadian Forest Service, Ottawa, ON.
	3) Impacts of various levels of biomass removals on the structure, function, and productivity of black spruce ecosystems: Research protocols.	Gordon, A.G.; Morris, D.M.; Balakrishnan, N. 1993. Impacts of various levels of biomass removals on the structure, function, and productivity of black spruce ecosystems: Research protocols. Ont. Min. Nat. Res., For. Res. Info. Paper No. 109. 21p.
Short-term response of the herbaceous layer within leave patches after harvest	**Objective(s)**: To characterize the short-term response of the herbaceous layer to clearcut harvesting disturbance within and adjacent to leave patches (uncut areas in a harvested forest). **Results:** Based on species' responses to forest operations, it appears that at least the common forest species are maintained in the short term within leave patches.	De Graaf, M. and M.R. Roberts. 2009. Short-term response of the herbaceous layer within leave patches after harvest. Forest Ecology and Management Volume 257 (3). Pages 1014-1025

Diversity and abundance of ground and rove beetles in different forest types under different silvicultural regimes	**Objective(s)**: To evaluate changes in the abundance, species richness and community composition of ground and rove beetle species within a different forest type areas and forest age class, and under various treatments.	Klimaszewski, J., Langor, D.W., Work, T.T., Hammond, J.H.E., and K. Savard. 2008. Smaller and more numerous harvesting gaps emulate natural forest disturbances: A biodiversity test case using rove beetles (Coleoptera, Staphylinidae), Diversity and Distributions 14 (6), pp. 969-982. Klimaszewski, J., Langor, D., Savard, K., Pelletier, G., Chandler, D.S., and J. Sweeney. 2007. Rove beetles (Coleoptera: Staphylinidae) in yellow birch-dominated stands of southeastern Quebec, Canada: Diversity, abundance, and description of a new species. Canadian Entomologist 139 (6), pp. 793-833 Pohl, G.R.; Langor, D.W.; Klimaszewski, J.; Work, T.T.; and P. Paquin. 2008. Rove beetles (Coleoptera: Staphylinidae) in northern Neartic forests. Can. Entomol. 140: 415-436. Klimaszewski, J., Sweeney, J., Price, J., and G. Pelletier. 2006. Rove beetles (Coleoptera: Staphylinidae) in red spruce stands, eastern Canada: Diversity, abundance, and descriptions of new species. Canadian Entomologist 137 (1), pp. 1-48. KLIMASZEWSKI, J., LANGOR, D.W., WORK, T.T., PELLETIER, G., HAMMOND, H.E.J. AND GERMAIN, C. 2005. The effects of patch harvesting and site preparation on ground beetles (Coleoptera, Carabidae) in yellow birch dominated forests of southeastern Quebec. Can. J. For. Res. 35(11):2616-2628.

Evaluation of carabid beetles as indicators of forest change in Canada	**Objective(s)**: To assess the potential of carabid beetles (Coleoptera: Carabidae) as effective bioindicators of the effects of forest management at a Canadian national scale; To explore the relationship between rare and dominant taxa and species characteristics as they relate to dispersal capacity and use of within-stand habitat features such as coarse woody debris **Results**: 1) Carabid assemblages consistently responded to disturbance, but responses of individual species and changes in species composition were nested within the context of regional geography and finer scale differences among forest ecosystems; 2) No relationship between life-history characteristics (such as body size, wing morphology, or reported associations with downed wood) and the relative abundance or frequency of occurrence of species was found. The results from this project suggest that carabids are better suited to finer scale evaluations of the effects of forest management than to regional or national monitoring programs.	Work. T.T., Koivula. M., Klimaszewski. J, Langor. D., Spence. J., Sweeney. J., Hébert. C. 2008. Evaluation of carabid beetles as indicators of forest change in Canada. Canadian Entomologist 140 (4). pp 393-414
Coarse woody debris dynamics in a post-fire jack pine chronosequence and its relation with site productivity.	**Objective(s)**: To describe CWD dynamics along a post-fire chronosequence (43-86 years after fire) in jack pine (*Pinus banksiana* Lamb.) stands, assess the importance of buried CWD in terms of soil available water holding capacity (AWHC), and investigate relationships between CWD, AWHC, nutrient retention and site productivity. **Results:** Current estimates of CWD that limit sampling to material lying on the forest floor underestimate the downed wood component in boreal forests and consequently its function in nutrient and carbon cycling processes. The soil cation exchange capacity (CEC) has been found to be conditioned by forest floor organic matter and buried wood content. This result highlights another contribution of CWD to forest ecosystems with implication in CWD retention in forest management treatments.	Brais, S., Sadi, F., Bergeron, Y., and Y. Grenier. 2005. Coarse woody debris dynamics in a post-fire jack pine chronosequence and its relation with site productivity. Forest Ecology and Management 220 (1-3), pp. 216-226

The Ecological Role of Coarse Woody Debris in British Columbia	**Objective(s):** This synthesis describes what is known about the contribution to ecosystems of large pieces of dead down wood.	http://www.for.gov.bc.ca/hfd/pubs/Docs/Wp/Wp30.htm
The Effect of Coarse Woody Debris on Species Diversity in the Boreal Forest	**Objective(s):** To analyze the species diversity and richness of mammal, insect, and amphibian populations in the boreal forest near Kapuskasing, Ontario. The four sites selected had been historically horse- or mechanically-logged. Sites were manipulated for coarse woody debris (CWD) as follows: within the site, one trapping grid had full removal of all CWD, another had half of the CWD removed, and the final was un-manipulated. **Results**: CWD had no significant effect on species number or abundance, however, mammal and insect diversity tended to be higher in locations with the most CWD. Historical management of sites had a significant effect on abundance; sites that were horse-logged had higher abundance of mammals ($P < 0.05$) and insects ($P < 0.05$) than mechanically-logged sites. The mechanically logged sites were suspected of having more compacted soil and litter, as well as fewer woody structures (CWD) which could explain lower abundance of mammals and insects.	http://www.fes.uwaterloo.ca/ers/research/490s/documents/angelafreemanthesis.pdf

Issues related to the development and implementation of afforestation and agroforestry technologies for energy biomass production: results of focus group sessions in Quebec and the Prairie provinces	**Objective(s):** This study identifies issues in the area of the development and implementation of four short-rotation afforestation and agroforestry technologies, mainly for energy biomass production, as perceived by landowners in Quebec and the three Prairie provinces. The technologies are short-rotation intensive culture of willow or hybrid poplar, block plantation of hybrid poplar, willow-based riparian buffer systems and willow or hybrid poplar-based alley cropping. **Results**: The perceived benefits and drawbacks associated with the technologies were identified. Participants' levels of interest rose significantly for two of the four technologies. The intention to implement a technology in the short term proved to be very good for three of the four technologies. However, the low anticipated implementation rates obtained for alley cropping reflect the early stage of development of that technology. The results obtained from participants' perceptions enabled the authors to prepare a list of technical, financial, legal, environmental and other issues relating to R&D and adoption. Since these issues are based on landowners' perceptions, their definition and relevance must be specified and validated with research scientists and other stakeholders.	http://warehouse.pfc.forestry.ca/lfc/29242.pdf
Mountain Pine Beetle Program - Recovering Economic Value Program Area	**Objective(s):** To assess impacts and develop options for recovering, where reasonable, the use of beetle-kill timber, to reduce impacts on long-term timber supply and to complete natural resource surveys within the beetle-zone. Funding is allocated to improving the bioenergy investment and development opportunities for beetle-killed wood.	http://mpb.cfs.nrcan.gc.ca/recover/index_e.html

	1) Bioconversion of beetle killed lodgepole pine (BKLP) to bioethanol: Development of solutions to address the physical and economic challenges to utilizing salvaged beetle timber in bio-energy and panel board production (on-going); Decision support tools to assess the economic opportunities associated with the conversion of MPB fibre into a range of alternative uses (on-going).	http://mpb.cfs.nrcan.gc.ca/archive/projects/7-19_e.html
	2) Bioenergy options for woody feedstock: are trees killed by mountain pine beetle in British Columbia a viable bioenergy resource? : -It appears unlikely that a new large-scale facility to produce energy from beetle-killed fibre would be feasible without being able to continue operation with another fuel after the 15-year window of beetle-killed pine supply availability.- Pre-treatment options such as pelletization offer a lower risk approach to utilizing a temporary source of feedstock such as beetle-killed pine	http://warehouse.pfc.forestry.ca/pfc/26537.pdf

Table 3 Monitoring impacts of the production and use of bioenergy/biofuels and related socio-economic aspects: Examples from Canada.

Title of Project	Description	Reference(s)
National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS)	**Objective(s):** To estimate forest carbon stocks, changes in carbon stocks, and emissions of non-CO2 greenhouse gases in Canada's managed forests for considerations in forest management and international reporting (e.g. IPCC, UNFCCC). **Results**: Key in the development of the NFCMARS are a series of Carbon Budget Models of the Canadian Forest Sector (CBM-CFS2, CBM-CFS3). These models have been applied to analyze past and future changes in forest biomass and dead organic matter carbon stocks in Canada's entire forest, in the managed forest, in individual provinces or regions and at the scale of operational units. These tools can be used for various types of forest ecosystem carbon reporting requirements, as well as forecasting and tracking carbon stocks in function with forest management scenarios, including biomass removal.	http://carbon.cfs.nrcan.gc.ca/index_e.html
Ontario's NEBIE (**n**atural disturbances and **e**xtensive, **b**asic**,** **i**ntensive and **e**lite level of silviculture) Plot Network	**Objective(s)**: Monitor the effects of silvicultural practices on microclimate, soil moisture and nutrient cycling, vegetation diversity, and wildlife habitat and compare with natural disturbances. **Results**: -evidence that the displacement of downed woody material and forest floor organic layers was the leading cause of changes in species richness and abundance on this site (Newmaster et al., 2007) -Survival of various species (e.g. marten, brown creeper) is strongly associated with coarse woody debris. -Intensification of biomass removal increases biodiversity impacts	http://www.mnr.gov.on.ca/en/Business/OFRI/2ColumnSubPage/STEL02_165647.html

		Newmaster, S.G., Parker, W.C., Bell, F.W.,and J.M. Paterson. 2007. Effects of forest floor disturbances by mechanical site preparation on floristic diversity in a central Ontario clearcut. Forest Ecology and Management 246 (2-3), pp. 196-207
What impact does forest biomass harvesting have on soils? Join the research effort!	**Objective(s)**: - to predict the ecological consequences of removing logging residues from the forest; - to establish a Canada-wide project involving a long-term study that encompasses a number of ecozones and a range of sites and stands. **Result(s)**: -a guide that describes the procedure for establishing plots that can be used to monitor the effects of the removal of forest biomass.	http://scf.rncan.gc.ca/news/612
Effects of harvest intensity on long-term site productivity in boreal conifer ecosystems	**Objective(s):** To evaluate the impact of harvest intensity (biomass removal) on long-term site productivity in conifer-dominated boreal ecosystems in Ontario. **Results: 1)** A steady state mass balance model (ForSust), developed to simulate potentially sustainable levels of tree biomass growth and related nutrient uptake dynamics, was applied to 17 jack pine sites across Canada. Specifically, the model simulates sustainable annual increment (SAI) of biomass growth for stem-only and whole-tree (aboveground biomass) harvesting, and for recurring forest fire conditions.	J.S. Bhatti, N.W. Foster, T. Oja, M.H. Moayeri, and P.A. Arp. 1998. Modeling potentially sustainable biomass productivity in jack pine forest stands.
	2) Evaluating the sustainability of forest production when jack pine stems and logging residues are used for energy production:	Bhatti, J.S.; Foster; Arp, P.A. 1997.Evaluating the sustainability of forest production when jack pine stems and logging residues are used for energy production. P. 9-13 in Richardson. J. (ed.) Proc. Bioenergy and Boreal Forest Management Workshop, Timmins, Ontario, 23 Sept. 1997. International Energy Agency Task XII: Biomass Production, Harvesting and Supply Forest Management Activity. Canadian Forest Service, Ottawa, ON.

	3) Impacts of various levels of biomass removals on the structure, function, and productivity of black spruce ecosystems: Research protocols.	Gordon, A.G.; Morris, D.M.; Balakrishnan, N. 1993. Impacts of various levels of biomass removals on the structure, function, and productivity of black spruce ecosystems: Research protocols. Ont. Min. Nat. Res., For. Res. Info. Paper No. 109. 21p.
Improving Canada's National Forest Biomass Estimates through the National Forest Inventory	**Objective(s):** - Assign biomass data to every record in Canada's Forest Inventory (CanFI 2001) database; - Report on Canada's forest biomass resources on a periodic basis in conjunction with the National Forest Inventory (NFI) reporting; -report on the application of the methodology to the new plot-based NFI as well as provincial and industrial inventories. **Results**: The expanded and updated version of the CanFI 2001 database incorporates significant improvements to individual tree biomass equations (adoption of new national equations) and to the model development process (model fitting and selection), which result in more robust and accurate estimates of forest biomass in Canada. This database will be used to develop all summaries and reports on Canada's biomass resources. Work continues on the development of methodology to allow reporting on Canada's forest biomass resources on a periodic basis in conjunction with NFI reporting.	http://www.cbin.gc.ca/pro/gillis-eng.php http://warehouse.pfc.forestry.ca/pfc/27434.pdf http://nfi.nfis.org/

Table 4 Impacts of the production and use of bioenergy/biofuels on indigenous and local communities: Examples from Canada.

Title of Project	Description	Reference(s)
The use of biomass heating system by two indigenous communities in Canada	**Description:** The Ouje-Bougoumou Cree were the first Canadian community to develop and implement a biomass district heating system. Talks began in 1986 and the concept and design of a biomass district heating system developed. The community's primary fuel source is wood waste from a sawmill located approximately 26 km from the village. The wood waste used in the heating system would otherwise have been stockpiled at the sawmill. **Results:** The community saves about $40/MW on oil costs; with biomass, the savings are approximately $69/MW. The system has reduced the production of nitrogen oxides by approximately 35% or 160 kg a year in comparison to an oil-fired system. It is estimated that during the first year, more than 200 tons of carbon dioxide emissions were avoided. The wood-burning system is designed to meet the most stringent environmental standards in North America.	http://www.ouje.ca/content/our-story/heating.php www.retscreen.net/download.php/fr/164/3/CBIO03-C.pdf
Memorandum of Understanding (MOU) between the Kamloops Indian Band (KIB) and Raven Biofuels in Kamloops, British Columbia, Canada	**Description:** The purpose of the MOU is to work together to develop, build and operate a cellulosic biorefinery and cogeneration facility in conjunction with the KIB and partner Price Biostock. KIB will provide access to feedstock resources secured via a multi-year Provincial forestry agreement in which KIB has rights to 124,000 cubic meters of beetle-killed wood within the Kamloops Timber Supply Area. The forestry agreement augments a forest and range agreement signed by the band in 2005, which granted $2.5 million in shared revenues and 272,000 cubic meters of timber over five years. The biorefinery is planned to have an annual capacity of 7 million gallons (MGY) of fuel grade ethanol and 4 million gallons of furfural, furfural alcohol, related eco-friendly derivative chemicals and lignin cake. Due to the size of the proposed location, future capacity could be increased to double or triple the plant's production.	http://www.ravenbiofuels.com/projects/projects-BC.asp