ORGANIC WASTE IN NL: A REVIEW OF AVAILABLE AGRICULTURE, FISHERY, FORESTRY AND MUNICIPAL WASTE LITERATURE

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Organic Waste in Newfoundland and Labrador: A review of available agriculture, fishery, forestry and municipal waste literature.

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1 Acknowledgments

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2 Executive Summary

Re-utilisation of organic waste is globally widely employed to maximise both economic and environmental sustainability of human activities. Re-utilisation of organic waste nutrients of biochars produced from such wastes do offer a critical element for enhancing soil fertility and thus supporting sustainable agriculture.

Newfoundland and Labrador produces a variety of organic waste streams ranging from municipal to farm, fishery and timber production. We carried out a best estimate of the amount of these waste streams with a goal to understand the potential utility of each as a source of nutrients or biochar for sustaining agricultural activities in the province.

Municipal sources, i.e. municipal organic waste streams and wastewaters, and fishery waste were estimated to offer the largest potential for nutrient recovery. Dairy industry is the largest producer of nutrient rich organic waste among agricultural activities. The dairy industry might possibly produce most of the nutrients required to fertilise their own land base; note that the dairies in the province still import a significant portion of their feed and that is reflected in the waste stream. Nutrients currently available in the estimated waste streams are likely sufficient to support most fertilisation needs of the current land-base, or nearly double the current land base in the case of phosphorus. Given the estimated balance of waste nutrients in the province any expansion in agricultural land base would require supplementary imports of fertilizers or, preferably, an integrated livestock and crop agriculture expansion.

A secondary estimation was carried out to assess the value of the same organic waste streams for biochar production. This offered an alternative to nutrient re-utilisation, an alternative that is also in support of soil fertility. Sawmill waste, that carried little nitrogen and phosphorus value, was also included in biochar estimates. The assessment has shown a significant potential for biochar production mainly for fishery and municipal organic waste. However, pursuing a biochar agenda for these materials would require a trade-off with the nutrients lost during pyrolysis.

The assessment presented here confirms that organic wastes are a valuable resource for agricultural production and sustainability. However specific decisions would require a more detailed analysis of the geographic integration of waste streams and agricultural production.

3 Introduction

3.1 Rationale and background

Re-use of organic waste is globally an established method of environmental protection and energy and nutrients recovery (Sadugh et al., 2010; Zabaleta and Rodic, 2015), particularly for recovering of carbon, nitrogen and phosphorous (Kjerstadius et al., 2015; Reijnders, 2014; Theobald et al., 2016). Accelerating nutrient costs and declining global availability made the re-use of organic wastes even more attractive.

The province of Newfoundland and Labrador has been estimated to produce between 400,000 (MMSB, 2012), 407,728 (Statistics Canada, 2009), or 499,038 (Dillon Consulting, 2014) metric tonnes of waste each year. Of this approximately 30% is organic waste. While exact numbers vary, municipal, industrial, and agricultural sectors in Newfoundland and Labrador (NL) all add to an estimated 108,000 metric tonnes of organic waste produced annually (MMSB, 2012). While there are estimates of organic waste in current literature, they are broad estimates (Dillon Consulting, 2014) and there has been limited consistent quantification of exact organic waste types and locations across all waste streams throughout the province. In 2002 the province of NL released the Provincial Waste Management Strategy, which laid the groundwork for reducing the amount of waste throughout the province (MMSB, 2012). Since then there have been some attempts to quantify organic waste amounts in different sectors throughout the province (Cull, 2000; Dillon Consulting, 2014; Jayasinghe et al., 2011; MMSB, 2012).

According to the Management of Organic Waste in Newfoundland and Labrador report by the Multi- Materials Stewardship Board (MMSB) (MMSB, 2012), organic waste in NL by sector is comprised of Residential, Institutional Commercial and Industrial (ICI) waste, and Construction and Demolition (C & D) waste. Residential waste refers to residual organic waste materials discarded from dwellings. ICI is the residual organic material discarded from manufacturing, transportation, retail, and wholesale sectors, etc. While in NL, ICI includes forestry, fishery, and agricultural sectors, which are pooled in the report with municipal wastes, it is estimated that 34% of waste is residential, 60% is ICI, and 6% is C&D (MMSB, 2012).

The total amount of organic waste is expected to increase within the next decades. Re-use of waste is thus expected to increase within the next decades. Re-use of organic waste could bring economic value to NL, beside any benefits to environmental processes. Benefits of re-using organic waste include: i) direct application (includes compost) of nutrients for agricultural crops, ii) amendments for enhancing soil carbon profile and soil nutrient storage capacity and availability, iii) pyrolysis based recovery of energy and the production of biochars (with all corresponding profits). In 2012 a practical 30 year organics management strategy for nutrient recovery was defined for Newfoundland and Labrador (Dillon Consulting, 2014). The initiated project "Options for Organic Waste Processing in the Province of Newfoundland and Labrador" produced a report that provided a first inventory of organic waste stream sources and their proportional breakdown. The report further developed different proposed waste recovery scenarios including suggested haul routes. However, the report did not consistently quantify the volumes and properties of all organic material across all possible waste streams in the province. Moreover, the report focused on municipal waste and provided total amounts of organic waste only; the nutrient value of waste i.e. carbon (C), nitrogen (N) and phosphorous (P) potential was not estimated. Understanding nutrients availability and their spatial-temporal availability across the province is required for any practical recommendations and planning of re-use strategies. Thus, further investigation, logistic planning and management recommendations for the re-use of organic waste in the province are highly desirable. The presented report i) provides a preliminary organic waste inventory across potential streams itemized by their nutrient and soil fertility value, both quantitatively and qualitatively, ii) identify agricultural use scenarios using organic waste and thus provide a basis to develop model and prediction approaches and iii) introduce viewpoints on an integrated decision support platform that balances nutrient accessibility and its demand.

3.2 Objectives

The goal of this assessment is to understand the value of organic wastes for supporting agricultural sustainability in Newfoundland and Labrador. To this end three main objectives were proposed:

- Evaluate volume of organic wastes and waste streams in the province
- Assess their fertilizer value of such organic wastes, especially for nitrogen and phosphorus
- Assess the value of such organic wastes for biochar production

3.3 Methodology - General & Nutrient Potential Analysis

Although the potential for organic waste re-use is also highly desirable and possible in Labrador, the report focuses mainly on the island of Newfoundland. A literature search was conducted to identify information on the location, management, and management protocols for various forms of waste. Search included academic sources and grey literature, and was constrained to articles written in English. When specific NL information could not be found, e.g. for waste make-up, the survey considered literature from similar areas in Canada or other regions with comparable conditions. Information was also obtained from personal communications.

To acquire information about the spatial variability of potential available nutrients from organic waste recovery, all collected waste streams were grouped by their location according to its economic zones (Government of Newfoundland and Labrador, 1995). For simplifying purposes, the four economic zones of the Avalon Island were merged to one zone that resulted in 12 zones in total for Newfoundland (Figure 1).

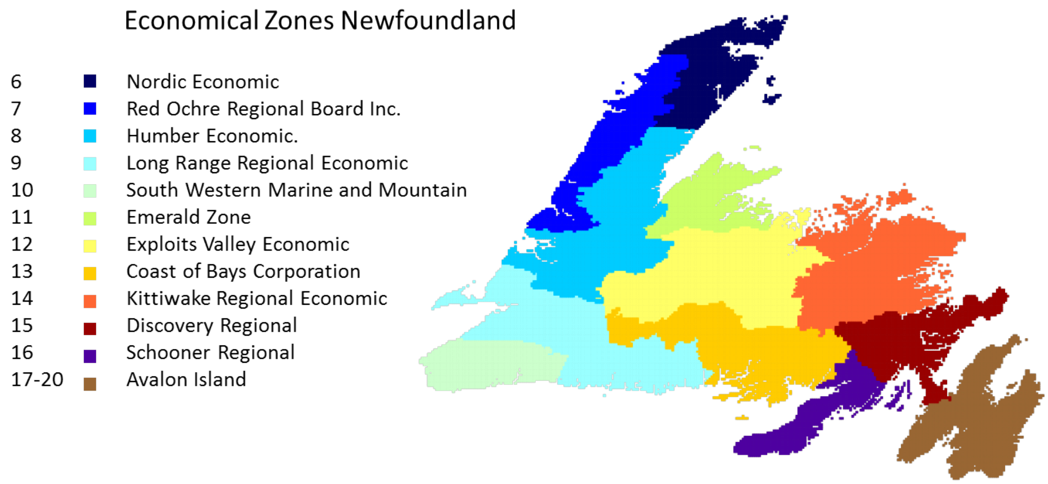

Figure 1. Simplified economic zones of Newfoundland with combined Avalon Island zones (17 to 20), numbers and names according to the Government of NL (Government of Newfoundland and Labrador, 1995); the zones 1 through 4, describing Labrador were not included here given the paucity of data

The considered waste streams included i) municipal wastewater and municipal organic waste, ii) agricultural waste, iii) sawmill waste, iv) fisheries, and v) forestry. The estimation of the amounts of N and P from the different organic waste streams were performed using references from the scientific literature unless actual numbers were available.

Details on methodology for each waste stream are presented in the relevant results sections.

Geo-referenced maps were generated using Surfer 8 (Golden Software, USA), pie charts were plotted by Excel (Microsoft, USA) and Systat 12 (Systat Inc, USA).

3.4 Methodology - Biochar estimations

The calculation of the annual biochar amount is based on equations for similar waste streams from the literature. For municipal waste we assumed 0.09Kg sludge per person as stated by several authors (e.g. (Cheremisinoff and Ferrante, 2013) and resulting 29.5% biochar from sewage sludge(Cao and Pawłowski, 2012). Estimation of agricultural waste was done according to Cantrell et al. (Cantrell et al., 2012), assuming the recovery amount for oven-dry ash free basis variable in relation to the waste stream origin at 350° C. We used recovery amounts of 54.4% for dairy, 45.9% for poultry and for mink waste because certain information about mink wastes was not available. Since more than 90 percent of the province's total lumber production came from 4 large commercial integrated sawmills (Government of Newfoundland and Labrador, 2014), we used for calculation of the saw dust information of these mills only. Given the fact only cumulative data of saw dust amounts for the whole island were available(Government of Newfoundland and Labrador, 2014), the total amount of saw residuals were divided into the four major mills for further regional analysis. The potential biochar amount was calculated assuming 41.86% yield for raw rubber-wood-sawdust at 450° C (Ghani et al., 2013). No information about the biochar amount from fish waste was given, hence we averaged the available amount for mussels and shrimps an (exclusive pure mussel shells) (K. Hawboldt, personal communication) assuming 20.9%. The amount of municipal organic waste was estimated by assuming an amount of 30% biochar from green waste (Tripathi et al., 2016; Zhang and Sun, 2014) representing compost with 30% loss. Finally, the amount of biochar from forestry waste was estimated by the assumption of pure soft wood and fast pyrolysis (400-500 C) with 21.9%.

4 Results

4.1 Organic Waste Sources in Newfoundland and Labrador

4.1.1 Forestry

4.1.1.1 Forestry waste, Background

As of 2012 there was one pulp and paper mill, and 581 commercial sawmills in the province of Newfoundland and Labrador. In 2011, 16,977 hectares of forest area were harvested (Government of Canada, 2011). These mills produce varying amounts of residues, while some also utilize residues. For example, reports indicate that the Corner Brook Pulp and Paper Mill Ltd (CBPPL) currently utilizes biomass to fuel parts of its production. In 2012 it is estimated more than 220,000 green metric tonnes were diverted (for 2014 The Forestry and Agrifoods Agency reported this number to be 155,000 gross metric tonnes). This biomass was produced both internally by the paper mill, or purchased from local sawmills (Government of Newfoundland and Labrador, 2014). Of the 581 commercial sawmills found within the province, 90% of the province's total lumber production comes from a few large sawmills (Government of Newfoundland and Labrador, 2014). The six mills with greater than 1-million-foot-board (fbm) in production are listed in Table 1.

Table 1. Largest sawmills in the Newfoundland and Labrador

Name	Location	Total Residue accumulated from 2000 to 2009 or yr of closure (green tonne)
Sexton Lumber Company	Bloomfield	67,037
Cottle's Island Lumber Company	Summerford	N/A
Harold Sheppard Company Ltd	Point Leamington	2,971
Burtons Cove Logging and Lumber	Hampden	6,800
Coates Lumber Company	Main Brook	23,427
Holson Forest Products Limited	Roddickton	13, 606

Biomass resources within the forestry sector in NL include pulp and paper mills, sawmills, construction and demolition sites, and forest residues (Bradley, 2010). The majority of literature for the province attempts to estimate residues through sawmills and/or pulp and paper mills MMSB (MMSB, 2012). Few grey literature reports and even fewer academic articles attempt to estimate or quantify biomass residues in the province of Newfoundland and Labrador (Bradley, 2010; Jayasinghe et al., 2011; MMSB, 2012; Winters, 2005). Most data come from provincial or national reports.

A national report from Natural Resources Canada and the Forest Products Association of Canada (BW McCloy & Associates Inc., 2004) estimates there were 29,875 Bone Dry Tonnes (BDT = 2000lbs of woody material at 0% moisture) of mill residue surpluses in Newfoundland and Labrador in 2004, and 188,000 BDT available of bark/hog fuel piles. Data for this report was gathered through a variety of sources, including two commissioned studies that used telephone and email surveys, and provincial data, for provinces where it existed. The majority of the data for this report was collected for the year 2004.

In a 2011 paper written for the Department of Natural Resources estimates that for 2008/2009 there were 24,414 BDT/y of in-forest residues, 41, 211 green t/y of active sawmill residues, 174,000 of pulp mill residues, and 5,041 of construction/demolition residues (Government of Newfoundland and Labrador, 2014). This study collected data through sawmill surveys, used provincial data, and visited sites to quantify residues. As shown in Table 1, the study estimated active sawmill residues and stockpiled residues for 2009. This study used green tonnes as its measurement, which used the following estimates for it's moisture content: 45% for sawdust, 50% for slabs, 50% for bark, 19% for kiln dried shavings, and 40% for shavings.

Data indicates that there are a total of 60,999 green tonnes residues from 2009 operations, and 904, 219 green t residues between the years 2000-2009. The figure from their report can be seen below).

Table 2. Forest and sawmill residues estimates (from (Government of Newfoundland and Labrador, 2014)

District	From 2009 operations				Operations between 2000-2009		
	Logging residues (BDT)	Sawmill residues (green t)[a]	Pulp and paper mill residues (BDT)[b]	Total	Active sawmills (green t)	Inactive sawmills (green t)	Total
1	871	1,095		1,966	7,098		7,098
2	3,490	4,320		7,810	67,037	58,251	125,288
5	4,840	0		4,840	2,495	5,904	8,399
8	4,896	0		4,896	2,971	698,504	701,475
12	3,992			3,992			
15			29,000	29,000			
16	2,258	0		2,258	6,800		6,800
18	3,226	1,915		5,141	37,033		37,033
21	840	256		1,096	7,382	10,744	18,126
Total	24,413	7,586	29,000	60,999	130,816	773,403	904,219

a, stockpiled on the mill yard; b, landfilled as black bark

While the Jayasinghe report for the Department of Natural Resources uses mostly 2009 figures and statistics, it is one of the few comprehensive inventories of forest biomass for the province (Jayasinghe et al., 2011).

Another report that addresses provincial sawmill residues and disposals is a 2005 survey conducted by the Newfoundland and Labrador Lumber Products Association. This report estimates 37,552 tonnes of residue to be available throughout the island (Winters, 2005). This study surveyed 37 sawmill producers throughout Newfoundland from January – March of 2005, and information was derived from site visits, and industry consultations. From this, nine models were developed to determined study data. However, the study reports on its own limitations, one example in particular being that a large mill stated they had no available residues, despite there being on site evidence to the contrary. Residues for this mill were estimated based on averages from similar technology calculations (Winters, 2005).

In their 2012 report the MMSB estimates that there were 41,211 metric tonnes of forestry biomass residues generated annually in the province, with 7,585 metric tonnes of wood waste stockpiled at mills across the province (MMSB, 2012). The report states that 55% of the residues are combusted as hog fuel, while cattle farms currently use approximately 26,000 metric tonnes of woodchips and sawdust. These figures indicate a shortage of some wood fibres, particularly for agricultural uses, as some farmers are importing residues. Despite this, residuals of 18,467 green tonnes/year are reported. This data was estimated through existing literature.

Lastly, data from the Centre for Forest, Science and Innovation indicates that there are residue piles amounting to 894,214 green tonnes in the province (Personal correspondence).

Biomass inventory may also be estimated with the Biomass Inventory and Assessment Tool (BIMAT, www.agr.gc.ca/atlas/bimat). BIMAT is a tool developed by the Canadian Biomass Innovation Network, Canadian Forest Service, Agri-Food Canada, and the National Land and Water Information Service, that uses internet map server technology to allow users to view and query spatial inventory of forestry and agricultural biomass sources (Bradley, 2010); "BIMAT includes data about the location of both leftover material from agricultural and forestry industries (residues) and agricultural crops that are used as feedstock by bioindustries". BIMAT allows users to view biomass supply and location by showing availability of a specific type of biomass or by creating a database query that generates information about the location and available amount of one or more types of biomass. However, for Newfoundland, the tool does not register any biomass availability in known major residue centres such as Corner Brook, Stephenville, or Grand Falls-Windsor.

4.1.1.2 Forestry waste, Location

While the quantities of residues can be estimated through a variety of sources, as seen above, determining the location of residue piles is less feasible. A residue pile location is available from (Jayasinghe et al., 2011).

While there is only one current pulp and paper mill site in Newfoundland and Labrador, and the exact number of sawmills does vary. The size of the sawmills greatly impacts the pile potential. While there are over 500 sawmills in the province, 90% of the residues come from the six larger mills identified previously. These mills are in the following communities: Bloomfield, Summerford, Point Leamington, Hampden, Main Brook, and Roddickton. Additional mills have been confirmed in all regions in Newfoundland and Labrador with two on the Avalon Peninsula, three in Eastern, four in Central Newfoundland, one in Labrador, and four in Western Newfoundland.

4.1.2 Agriculture

4.1.2.1 Agricultural waste, Background

Newfoundland and Labrador has a diverse agricultural sector, and many of the farms and commodity groups have the potential to produce organic waste. Organic wastes from agriculture can come from a variety of sources; woodchip bedding, manure, mortalities, discards, and offal (MMSB, 2012). Literature, reports, and communications found on organic waste in the province focus on manure, mortalities, and offal found on farms with livestock.

In Newfoundland, farms that potentially produce manure, mortalities, and offal include dairy, pork producers, fur farms (mink and fox), and broiler and layer farms. While all these farms produce organic wastes, it is the mink, dairy, and poultry farms that represent the largest farming operations in the province, with dairy and poultry farms producing the most significant amount of manure (MMSB, 2012; personal communication).

Because of the small nature of farms in Newfoundland, there is little accurate data on the size of farms and the waste they produce (Butler et al, unpublished manuscript). This is important in estimating organic waste in agriculture as the number of animals is used to calculate the manure wastage, which is a significant aspect of the organic waste from the industry (Personal correspondence). The 2006 national census reported over 500 different farms throughout the province (Department of Natural Resources, 2014), however, stakeholders in the industry feel that number is too high to be accurate (Carlson, 2016). Discrepancies also exist on the commodity level. While the Department of Natural Resources (2013) reported that there were 39 dairy producers in the province, personal communication with a commodity group stakeholder indicates there are only 27 active dairy producers. Personal communication and national statistics indicate that there were 11300 cattle in the province as of July 2015 and 5700 dairy cows specifically (Carlson, 2016; Statistics Canada, 2016). Provincial data for other commodity groups report there are two commercial pork producers, over 15 mink farms, five fox farms, and 36 generally small commercial apiculture operations in the province (Elsworth, 2016).

4.1.2.2 Cattle and Dairy waste

The exact number of cattle within the provinces has some variation. In a presentation in 2009, the then President of the Newfoundland and Labrador Federation of Agriculture (NLFA) cited there are 5,600 dairy cows in the province with the average herd size at 144 (Eugene Legge, presentation, October 2009). One dairy farm in St. David's Newfoundland has 1200 cows alone, making it the 3rd largest in Canada (www.holstein.ca/PublicContent/PDFS/EN/INFO%20 HOLSTEIN _EN/IH2010_Oct10.pdf). More current data from the Federal Government indicates this number to be 5700 (Statistics Canada, 2016), whereas an industry stakeholder stated around 6,000 (personal communication). This corresponds to the latest agriculture census which indicates in 2011 there were 6,153 head (Statistics Canada, 2016). Total cattle are stated to be 11, 300. Personal communication indicates that the dairy farms that are in operation are located west of Deer Lake and east of Lethbridge, Musgravetown, and Port Blandford areas (M. Carlson, personal communication, February 2016). A report from Dillon Consulting indicates there to be a total of 12,942 ft3/day of dairy manure produced in the province in the following areas, Avalon, Bonavista Bay, and West Coast (Dillon Consulting, 2014).

4.1.2.3 Poultry waste

Poultry data are less prevalent in national reports. For example, Stats Canada reports have suppressed data to maintain confidentiality (Statistics Canada, 2015). However, a report from 2014 from indicates there were eight chicken producers in Newfoundland and Labrador and that the average farm size was 2,368,000 kg (live weight) (Chicken Farmers of Canada, 2015). Meanwhile provincial data indicate NL has seven registered egg producers and 356,567 laying hens (Legge presentation, October 2009). Farm sizes range from under 6,000 layers to over 70,000 and the average flock size has increased from 12,000 to 23,000 (Legge presentation, October 2009). Meanwhile, a Stats Canada report indicated there are 1.82 million poultry in NL while the 2006 agriculture census indicated that there were 1,570,740 poultry inventory, including turkeys, broilers, layers, etc. (Statistics Canada, 2015).

A report that uses data from NLFA reports as well as data from the Newfoundland and Labrador Department of Environment, finds that there are 5478 kg/day of poultry litter produced, and 1438 kg/day of poultry mortalities (Dillon Consulting, 2014). However, the report does indicate that the data does not represent hobby farms, mass mortality situations, nor is indicative of abattoirs or other processing facilities. It should also be noted that the data represents organic waste generated, not all of which may be available for an organics processing facility.

Personal communication has indicated there are three layer and four broiler producers operating on the island. A poultry farm located in the Lewisporte area while another is operating in the Wooddale area. The remainder of the quota is produced on the Avalon Peninsula in the Whitbourne area, Roaches Line and at the Country Ribbon location in St. John's (Personal Communication).

4.1.2.4 Fur farming

Fur producers are predominantly mink and fox farms. Provincial figures from 2009 found there were three fox farms, 22 mink farms, and nine mixed farms in the province. (Forestry and Agrifoods Agency, 2016). For fur producers there were 233.9 thousand pelts produced in the province in 2011 (Statistics Canada, 2012).

There were 72,870 mink breeding stock reported in Newfoundland and Labrador in 2011 (Statistics Canada, 2011) and in the 2006 agriculture census counted 3,060 foxes an average 383 foxes per farm (Statistics Canada, 2006). While minks composition the majority of manure volumes generated within the province, animal numbers vary significantly as a result of furbearing management practices. An operation with 7,000 female breeders may rise to 47,000 animals throughout to growing season and back down to 7,000 female breeders after pelting (M. Carlson, personal communication, February 8 2016).

An organic waste report from Dillon Consulting (2014) found there to be a total of 518 ft3/day mink manure, and 478800 kg/yr of mink carcasses for disposal. The breakdown of location can be seen below.

4.1.2.5 Pork and Sheep

While farms with pork and sheep are not considered to be significant producers of organic waste, they still have the potential to add to organic waste produced in the province. While animal numbers for both commodities have decreased, provincial stats from the agriculture census indicate that in 2006 there were 4,600 market hogs and 300 breeding stock, and 4,800 lambs were produced at a rate of 1.3 lambs per ewe (Forestry and Agrifoods Agency, 2016). However, 2011 figures from Stats Canada cite 2,449 head in 2011 (Statistics Canada, 2011).

4.1.2.6 Current disposal

The disposal of manure, offal or mortalities is important in sourcing organic waste in agriculture. Current disposal methods of manure vary by commodity type. In general, mortalities and offal are limed and put in landfills (MMSB, 2012). However, reports indicate that all but three dairy operations handle manure as a liquid product stored in steel or concrete storage units (personal communication). A 2003 national report found that in 2001, 35 farms in NL with livestock stored liquid manure, and 120 stored solid/semi solid manure (Statistics Canada, 2003). The same report indicates that over 75% of dairy cattle storage systems are liquid storage. Communications indicate that poultry manure waste is removed between flocks and distributed on forage and vegetable fields (Personal communication). Mink farm wastes are more challenging to determine as some have significant composting processes in place on site that make use of mortalities and offal, and sometimes other commodity group waste, such as poultry or forestry residues (MMSB, 2014). In general, manure is typically managed on site. Mortalities for cattle are mainly managed on site, while mink mortalities, offal and carcasses are landfilled and poultry offal, mortalities and carcasses made into feed and landfilled (Murphy, G, personal communication).

4.1.2.7 Farm locations

Livestock farms can be found across the province of Newfoundland and Labrador; nevertheless, no livestock farm is listed for Labrador. There are 23 animal producers in the Avalon region, eight in Eastern, five in Central, and 21 in Western regions.

4.1.3 Fisheries

4.1.3.1 Fisheries, Background

Fish processing waste is another source of organic waste and potential biomass residues in Newfoundland and Labrador. With 94 licensed fish processing plants, that produce a variety of fish products including groundfish, shellfish, pelagics and seals, residue potential is significant. While federal legislation forbids dumping of fish waste into the ocean (MMSB, 2012) in Newfoundland and Labrador, all but two fish processors have a permit exempting them from the regulation that prohibits disposal of fish processing waste in marine waters.

As reports indicate (Cull, 2000; Dillon Consulting, 2014; MMSB, 2012) varying amounts of fish waste (offal) can be produced from fish processing. Depending on the fish being processed, offal may consist of the entire fish, viscera, skin, heads, etc. Additionally, the type of fish, and the end product, can greatly impact the amount of waste. Fileting of groundfish, such as cod, results in 40-60% of the fish being discarded, and 30% of salmon. For shellfish, up to 80%, or more, of the landings may be discarded.

One way through which organic fish waste can be estimated is through landings data. Cull's thesis evaluates the different types of organic waste being dumped in the ocean in Newfoundland in the late 90's, looking at fishery, aquaculture, sawmill, and municipal waste points (Cull, 2000); fish offal is the greatest source of organic waste in the province of Newfoundland. The level of offal was determined based on landings and production data for that 1996 and by calculating offal estimates through a variety of equations specific to each offal time. However, Cull's estimates are significantly higher than any other report reviewed in this search (AMEC Earth & Environmental Limited, 2003; MMSB, 2012). It is important to note that the data is no longer current as some is almost two decades old, and that Cull herself indicates that the sawmill estimates in this study are less accurate than the other industries due to limited access to data (Cull, 2000).

A variety of reports indicate differing levels of fish waste for the province. A 2012 report from MMSB, which collected data from various provincial and national stakeholders estimates that 52,000 metric tonnes of fish waste is disposed of at sea annually (MMSB, 2012). However, another report (AMEC Earth & Environmental Limited, 2003) which gathered and validated available baseline data estimates the maximum possible waste for Newfoundland in 2001 to have been 146,960 metric tonnes. Meanwhile, another report (Hardy, 2010) estimated the potential by-product available in Newfoundland and Labrador, to a total of 48,245 metric tonnes. It is important to note that the Hardy estimates for aquaculture were zero, which differs from other reports, (MMSB, 2014; Cull, 2000). This report also used 2009 figures (Hardy, 2010).

A report from Dillon Consulting indicates that the highest density of processing plants in Newfoundland and Labrador is on the Avalon peninsula and it is estimated that 30% of landed volume is waste (Dillon Consulting, 2014). Approximately 79% of waste by volume is shellfish; 21% is groundfish and pelagics. The report also indicates that a large volume of groundfish and pelagic wastes go to the fur farming sector. Using 2010 landings, processed volumes and waste figures, the report estimates that 105,962 tonnes of unutilized material results from fish processing. Additionally, the same report cites the MMSB figures that an estimated 52,000MT could come ashore annually if permits that allow dumping at sea are revoked. The report also estimates the following areas and their organic waste.:

Table 3: Newfoundland and Labrador Fish Species and By-Product Potential (Metric tonnes)

Burin Peninsula	2,700
Central	12,500
Discovery	2,200
Eastern	24,000
Northern Peninsula	17,200
Western	4,700
Total	63,300

Discrepancies between figures reported above, for example of 105,962 versus 63,300 can be explained as the figures are from different years; the latter is a broad estimate from 2012 operations. Additionally, the report does suspect that the 63,300 figure may be somewhat low due to a discrepancy between pelagic landings and processed number, some of which can be attributed to the production of fishmeal, as well as direct shipment to fur breeders and direct use as bait. Additionally, some of the waste materials identified may already be going to some form of composting as information suggests farmers are using various outputs for composting, as indicated in the MMSB report, and anecdotal information.

4.1.3.2 Fishery waste, Locations

Fish processing plants are located across the province, producing a variety of fish products; 20 seafood processors are in the Avalon region, four in Eastern, 12 in central, 2 in Labrador, and nine in Western Newfoundland.

4.1.3.3 Aquaculture

Aquaculture is another contributor to organic waste in the province. There were approximately 145 aquaculture licenses in 2011, for a total production in 2012 of (Hardy, 2010)21,228 metric tonnes. Expansion of the industry is expected to continue, from 12,000 MT to 50,000 MT by 2016 . Provincial statistics indicate that in 2014 there were 5890 metric tonnes of Salmonid produced and 3260 of shellfish in the aquaculture sector (Government of Newfoundland and Labrador, 2016). Aquaculture can produce organic waste in the processing of fish, with wastes ranging from 25-30% of processed fish (MMSB, 2014). Additionally, organic waste is produced through mortalities, which can range from 5-20% (MMSB, 2014). Estimates for 2016 indicate organic waste totals, including mortalities, could be between 15,000 and 25,000 metric tonnes a year. Unlike fish processors, aquaculture wastes are prohibited from dumping at sea, and the resulting waste must be managed onshore. A report that surveyed six companies on the east coast of Newfoundland on their by-product disposal methods, estimates that in 2009 the aquaculture industry produced 3.3 million Lbs. (1500 MTs) of offal by-products. This figure is based on stomach removal only and the report estimate this figure doubled in 2010 (Hardy, 2010). Meanwhile, it was estimated that 607,000 dry mass kg of aquaculture waste were produced in NL in 1996 (Cull, 2000). Figures from the Dillon Consulting (Dillon Consulting, 2014) report indicate that in 2011 there was 4,908 metric tonnes of mortality parts and offal, and predict 16,542 metric tonnes for 2016 (not including mass mortality estimates). The same report indicates that the aquaculture industry is concentrated in two areas: Notre Dame Bay and Connaigre Penninsula.

As previously mentioned, most aquaculture sites are in the Notre Dame Bay area (approximately 32), or the Connaigre Penninsula (approximately 73 sites). However, there are also approximately two sites on the Avalon region, eight on the Western region, and three on the Eastern.

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4.1.4 Municipal waste

4.1.4.1 Municipal waste, Background

Municipal wastes are another potential producer and source of organic waste in Newfoundland and Labrador. Waste is produced through residential, and non-residential sources. Residential waste in Newfoundland accounts for 53% of waste disposal. Experts estimate that 40-50% of residential waste in the province is organic, approximating that figure to be 61,200 mt/y for municipal wastes (MMSB, 2012). Total annual household waste generated in Newfoundland and Labrador is comprised of an estimated 30% organics and 37% paper fibres.

At 429 kg per capita Newfoundland and Labrador (NL) has the highest residential solid waste disposal in Canada (2012). Total annual waste figures for the province vary significantly. Figures from 2008 indicate 410,590 tonnes of waste was produced in NL, 216,992 of which were residential. Total waste disposal in 2012 was 391,571 (Statistics Canada, 2009). The provincial Solid Waste Management Strategy indicates that by March 2013, 361,124 metric tonnes of waste were disposed of in the province and 137,913 metric tonnes of solid waste were diverted from landfills. (http://miga.gov.nl.ca/waste_management/WM_Report.pdf). Meanwhile a report written by Dillon Consulting (Dillon Consulting, 2014) predicts that in 2015 there will be over 478,000 tonnes of waste produced in the province, and just over 145,000 tonnes of that will be organic.

However, Newfoundland and Labrador also has the lowest waste diversion rate, at 6.9% (MMSB presentation on getting to 50%). Total tonnage diverted for 2011 was 130,246 of which 10,385 tonnes was residential. This is of a total disposal of 323,991 tonnes provincially, of which 137,710 tonnes were residential and 186,282 tonnes were non-residential.

The current state of waste disposal in Newfoundland and Labrador is variable. The province is in the midst of its Waste Management Strategy (Government of Newfoundland and Labrador, 2002), and there are incinerators, lined and unlined landfills, composting facilities, materials recycling facilities, and transfer waste/waste recovery facilities in various states of operation.

There are eight regional waste management authorities in the province: Discovery Regional, Burin Peninsula, Central Regional, Coast of Bays, Eastern Regional, Baie Verte- Green Bay, Northern Peninsula, Western Regional.
In the Discovery regional service board there are nine unlined landfills located in the region. Sites are located at Lethbridge, Port Blandford, Musgravetown, Charleston/Southern Bay, Port Rexton, Trinity Bay North (Catalina), Bonavista, Newmans Cove and King's Cove. The Burin Peninsula operates a landfill site in Grand Bank. Additionally, there are seven active municipal waste disposal sites that are in operation in Grand Le Pierre, Terrenceville, English Harbour East, Bay L'Argent, Monkstown, Rushoon and Marystown. The Central Regional Service Board operates the Norris Arm Regional Waste Management Facility. The Facility includes an engineered, lined landfill with leachate treatment. In the Coast of Bays Waste Management Corporation, there are 12 waste disposal sites within the region, located in St. Jacques-Coombs Cove WDS, Conne River, Gaultois (remote site), Town of Harbour Breton, Hermitage-Sandyville WDS, Milltown/Head of Bay D'Espoire Site, Morrisville WDS, Pool's Cove Dump Site, Town of Rencontre East Landfill (remote site), Pass Island Road (Seal Cove), McCallam (remote site) and St. Alban's Municipal Disposal Site. These are open pit landfills. The Eastern Regional Service Board oversees the operations of the waste management facility at Robin Hood Bay facility, which includes a landfill, recycling facility and a hazardous waste facility. Additionally, there are six waste recovery facilities in the region, located in Placentia, St. Joseph's, Bay Bulls, Renews-Cappahayden, Old Perlican and Sunnyside. The Baie Verte – Green Bay Region has one scrap metal site and 10 active landfills located in Westport, Burlington, Seal Cove, Wild Cove, Baie Verte, Ming's Bight, Woodstock, Nipper's Harbour, Snook's Arm, La Scie while the Northern Peninsula Regional Service Board has waste disposal at four regional landfill sites located near St. Anthony, Roddickton, Barbe and Hawke's Bay. When the Provincial Waste Management Strategy is fully operational, there will be no landfills in the Northern

Peninsula. All garbage will be hauled to the Norris Arm regional landfill. In the Western Regional Service Board there are currently seven active landfills located at Portland Creek, Pollard's Point, Deer Lake, Wild Cove, McIver's (Corner Brook Area), St. Georges and Port au Basque that will be closed when the future transfer stations are built.

4.1.4.2 Municipal waste, Location

While not all municipalities have a comparable organic waste collection system, current or even planned, for the purpose of this exercise we assumed an average production per capita (Wett and Alex, 2003) and thus linked to the size of the population in all communities in the province. Each economic zone thus included the respective communities.

4.1.5 Municipal wastewater/sewage

4.1.5.1 Municipal wastewater, Background

Municipal wastewater can contain grit, debris, suspended solids, disease-causing pathogens, decaying organic waste, nutrients and about 200 different identified chemicals (cite). It is a leading source of suspended solids, nutrients, organic chemicals and metals discharged into Canadian waters (Giroux, 2014). Traditionally, septic waste and sewage sludge in Newfoundland and Labrador was predominantly disposed of at sea (MMSB, 2012, 2014) however, the waste is now treated and de-watered, and the resulting residuals, called bio-solids, must now be managed on land. MMSB estimates there to be between 5000-7000 metric tonnes of bio solids generated annually in the province, which are currently landfilled. A significant portion of the population of Newfoundland and Labrador is not served by any wastewater treatment, or is only served by preliminary treatment. Primary treatment is prominent in Newfoundland and Labrador (Environment Canada, 2013). In 2009 it was estimated that 7.7% of Newfoundland and Labrador used private septic systems. However, this data was obtained from a survey that sampled municipalities with population below 1000 people, and given that many small municipalities do not have sewer systems at all, it is likely that the total percent of Canadians using private septic systems and sewage haulage is somewhat higher than that reported here (Environment Canada, 2011).

4.1.5.2 Municipal wastewater, Location

While not all municipalities have a wastewater collection system, or indeed a wastewater treatment plant, for the purpose of this exercise we assumed an average production per capita and thus linked to the size of the population in all communities in the province. Each economic zone thus included the respective communities.

4.1.6 Composting

Food waste represents a significant proportion of organic material found in residential waste. It is generated primarily by the residential and ICI sectors, and can be either postconsumer, originating from residential and commercial kitchens (i.e., restaurants and hospitals), or pre-consumer, coming from distribution and retail agents (i.e., transporters and supermarkets) (Environment Canada, 2013). The percentage of households in Newfoundland and Labrador composting kitchen and/or yard waste was 43% in 2011 (Giroux, 2014). However, Statistics Canada reports the figures to be closer to 51% (Van Wesenbeeck, 2015).

Additionally, NL comprises more than 200 small communities with population between 100 and 600. Most of these small communities are in remote and isolated areas and cannot access large solid waste disposal sites or central organic processing facilities. Therefore, on-site composting facilities have been considered as a viable means to deal with organic wastes in the small communities (Kazemi et al., 2014). According to a MMSB report (MMSB, 2012) there are currently 15 locations throughout NL where organic waste is managed at a compost site. These sites include six community composts managed municipally, Kona Beach RV park, College of the North Atlantic (which location), Grenfell College, the Burin Peninsula Waste Management Corporation, Hi- Point Industries (near Corner Brook), Carew Services (Cape Broyle), Greenings Dairy Farm (no longer composting, Nu-Mink farm in Cox's Cove, Pardy's Waste Management near Cochrae Pond, and New World Dairy in St. Davids (MMSB, 2012).

With regards to composting for each of the eight waste management regions the Dillon Consulting report (Dillon Consulting, 2014)) does indicate which region promote composting. For example, Western Newfoundland promotes composting, and some municipalities within it, such as Corner Brook, provide curbside collection; MMSB runs compost projects in Cape St. George and Deer Lake. Additionally, there are composting facilities in the region including Memorial University Grenfell Campus (in-vessel system), Hi-Point organics (private facility known as Genesis Organics), Potential ICI organic feedstock providers are from fish plants and grocery stores (2014). The report also indicates that carbon-rich materials from non-residential sources may be challenging to obtain in the western region as the Corner Brook Pulp and Paper Mill uses carbon-rich materials from its own operations, scrap wood from landfills, sawdust from Clarenville saw mill and debris from forestry operations for hog fuel. Additionally, there is currently no food waste collection within the region (Dillon Consulting, 2014). As of 2014, Coast of Bays was interested in finding a way to manage compost and the report identified the option of stockpiling recyclables until sufficient quantities are collected for efficient transport to processors. In the Northern Peninsula region there is no organic collection program. The central region has potential non-residential generators of composting feedstock/bulking agents are fisheries, agricultural operations, food processors and institutions (Dillon Consulting, 2014). The burin region has potential future sources of non-residential composting with feedstock/bulking agents that are currently contributing to the pilot composting program are White's Sawmill in Burin, Ocean Choice International in St. Lawrence and Sobeys in Grand Bank (Dillon Consulting, 2014). Discovery regional has potential sources of non-residential composting, which include feedstock/bulking agents from two fish plants, a mink farm, hospital and restaurants (Dillon Consulting, 2014).

There is significant research that describes the chemical composition of various organic waste residues (Bellamy et al., 1995; Goyal et al., 2005; Magdziarz and Wilk, 2013).

Composting definition
Composting is an aerobic biological process that relies on different types of microorganisms. The predominant types of microorganisms present during the composting process are bacteria, fungi, and actinomycetes (Environment Canada, 2013). There are a wide range of parameters which can be used to monitor physical, chemical, biological, and biochemical variations during composting, such as the aeration rate, temperature, pH, moisture content, carbon/nitrogen (C/N) ratio, respiration, enzyme activity, microbial colony, and bioassay (Zhang and Sun, 2014). These parameters apply to all composting methods and technologies. However, the emphasis placed on each parameter varies from facility to facility, depending upon feedstock types, composting technology, and operator experience.

Table 4. Summary of optimal composting conditions (Environment Canada, 2013)

Parameter	Active composting	Curing	Product storage
Oxygen concentration	13 to 18%		
Free air space (air filled porosity)	40 to 60%		
Particle size (mm	A mixture of particles between 3 and 50 mm		
C:N ratio	25:1 to 30:1	18:1 to 23:1	15:1 to 20:1
Moisture content	55 to 60%	45 to 55%	40 to 45%
Temperature	55 to 60C	< 50C	Ambient
pH	6.5 to 8		

4.2 Estimated nutrient values in organic waste

Firstly, the total amount of nitrogen and phosphorus were estimated both for ideal management conditions and for non-ideal management. The latter assumed a larger loss of nutrient as gaseous losses or in leachates during storage and composting, where appropriate.
Secondly the total agricultural land surface that might be fertilized with the putatively recovered nutrients was estimated. The scenarios considered average fertilization per agricultural hectare for either the EU27 countries (all European Union countries), the EU15 countries (western EU countries), or the CEC countries (Central and Eastern European Countries). This allowed for three ranges of agricultural intensity from more intensive agriculture (EU27) to least intensive

agriculture (CEC countries), possibly relevant to current and future agriculture in Newfoundland and Labrador.

Average level of fertilisation for regions assumed similar to NL			
	EU 15	EU 27	CEC countries
Average N per Ha	158 kg	143 kg	105 kg
Average P per Ha	21 kg	19 kg	13 kg

Recoverable nutrients were calculated based on literature information as described in detail in the section dedicated to each waste stream. No recoverable nutrients were estimated for forestry waste. For the total amount of available nutrients, two scenarios were developed, representing the least and the best recovery potential, variable for each waste type.

In addition to the tabular listing, the calculated results were displayed per economic zone as map, indicating the total amount of N and P per year (a^{-1}) as well as the amount available per year and person (a^{-1} pp^{-1}). If it was available, the exact locations of the waste producer were presented within the maps, separated by its professional affiliation (e.g. Fisheries, Farms). Further, the amounts of total N and P were plotted as pie chart, separated by the economic zones of source location. In doing so municipal waste of each of the 681 communities in Newfoundland (Government of NL, 2011) was listed and considered. In addition to the used literature, personal communications were extensively used to fill important knowledge gaps.

4.2.1 Municipal organic waste

Determining the composition of municipal wastes can be challenging. The first step is determining the breakdown of the waste stream. As previously stated, it is estimated in Canada that 40% of residential waste is organic (FCM, 2009, 2011). A report from Dillon Consulting estimated the compostable residential organics breakdown by generator type for the province and found the most significant organic source to be paper (24.7%), followed by food waste at 23.9%, recyclables 15.3%, and other 20.0% (Dillon Consulting, 2014). For rural residential the figures were slightly different with paper at 21.6%, food wastes at 22.6%, recyclables at 18.8% and other at 19.4%. However, the composition of the organic wastes stream does fluctuate throughout the year (Environment Canada, 2013). Some reports state that the residential sector generates food scraps in a relatively constant quantity, solid waste increases in warmer months, and that leaf and yard wastes fluctuates according to factors such as season and area (rural vs. urban) (Environment Canada, 2013)

While data on materials prepared for recycling by type and data specific to Newfoundland and Labrador have been suppressed by Statistics Canada (Statistics Canada, 2008b, 2010; Van Wesenbeeck, 2015), in 2008, at the country level organic materials accounted for the largest proportion, by weight, of waste diversion

(2,439,223 tonnes diverted, 29% of total waste diversion), followed by cardboard and boxboard (17%) and newsprint (13%).

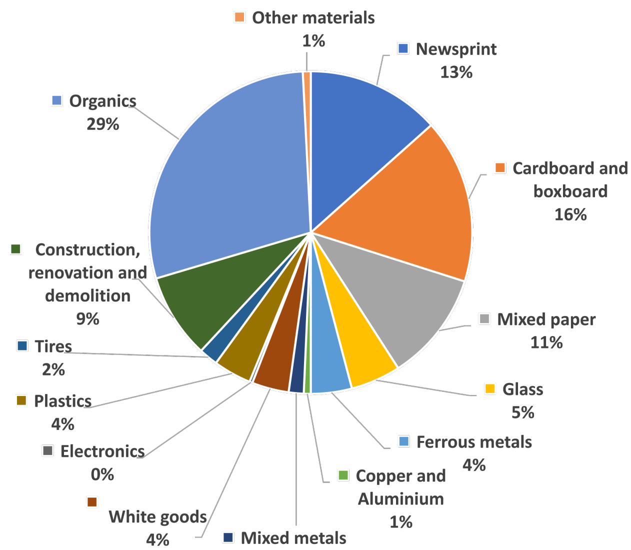

Figure 2. Proportional composition of municipal organic waste; country level averages (Environment Canada, 2013).

One study of food wastes (Adhikari et al., 2009) found the following composition of food wastes: pH 4.1 (0.2), Dry matter 12.2% (±3.1%), Carbon 47.4% (±3.1%), TKN 2.0% (±0.3%), C/N ration 24% (±3.0%), Wet bulk density 410 kg/m^3, particle size 10-100mm.

4.2.1.1 Estimated Municipal Organic Waste amounts:

Data for both current scenario (year 2015) and future estimates (year 2045) were used in th1 e calculations. It is assumed that materials are used composted.

Table 5. Estimated municipal waste organics amounts (Dillon Consulting, 2014).

Region	Generation sector	Estimated total population	2015 Total waste generated (t)	2015 Organics generated (t)	2045 Total waste generated (t)	2045 Organics generated (t)
Discovery	Residential		5,123	1,726	8,315	2,801
	ICI [1]		6,654	1,658	10,800	2,692
	Total	11,500	11,777	3,384	19,115	5,493
Burin Peninsula	Residential		8,014	2,744	10,492	3,592
	ICI		10,508	2,761	13,757	3,615
	Total	18,394	18,523	5,505	24,250	7,207
Central	Residential	,	31,496	10,646	41,234	13,937
	ICI		40,908	10,268	53,556	13,443
	Total	71,840	72,404	20,913	94,790	27,380
Coast *of* Bays	Residential		2,878	973	3,768	1,274
	ICI		3,738	938	4,894	1,228
	Total	6,602	6,616	1,911	8,662	2,502
Eastern	Residential		114,876	40,111	150,393	52,512
	ICI		153,576	44,455	201,059	58,199
	Total	266,294	268,451	84,565	351,453	110,712
Green Bay	Residential		5,632	1,904	7,373	2,492
	ICI		7,315	1,836	9,577	2,404
	Total	12,863	12,947	3,740	16,950	4,896
Northern Peninsula	Residential		5,553	1,877	7,270	2,457
	ICI		7,212	1,810	9,442	2,,370
	Total	12,699	12,947	3,687	16,712	4,827
Western	Residential		32,692	11,050	42,801	14,467
	ICI		42,463	10,658	55,591	13,953
	Total	74,571	75,155	21,708	98,392	28,420
Total		474,763	478,638	145,414	630,324	191,436

1 - ICI, (Industrial, Commercial and Institutional sector) includes businesses, restaurants, hospitals, schools, manufacturing facilities and retail operations.

4.2.1.2 Assumptions employed for the calculation of nutrient values for municipal organic waste

Assumptions from literature and as per the authors':

Material is composted = 20 to 50% DM loss; 60% moisture	
Compost composition	
Total-N	18 mg/kg
Organic N	13 mg/kg
Ammonia N	5 mg/kg
Total-P	2.9 mg/kg

4.2.1.3 Scenario 1; based on data for 2015

Table 6. Estimates of nutrient value in municipal organic waste (based on year 2015)

Region	Waste Source	Fresh waste (t)	Compost (t)		Total N (t)		NH3-N (t)		Total P (t)	
			Estimated loss during handling/composting							
			30%	50%	30%	50%	30%	50%	30%	50%
15	Residential	1,762	1,233	881	13.3	9.5	3.7	2.6	2.1	1.5
	ICI [1]	658	461	329	5.0	3.6	1.4	1.0	0.8	0.6
16	Residential	2,744	1,921	1,372	20.7	14.8	5.8	4.1	3.3	2.4
	ICI	2,761	1,933	1,381	20.9	14.9	5.8	4.1	3.4	2.4
12 &14	Residential	10,646	7,452	5,323	80.5	57.5	22.4	16.0	13.0	9.3
	ICI	1,268	888	634	9.6	6.8	2.7	1.9	1.5	1.1
13	Residential	973	681	487	7.4	5.3	2.0	1.5	1.2	0.8
	ICI	938	657	469	7.1	5.1	2.0	1.4	1.1	0.8
17-20	Residential	40,111	28,078	20,056	303.2	216.6	84.2	60.2	48.9	34.9
	ICI	44,455	31,119	22,228	336.1	240.1	93.4	66.7	54.1	38.7
11	Residential	1,904	1,333	952	14.4	10.3	4.0	2.9	2.3	1.7
	ICI	1,836	1,285	918	13.9	9.9	3.9	2.8	2.2	1.6
6&7	Residential	1,877	1,314	939	14.2	10.1	3.9	2.8	2.3	1.6
	ICI	1,810	1,267	905	13.7	9.8	3.8	2.7	2.2	1.6
8, 9, 10	Residential	11,050	7,735	5,525	83.5	59.7	23.2	16.6	13.5	9.6
	ICI	10,658	7,461	5,329	80.6	57.6	22.4	16.0	13.0	9.3
TOTAL		**135,451**	**94,816**	**67,726**	**1,024**	**731**	**284**	**203**	**165**	**118**

1 - ICI, (Industrial, Commercial and Institutional sector) includes businesses, restaurants, hospitals, schools, manufacturing facilities and retail operations.

Table 7. Fertilization potential for Total-N in municipal organic waste Total-N (based on year 2015)

Region	Waste Source	Assuming 30% composting loss			Assuming 50% composting loss		
		Equivalent hectares fertilized					
		EU27	EU15	CEC countries	EU27	EU15	CEC countries
15	Residential	93	84	127	67	60	91
	ICI [1]	35	31	47	25	22	34
16	Residential	145	131	198	104	94	141
	ICI	146	132	199	104	94	142
12 &14	Residential	563	509	767	402	364	548
	ICI	67	61	91	48	43	65
13	Residential	51	47	70	37	33	50
	ICI	50	45	68	35	32	48
17-20	Residential	2121	1919	2888	1515	1371	2063
	ICI	2350	2127	3201	1679	1519	2286
11	Residential	101	91	137	72	65	98
	ICI	97	88	132	69	63	94
6&7	Residential	99	90	135	71	64	97
	ICI	96	87	130	68	62	93
8, 9, 10	Residential	584	529	796	417	378	568
	ICI	563	510	767	402	364	548
Total		**7161**	**6481**	**9752**	**5115**	**4629**	**6966**

1 - ICI, (Industrial, Commercial and Institutional sector) includes businesses, restaurants, hospitals, schools, manufacturing facilities and retail operations.

Table 8. Fertilization potential for Organic-N (assuming total loss of ammonia) in municipal organic waste (based on year 2015)

Region	Waste Source	Assuming 30% composting loss			Assuming 50% composting loss		
		Equivalent hectares fertilized					
		EU27	EU15	CEC countries	EU27	EU15	CEC countries
15	Residential	67	61	92	48	43	65
	ICI [1]	25	23	34	18	16	24
16	Residential	105	95	143	75	68	102
	ICI	105	95	144	75	68	103
12 &14	Residential	406	368	554	290	263	395
	ICI	48	44	66	35	31	47
13	Residential	37	34	51	27	24	36
	ICI	36	32	49	26	23	35
17-20	Residential	1532	1386	2086	1094	990	1490
	ICI	1697	1536	2312	1212	1097	1651
11	Residential	73	66	99	52	47	71
	ICI	70	63	95	50	45	68
6&7	Residential	72	65	98	51	46	70
	ICI	69	63	94	49	45	67
8, 9, 10	Residential	422	382	575	301	273	410
	ICI	407	368	554	291	263	396
TOTAL		**5172**	**4681**	**7043**	**3694**	**3343**	**5031**

1 - ICI, (Industrial, Commercial and Institutional sector) includes businesses, restaurants, hospitals, schools, manufacturing facilities and retail operations.

Table 9. Fertilization potential for Total-P in municipal organic waste (based on year 2015)

Region	Waste Source	Assuming 30% composting loss			Assuming 50% composting loss		
		Equivalent hectares fertilized					
		EU27	EU15	CEC countries	EU27	EU15	CEC countries
15	Residential	113	102	165	81	73	118
	ICI [1]	42	38	62	30	27	44
16	Residential	176	159	257	126	114	184
	ICI	177	160	259	126	114	185
12 &14	Residential	682	617	997	487	441	712
	ICI	81	74	119	58	53	85
13	Residential	62	56	91	45	40	65
	ICI	60	54	88	43	39	63
17-20	Residential	2571	2326	3758	1837	1662	2684
	ICI	2850	2578	4165	2036	1842	2975
11	Residential	122	110	178	87	79	127
	ICI	118	106	172	84	76	123
6&7	Residential	120	109	176	86	78	126
	ICI	116	105	170	83	75	121
8, 9, 10	Residential	708	641	1035	506	458	740
	ICI	683	618	999	488	442	713
TOTAL		**8683**	**7856**	**12691**	**6202**	**5612**	**9065**

1 - ICI, (Industrial, Commercial and Institutional sector) includes businesses, restaurants, hospitals, schools, manufacturing facilities and retail operations.

4.2.1.4 Scenario 2; based on data for 2045

Table 10. Estimates of nutrient value in municipal organic waste (based on year 2045)

Region	Waste Source	Fresh waste (t)	Compost (t)		Total N (t)		NH3-N (t)		Total P (t)	
			Estimated loss during handling/composting							
			30%	50%	30%	50%	30%	50%	30%	50%
15	Residential	2801	1961	1401	21.2	15.1	5.9	4.2	3.4	2.4
	ICI [1]	2692	1884	1346	20.4	14.5	5.7	4.0	3.3	2.3
16	Residential	3592	2514	1796	27.2	19.4	7.5	5.4	4.4	3.1
	ICI	3615	2531	1808	27.3	19.5	7.6	5.4	4.4	3.1
12 &14	Residential	13937	9756	6969	105.4	75.3	29.3	20.9	17.0	12.1
	ICI	13443	9410	6722	101.6	72.6	28.2	20.2	16.4	11.7
13	Residential	1274	892	637	9.6	6.9	2.7	1.9	1.6	1.1
	ICI	1228	860	614	9.3	6.6	2.6	1.8	1.5	1.1
17-20	Residential	52512	36758	26256	397.0	283.6	110.3	78.8	64.0	45.7
	ICI	58199	40739	29100	440.0	314.3	122.2	87.3	70.9	50.6
11	Residential	2492	1744	1246	18.8	13.5	5.2	3.7	3.0	2.2
	ICI	2404	1683	1202	18.2	13.0	5.0	3.6	2.9	2.1
6&7	Residential	2457	1720	1229	18.6	13.3	5.2	3.7	3.0	2.1
	ICI	370	259	185	2.8	2.0	0.8	0.6	0.5	0.3
8, 9, 10	Residential	14467	10127	7234	109.4	78.1	30.4	21.7	17.6	12.6
	ICI	13953	9767	6977	105.5	75.3	29.3	20.9	17.0	12.1
TOTAL		**189436**	**132605**	**94718**	**1432**	**1023**	**398**	**284**	**231**	**165**

1 - ICI, (Industrial, Commercial and Institutional sector) includes businesses, restaurants, hospitals, schools, manufacturing facilities and retail operations.

Table 11 Fertilization potential for Total-N in municipal organic waste Total-N (based on year 2045)

Region	Waste Source	Assuming 30% composting loss			Assuming 50% composting loss		
		Equivalent hectares fertilized					
		EU27	EU15	CEC countries	EU27	EU15	CEC countries
15	Residential	148	134	202	106	96	144
	ICI [1]	142	129	194	102	92	138
16	Residential	190	172	259	136	123	185
	ICI	191	173	260	137	124	186
12 &14	Residential	737	667	1003	526	476	717
	ICI	711	643	968	508	459	691
13	Residential	67	61	92	48	44	66
	ICI	65	59	88	46	42	63
17-20	Residential	2776	2513	3781	1983	1795	2701
	ICI	3077	2785	4190	2198	1989	2993
11	Residential	132	119	179	94	85	128
	ICI	127	115	173	91	82	124
6&7	Residential	130	118	177	93	84	126
	ICI	20	18	27	14	13	19
8, 9, 10	Residential	765	692	1042	546	494	744
	ICI	738	668	1005	527	477	718
Total		**10015**	**9064**	**13639**	**7154**	**6474**	**9742**

1 - ICI, (Industrial, Commercial and Institutional sector) includes businesses, restaurants, hospitals, schools, manufacturing facilities and retail operations.

Table 12. Fertilization potential for Organic-N (assuming total loss of ammonia) in municipal organic waste (based on year 2045)

Region	Waste Source	Assuming 30% composting loss			Assuming 50% composting loss		
		Equivalent hectares fertilized					
		EU27	EU15	CEC countries	EU27	EU15	CEC countries
15	Residential	107	97	146	76	69	104
	ICI [1]	103	93	140	73	66	100
16	Residential	137	124	187	98	89	133
	ICI	138	125	188	99	89	134
12 &14	Residential	532	482	725	380	344	518
	ICI	513	465	699	367	332	499
13	Residential	49	44	66	35	31	47
	ICI	47	42	64	33	30	46
17-20	Residential	2005	1815	2731	1432	1296	1950
	ICI	2222	2011	3026	1587	1437	2162
11	Residential	95	86	130	68	62	93
	ICI	92	83	125	66	59	89
6&7	Residential	94	85	128	67	61	91
	ICI	14	13	19	10	9	14
8, 9, 10	Residential	552	500	752	395	357	537
	ICI	533	482	726	381	344	518
TOTAL		**5172**	**7233**	**6546**	**9851**	**5166**	**4676**

1 - ICI, (Industrial, Commercial and Institutional sector) includes businesses, restaurants, hospitals, schools, manufacturing facilities and retail operations.

Table 13. Fertilization potential for Total-P in municipal organic waste (based on year 2015)

Region	Waste Source	Assuming 30% composting loss			Assuming 50% composting loss		
		Equivalent hectares fertilized					
		EU27	EU15	CEC countries	EU27	EU15	CEC countries
15	Residential	179.6	162.5	262.4	128.3	116.0	187.5
	ICI [1]	172.6	156.1	252.2	123.3	111.5	180.2
16	Residential	230.3	208.3	336.5	164.5	148.8	240.4
	ICI	231.7	209.7	338.7	165.5	149.8	241.9
12 &14	Residential	893.4	808.3	1305.8	638.2	577.4	932.7
	ICI	861.8	779.7	1259.5	615.5	556.9	899.6
13	Residential	81.7	73.9	119.4	58.3	52.8	85.3
	ICI	78.7	71.2	115.1	56.2	50.9	82.2
17-20	Residential	3366.3	3045.7	4920.0	2404.5	2175.5	3514.3
	ICI	3730.9	3375.5	5452.8	2664.9	2411.1	3894.9
11	Residential	159.8	144.5	233.5	114.1	103.2	166.8
	ICI	154.1	139.4	225.2	110.1	99.6	160.9
6&7	Residential	157.5	142.5	230.2	112.5	101.8	164.4
	ICI	23.7	21.5	34.7	16.9	15.3	24.8
8, 9, 10	Residential	927.4	839.1	1355.4	662.4	599.3	968.2
	ICI	894.5	809.3	1307.3	638.9	578.1	933.8
TOTAL		**12144**	**10987**	**17749**	**8674**	**7848**	**12678**

1 - ICI, (Industrial, Commercial and Institutional sector) includes businesses, restaurants, hospitals, schools, manufacturing facilities and retail operations.

4.2.2 Municipal wastewaters

Wastewater from households, industrial, commercial, and institutional sources typically contains a broad range of substances. The following organisms are found in domestic sewage: bacteria, archaea, algae, fungi, protozoa, viruses, helminths. Wastewater composition can vary depending on certain variables such as urban vs. rural area, environment, income of area.

4.2.2.1 Assumptions employed for the calculation of nutrient values for municipal wastewater

Given the variability in volumes for different water intensity usages the calculations employed average daily nutrient production per person as previously described in literature (Jeanmaire and Evans, 2001; Wett and Alex, 2003)
The production per each community was estimated as a function of the population; the regions then sum the data for the component communities.

Table 14. Nutrient value estimates for Municipal Wastewaters

Region	Total-N (t)	Organic-N (t)	NH4-N (t)	NO3-N (t)	Usable Total-N assuming recovery rates of (t)		Usable Total-P assuming recovery rates of (t)	
					18% (biosolids)	100%	100%	75%
1	8.2	3.6	4.6	0.2	1.5	3.5	1.0	0.8
2	32.7	14.3	18.4	0.8	5.9	14.1	4.1	3.1
3	29.9	13.1	16.8	0.7	5.4	12.9	3.7	2.8
4	8.4	3.7	4.7	0.2	1.5	3.6	1.0	0.8
5	6.0	2.6	3.4	0.2	1.1	2.6	0.8	0.6
6	33.7	14.8	19.0	0.8	6.1	14.5	4.2	3.2
7	32.6	14.3	18.3	0.8	5.9	14.0	4.1	3.1
8	130.0	56.9	73.1	3.2	23.4	55.9	16.2	12.2
9	77.6	33.9	43.6	1.9	14.0	33.4	9.7	7.3
10	32.9	14.4	18.5	0.8	5.9	14.1	4.1	3.1
11	53.2	23.3	29.9	1.3	9.6	22.9	6.6	5.0
12	85.6	37.4	48.1	2.1	15.4	36.8	10.7	8.0
13	28.2	12.3	15.8	0.7	5.1	12.1	3.5	2.6
14	158.7	69.4	89.2	4.0	28.6	68.2	19.8	14.9
15	98.3	43.0	55.3	2.5	17.7	42.3	12.3	9.2
16	78.7	34.4	44.3	2.0	14.2	33.9	9.8	7.4
17	129.1	56.5	72.6	3.2	23.2	55.5	16.1	12.1
18	28.7	12.6	16.1	0.7	5.2	12.3	3.6	2.7
19	531.1	232.3	298.7	13.3	95.6	228.4	66.4	49.8
20	29.2	12.8	16.4	0.7	5.3	12.6	3.7	2.7
TOTAL	1613	706	907	40	290	694	202	151

Table 15. Fertilization potential for N in Municipal Wastewaters

Region	100% TN use			18% recovery (in solids)			43% recovery (in sludge)		
	EU27	EU15	CEC countries	EU27	EU15	CEC countries	EU27	EU15	CEC countries
									Equivalent ha
1	57.6	52.2	78.5	10.4	9.4	14.1	24.8	22.4	33.7
2	228.5	206.8	311.2	41.1	37.2	56.0	98.3	88.9	133.8
3	209.1	189.2	284.8	37.6	34.1	51.3	89.9	81.4	122.5
4	58.7	53.2	80.0	10.6	9.6	14.4	25.3	22.9	34.4
5	42.1	38.1	57.3	7.6	6.9	10.3	18.1	16.4	24.7
6	235.9	213.5	321.2	42.5	38.4	57.8	101.4	91.8	138.1
7	227.9	206.3	310.4	41.0	37.1	55.9	98.0	88.7	133.5
8	909.0	822.7	1,237.9	163.6	148.1	222.8	390.9	353.8	532.3
9	542.5	491.0	738.8	97.7	88.4	133.0	233.3	211.1	317.7
10	230.1	208.2	313.4	41.4	37.5	56.4	98.9	89.5	134.7
11	372.0	336.7	506.7	67.0	60.6	91.2	160.0	144.8	217.9
12	598.6	541.8	815.2	107.7	97.5	146.7	257.4	233.0	350.5
13	197.0	178.3	268.3	35.5	32.1	48.3	84.7	76.7	115.3
14	1,109.5	1,004.2	1,511.1	199.7	180.8	272.0	477.1	431.8	649.8
15	687.6	622.3	936.4	123.8	112.0	168.6	295.7	267.6	402.7
16	550.6	498.4	749.9	99.1	89.7	135.0	236.8	214.3	322.5
17	902.8	817.1	1,229.5	162.5	147.1	221.3	388.2	351.3	528.7
18	200.7	181.6	273.3	36.1	32.7	49.2	86.3	78.1	117.5
19	3,713.7	3,361.2	5,057.7	668.5	605.0	910.4	1596.9	1445.3	2,174.8
20	204.4	185.0	278.4	36.8	33.3	50.1	87.9	79.6	119.7
Total	**11,278**	**10,208**	**15,360**	**2,030**	**1,837**	**2,765**	**4,850**	**4,389**	**6,605**

Table 16. Fertilization potential for P in Municipal Wastewaters

Region	100% recovery			75% recovery (in sludge)		
	EU27	EU15	CEC countries	EU27	EU15	CEC countries
	Equivalent Ha					
1	54.21	49.05	79.23	40.66	36.79	59.42
2	214.97	194.49	314.18	161.22	145.87	235.64
3	196.72	177.98	287.51	147.54	133.49	215.63
4	55.25	49.99	80.75	41.44	37.49	60.56
5	39.61	35.84	57.89	29.71	26.88	43.42
6	221.90	200.77	324.32	166.43	150.58	243.24
7	214.45	194.02	313.42	160.84	145.52	235.07
8	855.16	773.71	1249.84	641.37	580.28	937.38
9	510.39	461.78	745.95	382.79	346.33	559.46
10	216.46	195.85	316.37	162.35	146.89	237.28
11	350.00	316.66	511.53	262.50	237.50	383.65
12	563.14	509.51	823.05	422.35	382.13	617.29
13	185.30	167.66	270.83	138.98	125.74	203.12
14	1043.82	944.41	1525.59	782.87	708.31	1144.19
15	646.88	585.27	945.43	485.16	438.95	709.08
16	518.03	468.69	757.12	388.52	351.52	567.84
17	849.32	768.43	1241.31	636.99	576.32	930.98
18	188.78	170.80	275.91	141.59	128.10	206.93
19	3493.84	3161.09	5106.38	2620.38	2370.82	3829.78
20	192.32	174.00	281.08	144.24	130.50	210.81
TOTAL	10611	9600	15508	7958	7200	11631

4.2.2.2 Agricultural Waste

One of the main sources of agricultural organic waste in the province is livestock manure. Livestock manure provides nutrients essential to plant growth, such as nitrogen and phosphorus and is a source of organic matter (Statistics Canada, 2012). As previously stated, dairy, poultry, and mink farms are thought to produce the largest sources of agricultural organic wastes for the province of Newfoundland and Labrador. One review outlines the average composition of animal slurry for various manure producers, including cattle, pig, and poultry (Bernal et al., 2009). They report the following characteristics: excess of moisture, low porosity, high N concentration for the organic-C, which gives a low C/N ratio, and in some cases, high pH values.

Table 17. Estimated livestock waste amounts

Region	Poultry		Dairy	Mink	
	Litter	Mortalities	Manure	Manure	Carcasses
	[kg/day]		[ft3/day]	[ft3/day]	[kg/yr]
8 West Coast	0	0	6330	230	216000
12 Central NFLD (Grand Falls- Windsor and Gander)	3966	264	0	129	114300
15 Bonavista Bay	1512	101	1640	33	30600
20 Avalon	16098	1073	4972	126	117900

4.2.2.2.1 Poultry Waste

4.2.2.2.1.1 Assumptions for calculation of nutrients in Poultry Waste

For poultry manure values were averaged over season and poultry age (Brown, 2013):

Table 18. Assumptions for nutrient concentrations in Poultry Manure

	Dry Matter Range			Total Nutrient Content (as-is basis)		
	Solid/ Liquid	Average DM	Total N	NH4-N	P	K
	%	%	%	%	%	%
Layers	S	34.00	1.93	0.78	0.89	0.80
Pullets	S	48.00	3.14	0.72	1.36	1.35
Broilers	S	68.00	3.09	0.44	1.33	1.52
		Average	2.72	0.65	1.19	1.22

For poultry mortalities the assumptions were (Alberta Government, 2015; Ritz and Worley, 2015):

Table 19. Assumptions for nutrient concentrations in Poultry Mortalities

Assumptions: 2.4% N in fresh mortalities Assume loss of N to be 30 % during composting Assume N:P ratio of 7:1

4.2.2.2.1.2 Estimated nutrients in Poultry Waste

Table 20. Estimated nutrients in Poultry Waste

Region	Manure					Mortalities		
	Nitrogen				Phosphorus	Nitrogen		Phosphorus
	TN	Org N	NH4-N	NO3-N		TN	TN after composting	
	t / yr							
8	0	0	0.00	0	0	0.0	0	0.0
12	39	17	9.4	0	17	2.3	1.6	2.3
15	15	7	3.6	0	7	0.9	0.6	0.9
20	160	70	38.0	0	70	9.4	6.6	9.4
TOTAL	**214**	**163**	**51**	**0**	**94**	**13**	**9**	**13**

Table 21. Fertilization potential for N in Poultry Manure

Region		100% TN use			TN after composting (Assuming total loss of ammonia)		
		EU27	EU15	CEC countries	EU27	EU15	CEC countries
		Equivalent Ha					
8	West Coast	0	0	0	0	0	0
12	Central NFLD (Grand Falls- Windsor and Gander)	275	249	375	210	190	286
15	Bonavista Bay	105	95	143	80	72	109
20	Avalon	1,118	1,012	1,522	852	771	1,160
	TOTAL	**1,498**	**1,356**	**2,040**	**1,142**	**1,033**	**1,555**

Table 22. Fertilization potential for N in Poultry Mortalities

Region		100% TN use			TN after composting (Assuming total loss of ammonia)		
		EU27	EU15	CEC countries	EU27	EU15	CEC countries
		Equivalent Ha					
8	West Coast	0	0	0	0	0	0
12	Central NFLD (Grand Falls-Windsor and Gander)	16	15	22	11	10	15
15	Bonavista Bay	6	6	8	4	4	6
20	Avalon	66	59	90	46	42	63
	TOTAL	**88**	**80**	**120**	**62**	**56**	**84**

Table 23. Fertilization potential for P in Poultry Manure & Mortalities

Region		Manure 100% TP use			Mortalities 100% TP use		
		EU27	EU15	CEC countries	EU27	EU15	CEC countries
		Equivalent Ha					
8	West Coast	0	0	0	0.0	0.0	0.0
12	Central NFLD (Grand Falls- Windsor and Gander)	909	823	1,329	17.4	15.7	25.4
15	Bonavista Bay	347	314	507	6.7	6.0	9.7
20	Avalon	3,690	3,339	5,394	70.7	63.9	103.3
	TOTAL	**4,946**	**4,475**	**7,229**	**95**	**86**	**138**

4.2.2.2.2 Dairy Manure

4.2.2.2.2.1 Assumptions employed for the calculation of nutrient values in Dairy Manure:

Dairy manure composition was estimated according to OMAFRA (Brown, 2013):

25% DM
0.35% N
0.15 NH4-N
0.08% P

Table 24. Estimated nutrients in Dairy Manure

Region		Nitrogen				Phosphorus
		TN	Org N	NH4-N	NO3-N	
		t / yr				
8	West Coast	229.0	130.8	98.1	0	52.3
12	Central NFLD (Grand Falls- Windsor and Gander)	0.0	0.0	0.0	0	0.0
15	Bonavista Bay	59.3	33.9	25.4	0	13.6
20	Avalon	179.9	102.8	77.1	0	41.1
TOTAL		**468**	**268**	**201**	**0**	**107**

Table 25. Fertilization potential for N in Dairy Manure

Region		100% TN use			TN after composting (Assuming total loss of ammonia)		
		EU27	EU15	CEC countries	EU27	EU15	CEC countries
		Equivalent Ha					
8	West Coast	1,601	1,449	2,181	915	828	1,246
12	Central NFLD (Grand Falls- Windsor and Gander)	0	0	0	0	0	0
15	Bonavista Bay	415	375	565	237	215	323
20	Avalon	1,258	1,138	1,713	719	650	979
	TOTAL	**3,274**	**2,963**	**4,459**	**1,871**	**1,693**	**2,548**

Table 26. Fertilization potential for P in Dairy Manure

Region		100% TP use		
		EU27	EU15	CEC countries
		Equivalent Ha		
8	West Coast	2755	2492	4026
12	Central NFLD (Grand Falls- Windsor and Gander)	0	0	0
15	Bonavista Bay	714	646	1043
20	Avalon	2164	1958	3162
	TOTAL	**5632**	**5096**	**8232**

According to a personal communication (Bishop, 2016b), in Newfoundland, dairy farms occupy about 5500 Ha. Given their waste output the dairy farms in the province could possibly cover 30 to 80% of their annual N needs and 90 to 150% of their annual P needs, depending on the management efficiency, directly from dairy waste.

4.2.2.2.3 Mink Waste

4.2.2.2.3.1 Assumptions for mink waste nutrient value calculations:

Mink manure composition was estimated according to OMAFRA (Brown, 2013):

25% DM
0.45% N
0.26 NH4-N
0.1% P

For Mink Mortalities the assumptions were (Alberta Government, 2015; Ritz and Worley, 2015):

Assumptions: 2.4% N in fresh mortalities Assume loss of N to be 30 % during composting Assume N:P ratio of 7:1

Table 27. Estimated nutrients in Mink waste

Region	Manure					Mortalities		
	Nitrogen				Phosphorus	Nitrogen		Phosphorus
	TN	Org-N	NH4-N	NO3-N		TN	Organic N	
	t / yr							
8	10.7	4.5	6.2	0	2.4	5.2	4	0.7
12	6.0	2.5	3.5	0	1.3	2.7	2	0.4
15	1.5	0.6	0.9	0	0.3	0.7	1	0.1
20	5.9	2.5	3.4	0	1.3	2.8	2	0.4
TOTAL	**24**	**10**	**14**	**0**	**5**	**11**	**8**	**2**

Table 28. Fertilization potential for N in Mink Manure

Region		100% TN use			TN after composting (Assuming total loss of ammonia)		
		EU27	EU15	CEC countries	EU27	EU15	CEC countries
		Equivalent Ha					
8	West Coast	75	68	102	32	29	43
12	Central NFLD (Grand Falls-Windsor and Gander)	42	38	57	18	16	24
15	Bonavista Bay	11	10	15	5	4	6
20	Avalon	41	37	56	17	16	24
	TOTAL	**168**	**152**	**229**	**71**	**64**	**97**

Table 29. Fertilization potential for N in Mink Mortalities

Region		100% TN use			TN after composting (Assuming total loss of ammonia)		
		EU27	EU15	CEC countries	EU27	EU15	CEC countries
		Equivalent Ha					
8	West Coast	36	33	49	25	23	35
12	Central NFLD (Grand Falls- Windsor and Gander)	19	17	26	13	12	18
15	Bonavista Bay	5	5	7	4	3	5
20	Avalon	20	18	27	14	13	19
	TOTAL	**80**	**73**	**109**	**56**	**51**	**77**

Table 30. Fertilization potential for P in Mink Manure & Mortalities

Region		Manure 100% TP use			Mortalities 100% TP use		
		EU27	EU15	CEC countries	EU27	EU15	CEC countries
		Equivalent Ha					
8	West Coast	125.1	113.2	182.9	39.0	35.3	57.0
12	Central NFLD (Grand Falls- Windsor and Gander)	70.2	63.5	102.6	20.6	18.7	30.1
15	Bonavista Bay	18.0	16.2	26.2	5.5	5.0	8.1
20	Avalon	68.5	62.0	100.2	21.3	19.2	31.1
	TOTAL	**282**	**255**	**412**	**86**	**78**	**126**

4.2.2.3 Fishery Waste

4.2.2.3.1 Fisheries

Seafood processing results in both liquid (effluent) and solid wastes. Untreated effluents often contain varying amounts of solid matter including offal, skin, and bone (which is generally removed) and the remaining suspended and dissolved solids are discharged in the effluents (AMEC Earth & Environmental Limited, 2003). Wastewater characteristics vary substantially with the type of species processed, processing technology applied, and type of finished product. Additionally, site specific data on solid and liquid wastes is lacking, but general estimations have been made from a variety of sources. Overall, high BOD, oil and grease, and nitrogen content can be expected in effluents from fish processing facilities, with lower BOD and nitrogen concentrations expected from shellfish processing.

Table 31. Parameters of fish processing wastewater in comparison with municipal wastewaters (AMEC Earth & Environmental Limited, 2003; Hardy, 2010).

Industry	**BOD mg/L**	**TSS mg/L**	**NH3 mg/L**
Crab Processing	180-1,280	80-815	13-Jun
Shrimp Processing	530-1,240	240-660	
Ground fish	27-1,775	7-1,550	20
Herring Pump out water	33,500	7,955	
Stickwater discharge	34,000	54,000	
Salmon Processing	397-3,082	40-1,600	42
Potato Processing	61	8	2
Meat Rendering	22	64	8
Raw Municipal Wastewater	220	220	25
Treated Municipal Wastewater	20	20	20

In addition to these characteristics, fish offal is considered to be a good source of protein, fat, minerals and processed nutriceutical compounds such as chitin, glucosamine, collagen, chondroitin, and gelatin (Hardy, 2010).

4.2.2.3.2 Data used in developing assumptions for the estimation of nutrients in fish waste

Given the limited understanding of wastewaters volumes produced by fish plants or by enclosed aquaculture facilities these waste stream were not included in the current analysis. This analysis therefore includes estimations of nutrient value of fish waste only associated with fish plants.

Table 32. Coast of Bay region fish production

Coast of Bay region (used to estimate proportions) (t)					
Year	Industry Production (Farm-Gate)	Stock Mortality	Offal	Total Fish Parts	Estimated Mass Mortality Contingency assuming 6,000 MT Event(s)
2006	7,300	876	1,869	2,745	7,300
2007	5,580	670	949	1,618	5,580
2008	9,697	1,164	2,327	3,491	9,491
2009	13,404	1,608	2,949	4,557	10,557
2010	14,945	1,793	3,288	5,081	11,081
2011	15,338	1,841	3,068	4,908	10,908
2012	19,126	2,295	5,735	7,030	13,030
2013	25,000	3,000	6,190	9,190	15,190
2014	32,500	3900	8047	11947	17947
2015	40,000	48,000	9,904	14,704	20,704
2016	4,500	5,400	11,142	16,542	22,542
2017	50,000	6,000	12,380	18,380	24,380

Total fish production by region (tonnes/yr)

Table 33. Total fish production by region (tonnes/yr)

Region		Catch	Mortality	Offal	Fish parts
6	Burin Peninsula	2700	441	909	1350
7	Central	12500	2040	4210	6250
8	Discovery	2200	359	741	1100
12	Eastern	24000	3917	8083	12000
15	Northern Peninsula	17200	2807	5793	8600
17-20	Western	4700	767	1583	2350

Table 34. Assumptions employed for calculation of fish waste nutrient contents (Olsen and Olsen, 2011)

	DM	Total N	NH4+	P	K
	%	Kg/T	Kg/T	Kg/T	Kg/T
Fish offal, acidified (Category 2)	48	19	1.43	2.7	1.6
Fish offal, composted, matured 2-3 mts	40	16.3	4.94	2.2	1.7
Fish offal, composted, matured >6 mts.	48	14.7	6.63	2.9	1.9

Table 35. Estimated nutrients in Fish Waste

Region		Nitrogen				Phosphorus
		TN	Org N	NH4-N	NO3-N	
		t / yr				
6	Burin Peninsula	42	26	15.62	0	7
7	Northern Peninsula	267	167	99.50	0	44
8	Western	73	46	27.19	0	12
12	Central	194	121	72.31	0	32
15	Discovery	34	21	12.73	0	6
17-20	Eastern	372	233	138.84	0	61
TOTAL		**468**	**981**	**615**	**0**	**161**

Table 36. Fertilization potential for N in Fish Waste

Region		100% TN use			TN after composting (Assuming total loss of ammonia)		
		EU27	EU15	CEC countries	EU27	EU15	CEC countries
		Equivalent Ha					
6	Burin Peninsula	293	265	399	293	265	399
7	Northern Peninsula	1,864	1,687	2,539	1,864	1,687	2,539
8	Western	509	461	694	509	461	694
12	Central	1,355	1,226	1,845	1,355	1,226	1,845
15	Discovery	238	216	325	238	216	325
17-20	Eastern	2,601	2,354	3,543	2,601	2,354	3,543
	TOTAL	**6,861**	**6,210**	**9,344**	**6,861**	**6,210**	**9,344**

Table 37. Fertilization potential for P in Fish Waste

Region		100% TN use		
		EU27	EU15	CEC countries
		Equivalent Ha		
6	Burin Peninsula	362	328	530
7	Northern Peninsula	2,308	2,089	3,374
8	Western	631	571	922
12	Central	1,678	1,518	2,452
15	Discovery	295	267	432
17-20	Eastern	3,221	2,914	4,708
	TOTAL	8,496	7,686	12,417

4.2.2.4 Forestry

As previously discussed forestry organic residues include sawmill residues, pulp and paper residues, wood biomass, etc. Pulp-and-paper mills produce various types of contaminants and a significant amount of wastewater depending on the type of processes used in the plant (Ashrafi et al., 2015).

Mills often rely on more than one treatment process (Bellamy et al., 1995). Primary sludges consist of organic matter mostly in the form of wood fibers or cellulosic paper and have low nitrogen (N) content (0.1 to 0.25%, dry weight basis). Nitrogen and Potassium (P) are essential for biological processes and are added to secondary treatment processes resulting in higher N, approximately 3.0-4.0%, and moderate, P 0.1-0.3%, contents in the secondary sludges. A variety of organic chemicals are reported in paper sludges, such as wood extractives (resin and fatty acids and terpenes); phenolics, including lignin and chlorophenol compounds; organochlorine pesticides, phthalate-esters, PCB (polychlorinated biphenyl) and volatile organic compounds.

Saw mill residues are another source of organic waste, and have varying levels of moisture content, heating value, and contents of ash. This is because they are made up of varying types of wood in different forms, sawdust, shavings, bark or any combination of those (Jayasinghe et al., 2011). Moisture content, heating value and ash content are not uniform.

Table 38. Moisture and ash contents of residue samples from inactive sawmill sites (Jayasinghe et al., 2011)

Sawmill	Age (y)	Moisture (wt. %)				Ash (wt.%)			
		Sawdust	Shavings	Bark	Mixed	Sawdust	Shavings	Bark	Mixed
Jamestown Lumber	2		28.23		53.33		0.15		0.37
	3 - 8	63.95-64.44		34.32-47.92		0.30 - 0.82		2.7-417.7	
	>8	54.15		39.88		0.41			5.72
	14- 15	59.01				0.56			
Cashin's Pond	2	62.57	64.14	21.70-41.57		0.29	4.46	2.26-4.5	
Rideout & Milley	4	66.36			17.90-31.75	0.31			2.4-12.72
	>4	68.34			68.72	4.65			3.86
Harold Shep.	2-30	65.94	66.08			0.62	0.27		
Economix	5		69.41				0.28		
	5-25			68.55	72.85			2.87	0.82
Goose Bay Lumber	5	67.81	69.13			17.93	1.38		

The study also determined the following moisture, ash and heating values for black bark and sludge from inactive mills: moisture content (wt. %) 53.27 71.58, ash content (wt. %) 3.11 14.72, and heating value (MJ/kg) 19.58 18.25.

Table 39. Estimated accumulated sawmill waste amounts

District	Latitude	Longitude	Name	Yrs in Operation (2009)	Residue from 2000 to 2009 or yr of closure (green tonne)				
					Sawdust	Bark Residue	Shavings Residue	Slab Residue	Total Residue
1	47.63984800	-53.29372100	Paul Garland Forest Products N-5	30	2,439	-	298	4,361	7,098
2	48.35252778	-53.88770556	Sexton Lumber Company (N-1)	30	15,078	40,869	11,089	-	67,037
5	48.98519722	-54.86522222	T&G Lumber Limited - Current (N-7)	5	2,438	-	57	-	2,495
8	49.47157500	-54.74151944	Cottles Island Lumber Ltd. (N-3)	20	-	-		-	-
8	49.31693056	-55.37870278	Harold Shepard Ltd. (N-8)	1.5	-	-	2,971	-	2,971
16	49.53222222	-56.84801667	Burton's Cove Logging & Lumber (N-2)	20	0	6,800	0	0	6,800
18	50.91231111	-56.10889444	Holson Forest Products (N-4)	5	896	12,430	280	0	13,606
18	51.16523889	-56.04848333	Coates Lumber (N-6)	40	8,586	-	5,624	9,217	23,427
21	52.55523056	-56.30686944	S&N Wood Products (L-1)	12	1,993	-	620	1,862	4,475
21	52.53718889	-56.29186667	Strugnell's Woodworking Ltd. (L-2)	35	1,512	-	1,395	0	2,907
2	48.42946389	-53.78756389	Jamestown Lumber Company	closed 2008	37,867	16,863	3,521	-	58,251
5	48.70308200	-54.12784000	Cashin’s Pond Chipping.	closed 2008	4,295	1,609	0	-	5,904
8	49.28610833	-54.95244444	Rideout & Milley	closed 2006	19,054	22,184	7,359	-	48,597
6	48.98215000	-54.90892222	Eco2Nomix (A.L.Stuckless)	closed 2005	158,722	268,687	212,493	-	639,902
18	50.90138056	-56.11990278	Canada Bay Lumber	closed 2002	-	-	-	-	-
19	53.37889000	-60.43328000	Goose Bay Lumber	closed 2005	4,050	0	819	5,875	10,744
8	49.01468056	-54.88030556	T & G Lumber Ltd.	-	-	-	-	-	-
15	49.39557900	-57.61275900	Wiltondale Lumber Co. Ltd.	-	-	-	-	-	-
15	49.27804200	-57.42204400	Welco Ventrues	Closed 2002/3	-	-	-	-	-

Table 40. Annual sawmills waste estimates

District	Name	Annual Residue estimates				
		Sawdust	Bark	Shaving	Slab	Total
1	Paul Garland Forest Products N-5	271	-	33	485	789
2	Sexton Lumber Company (N-1)	1,675	4,541	1,232	-	7,449
5	T&G Lumber Limited - Current (N-7)	271	-	6	-	277
8	Cottles Island Lumber Ltd. (N-3)	-	-		-	-
8	Harold Shepard Ltd. (N-8)	-	-	330	-	330
16	Burton's Cove Logging & Lumber (N-2)	0	756	0	0	756
18	Holson Forest Products (N-4)	100	1,381	31	0	1,512
18	Coates Lumber (N-6)	954	-	625	1,024	2,603
21	S&N Wood Products (L-1)	221	-	69	207	497
21	Strugnell's Woodworking Ltd. (L-2)	168	-	155	0	323

4.3 Estimated nutrient value in organic waste - Summary

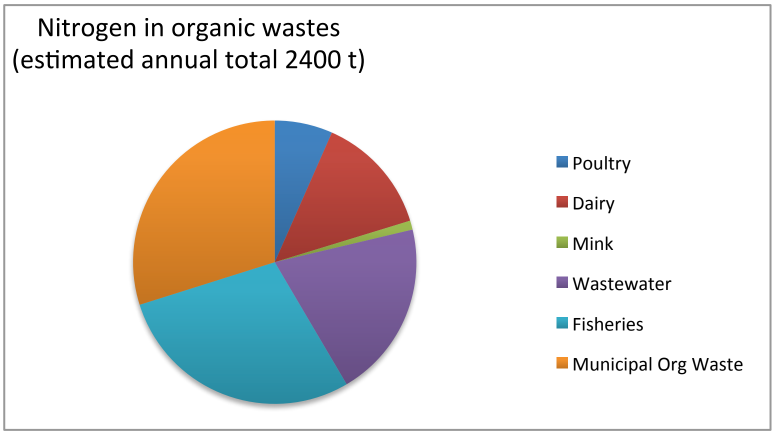

Figure 3. Proportional distribution of Nitrogen in all organic wastes evaluated for Newfoundland

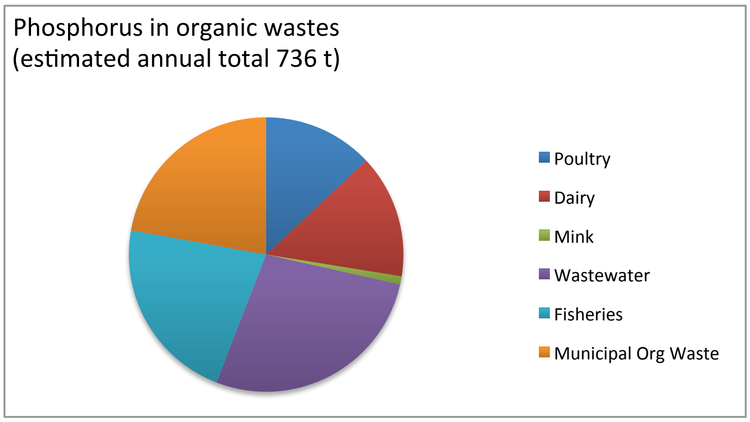

Figure 4. Proportional distribution of Phosphorus in all organic wastes evaluated for Newfoundland

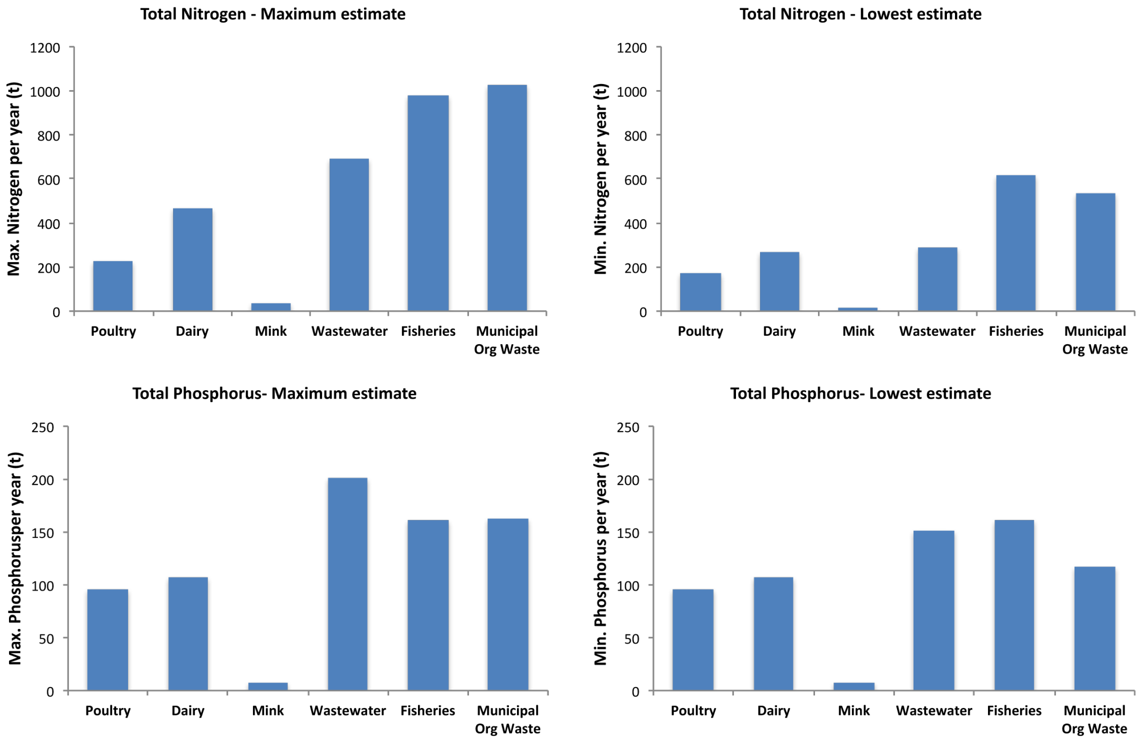

Figure 5. Total estimated recoverable Nitrogen and Phosphorus in organic wastes in Newfoundland

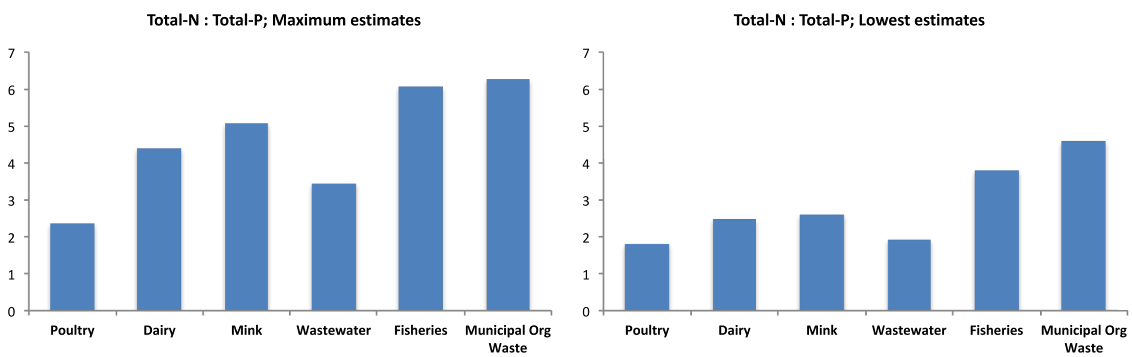

Figure 6. Nitrogen: Phosphorus ratio for the maximum an lowest nutrient recovery scenarios

4.3.1.1 Fertiliser potential of organic waste nutrients

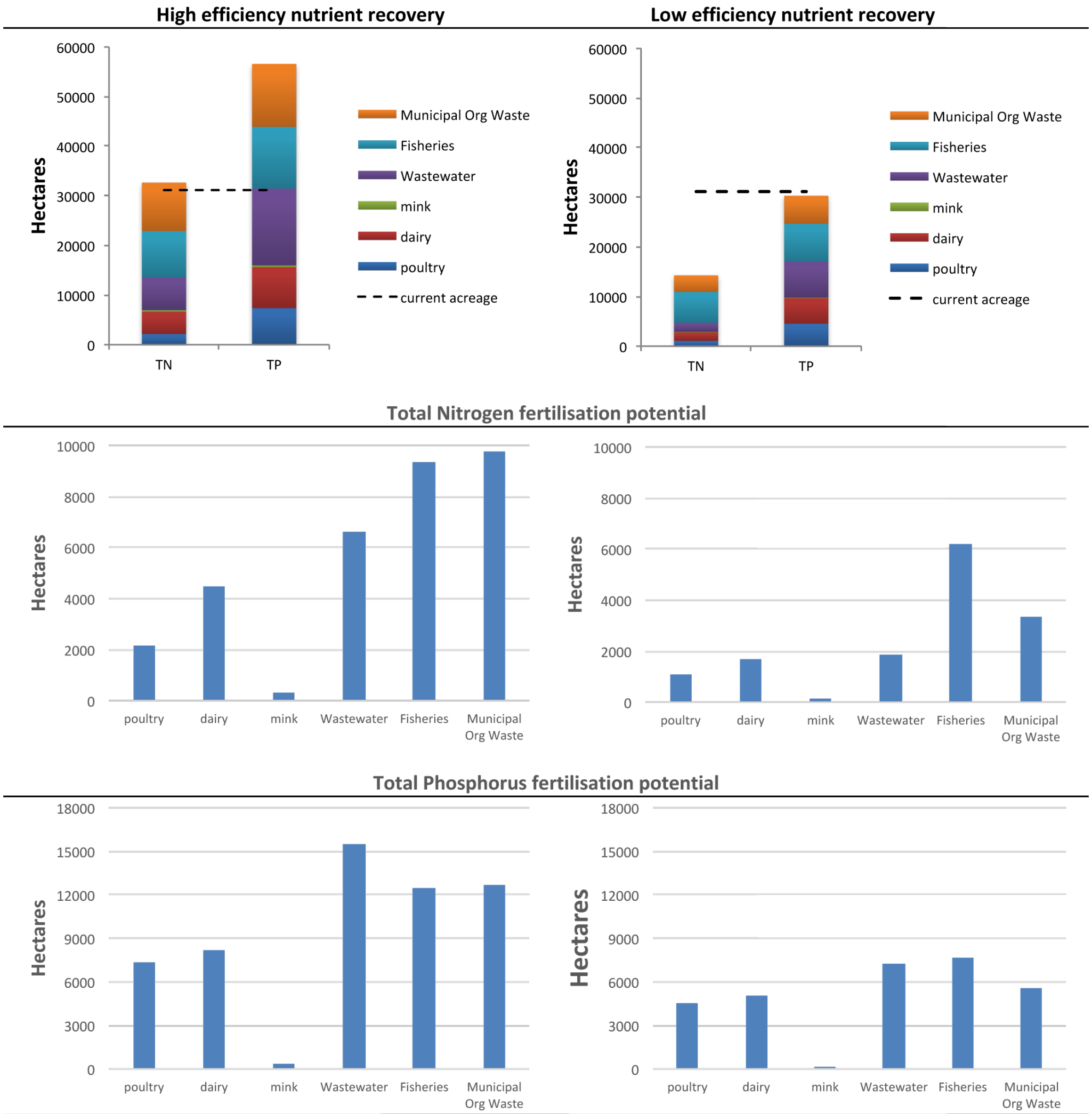

Figure 7. Fertilization potential for the Nitrogen or Phosphorus in organic wastes in Newfoundland; right column summarizes a high efficiency nutrient recovery scenario while the left columns summarizes a low efficiency nutrient recovery scenario. The scenarios integrate nurtrient recovery variability with application rate variability as described at the appropriate sections.

4.3.1.2 Geographical distribution of waste nutrients

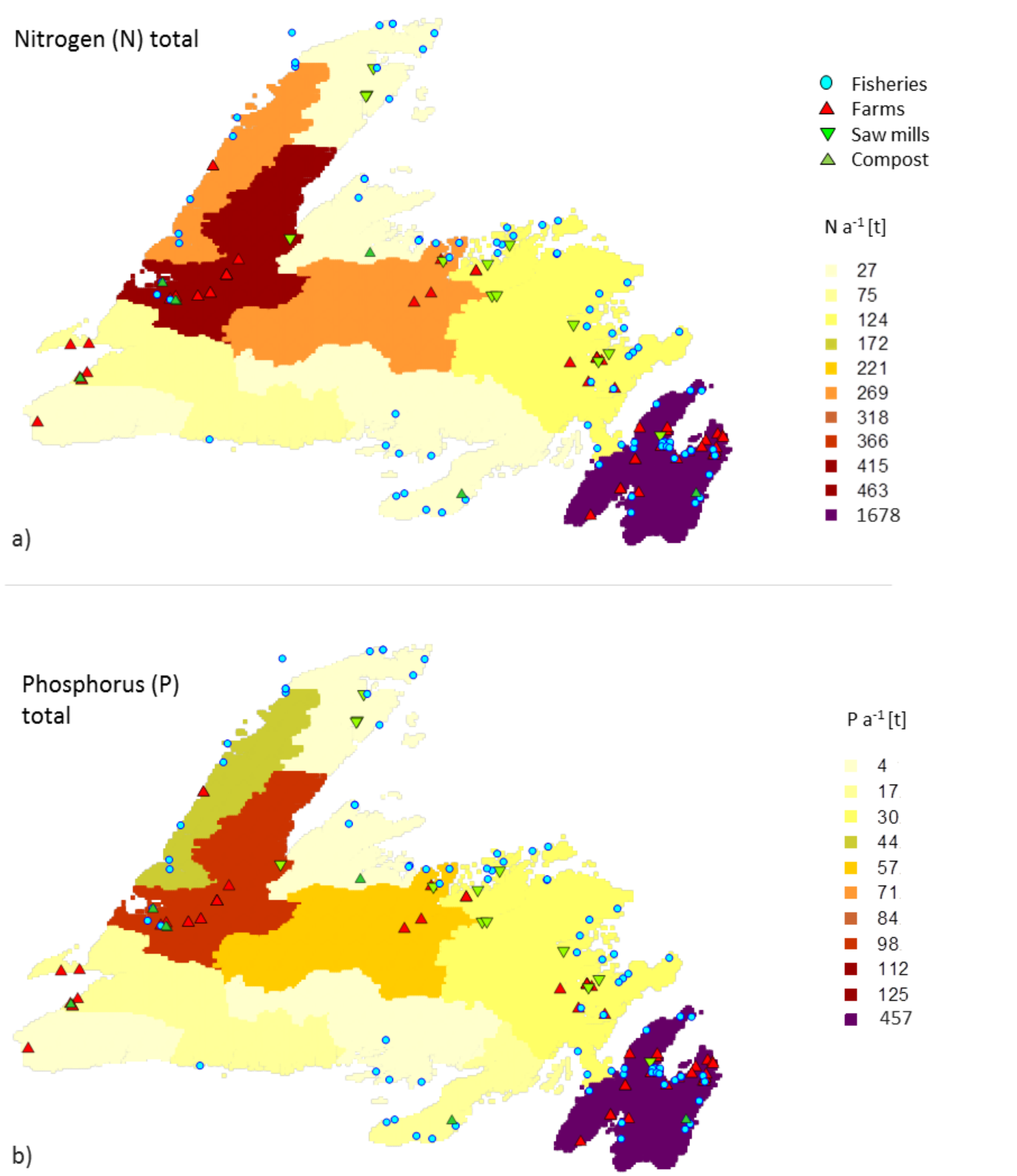

Figure 8. Annual nutrient availability in Newfoundland separated by economic zones: a) total nitrogen amount, b) total phosphorus amount. Location of main point sources indicated by different symbols.

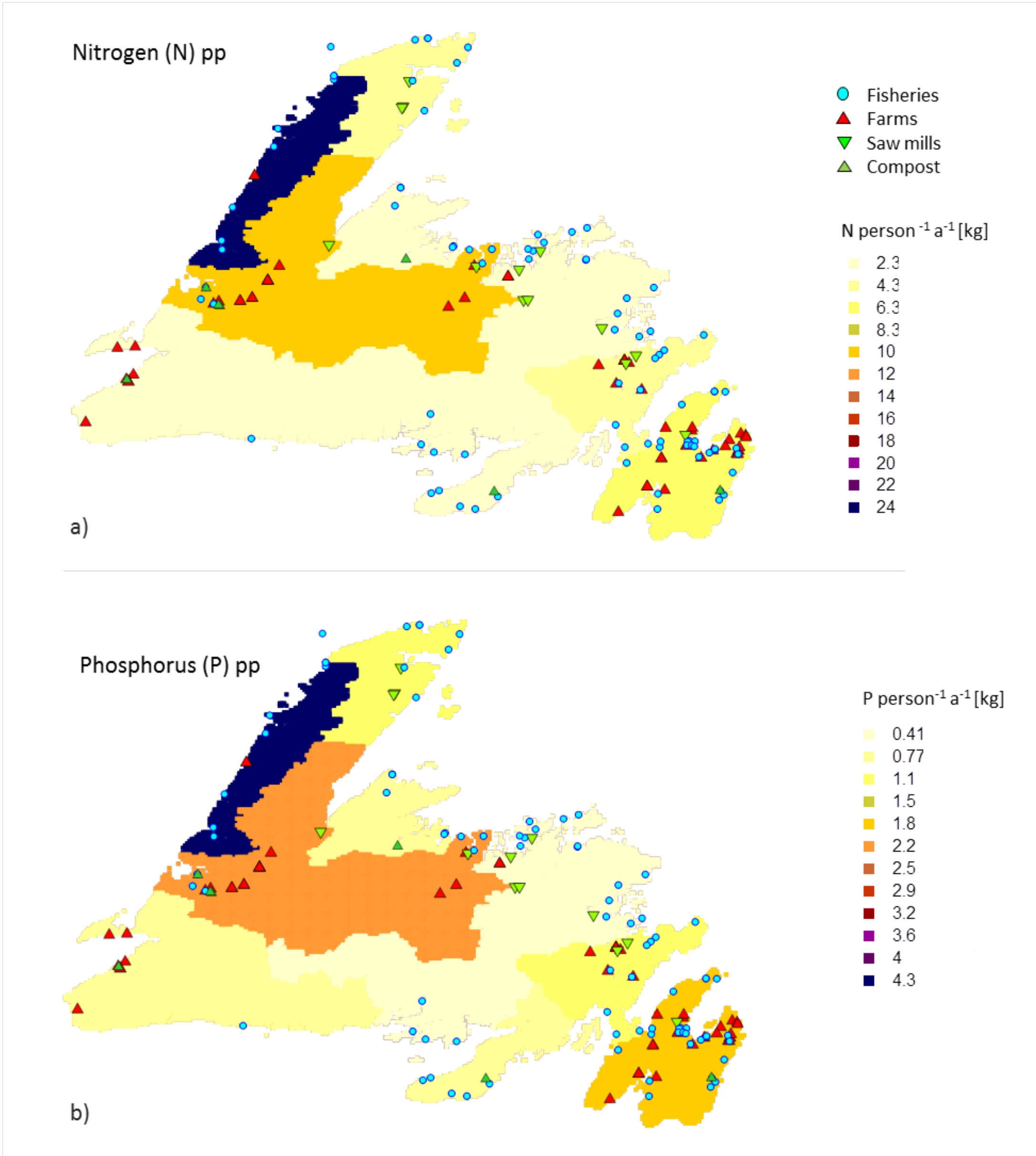

Figure 9. Per capita annual nutrient availability in Newfoundland per separated by economic zones: a) total nitrogen amount, b) total phosphorus amount, location of point sources indicated by different symbols.

4.4 Biochar potential for the organic waste streams

A total amount was calculated assuming utilization of the entire organic waste amount for biochar purposes.

A ratio of biochar to nutrient equivalency was also graphically presented to allow an estimate of the value of re-directing nutrient laden waste to biochar production.

Among the wastes evaluated fishery waste and municipal organic waste have the largest potential for biochar production. Moreover, for both these waste streams the exchange between nutrient loss per unit gain biochar was the lowest.

Depending on the rate of biochar addition, usually recommended anywhere between 5 and 50 t/Ha, the total potential for biochar utilization on cropped fields can reach 4 to 20% of the current agricultural land base. Thus, the biochar pathway reutilization of organic wastes is a valid proposal but only as an element of a long-term comprehensive soil fertility management.

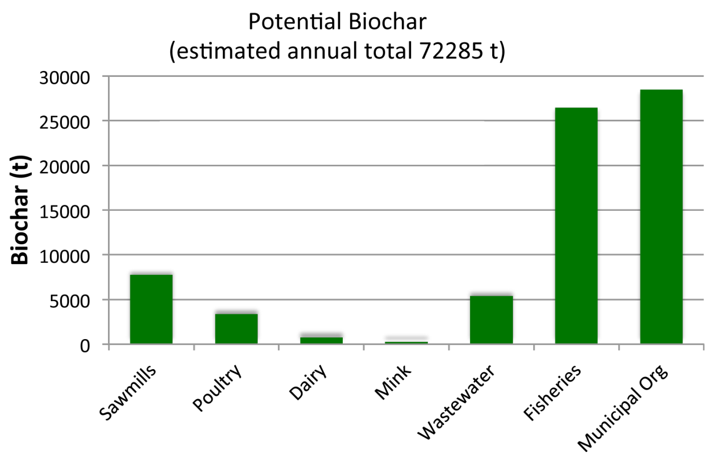

Figure 10. Annual potential of biochar production in Newfoundland separated by waste streams; the calculation assumes utilization of 100% of organic waste.

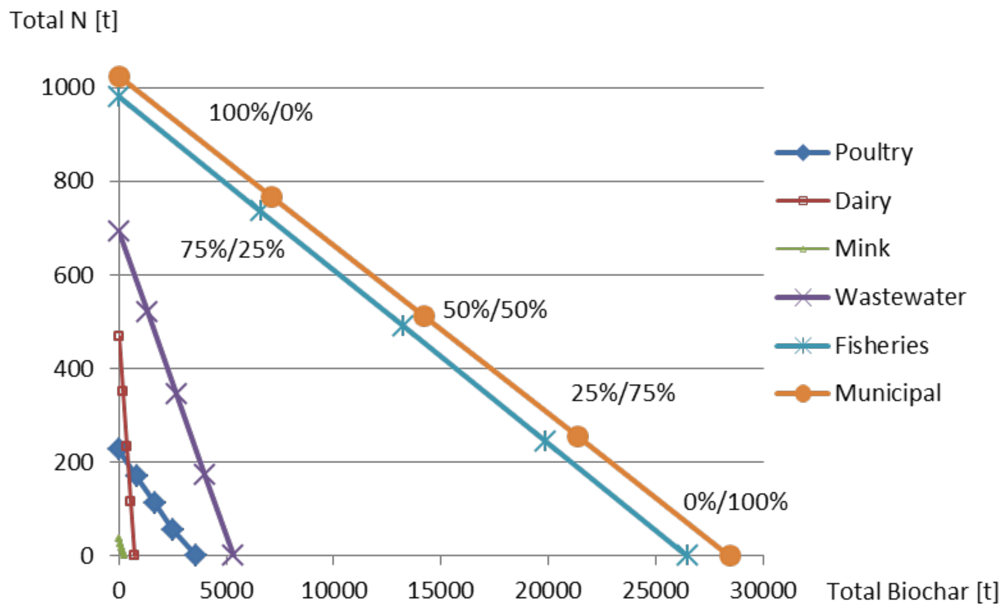

Figure 11. Annual potential of biochar (x axis) vs. nitrogen (N) (y axis) availability in Newfoundland separated by waste streams. Every marker indicated a scenario of mixed waste use in percent, e.g. 100%/0% means 100% waste use towards N while no biochar will be generated. Note that for the nutrient to biochar exchange ratios the maximum nutrient recovery estimates were employed. The steeper the slope the greatest nutrients trade-off, i.e. the loss of nutrient value per unit of biochar gained.

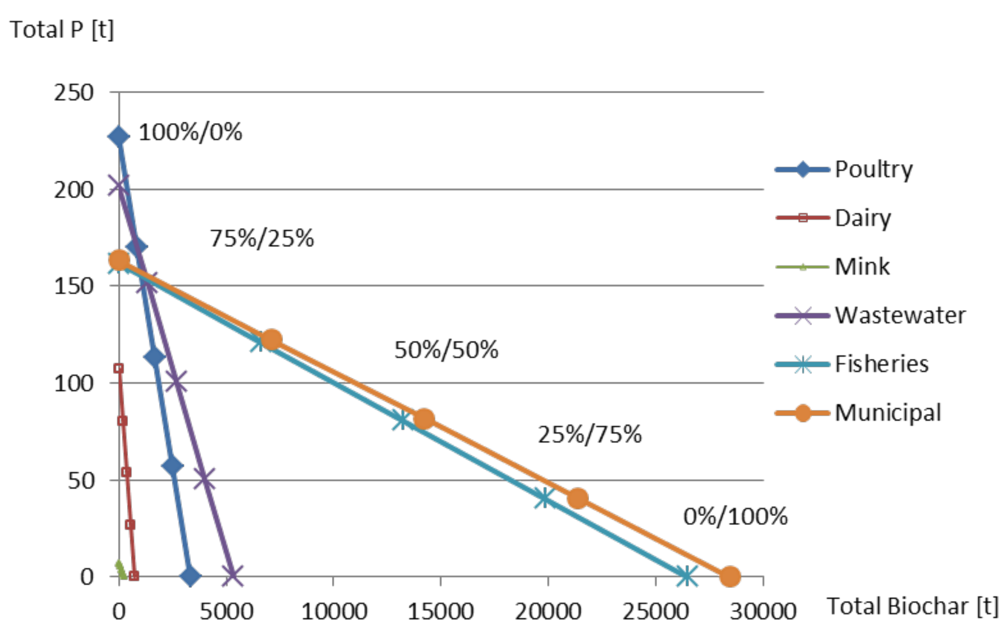

Figure 12. Annual potential of biochar (x axis) vs. phosphorus (P) (y axis) availability in Newfoundland separated by waste streams. Every marker indicates a scenario of mixed waste use in percent, e.g. 100%/0% means 100% waste use towards P while no biochar will be generated. Note that for the nutrient to biochar exchange ratios the maximum nutrient recovery estimates were employed. The steeper the slope the greatest nutrients trade-off, i.e. the loss of nutrient value per unit of biochar gained.

5 Recommendations

This assessment has shown the value of each organic waste stream for nutrient recovery and/or biochar production. Both can be critical elements in the quest for a sustainable agriculture and environmental practices in the province. It was identified that municipal wastes cam provide a significant value to agriculture and thus it ought to be a critical target for future research and policy efforts; while municipal organics and fishery wastes are a good feedstock for both nitrogen or biochar production, the municipal wastewaters can provide a significant amount of phosphorus. While a more efficient utilisation of the current wastes streams can provide nearly all nutrients for the extant cropped land base any expansion of agriculture ought to consider integrated livestock and plant agriculture activities.

Therefore, detailed research, and policy efforts, aimed at integrating waste stream management and agricultural re-utilisation is warranted, with a focus on 1) municipal wastes, 2) integrated development of livestock/plant agriculture activities and 3) integrated fishery waste management.

A significant gap in the information was found to exist around liquid waste streams produced by aquaculture operations; it is recommended that this be a focus of future research and policy efforts.

6 Conclusions

- Municipal organic wastes and fishery waste offer the greatest potential for both nitrogen and phosphorus recovery
- Municipal wastewaters offer the greatest potential for phosphorus recovery
- Therefore the more populated regions of the province, where also both municipal wasters and fishery wastes can be exploited offer the best scenario for re-utilization of organic wastes nutrients
- The current production of organic wastes may offer sufficient nitrogen for 100% of the needs of the current agricultural land base and phosphorus for nearly double the current cropped land base. This can support the current food output in the province. Thus, to minimize reliance on imported nutrients any expansion in agricultural lands would require an integration of plant agriculture with livestock agriculture.
- Producing biochar for organic wastes requires a trade-off, balancing the value of nutrient versus the value of recovered biochar. Employing fishery waste and municipal organics for production of biochar have the least negative impact on the balance of organic nutrients.
- While both nutrient recovery and biochar addition to soils have a positive impact on agricultural productivity and its long-term sustainability the decision on re-using wastes as source of nutrients or as a feedstock for biochar production or any combination thereof needs to account for other logistics and infrastructure parameters that might affect the economics of such decision.

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