VEGETATIVE AGRICULTURAL WASTE IN METRO VANCOUVER: UNDERSTANDING WASTE MANAGEMENT METHODS, BARRIERS, AND OPPORTUNITIES

Prepared by: Amy Sigsworth, UBC Sustainability Scholar, 2020
Prepared for: Grace Cockle, Senior Permit and Enforcement Officer, Parks and Environment, Metro Vancouver

August 2020

Disclaimer

This report was produced as part of the UBC Sustainability Scholars Program, a partnership between the University of British Columbia and various local governments and organizations in support of providing graduate students with opportunities to do applied research on projects that advance sustainability across the region.

This project was conducted under the mentorship of Metro Vancouver staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of Metro Vancouver or the University of British Columbia.

Acknowledgements

First and foremost, the author would like to extend sincere gratitude and thanks to Grace Cockle, Metro Vancouver, for her mentorship and encouragement throughout this project. The author would also like to recognize and thank the following groups for their assistance, guidance and support: Society Promoting Environmental Conservation's Food Committee; UBC Farm Practicum 2019 cohort; and friends in the Master of Land and Water Systems program.

Cover photo courtesy of Ricardo Gomez Angel

Table of Contents

List of Figures

List of Tables

Executive Summary

Managing vegetative waste created as a by-product of agricultural production is a feature of day-to-day farming operations. Vegetative waste can include debris from activities such as land clearing, crop and field maintenance, harvesting, and product processing. No matter what the farming system, vegetative debris as a by-product is always a consequence of production. Accordingly, farmers must efficiently and cost-effectively utilize diverse management strategies to dispose of varying types of vegetative waste.

Understanding what type of vegetative agricultural waste is generated and related management strategies in Metro Vancouver is necessary to support producers, strengthen the agricultural sector, and enhance environmental health. Additionally, growing public and academic concerns with regards to the potential contribution of greenhouse gases (GHG) and air contaminants from agricultural activities have become a point of discussion over the years. Alongside this is the need to ensure agricultural land is protected to support regional resilience. With this information, solutions can be put forth to minimize pollutants released as a result of open-air burning, as well as enhance reducing, reusing, and recycling vegetative waste by transitioning to a circular economy.

The Lower Fraser Valley's temperate climate and valuable agricultural land has fostered a booming agricultural sector. Agriculture in the Metro Vancouver region contributes 26 percent of British Columbia's gross annual farm receipts with only 1.5 percent of the province's agricultural land (Metro Vancouver, 2017). The majority of Metro Vancouver's agricultural land cover falls under the category of 'forage and pasture' and 'berries'. This suggests that large quantities of both herbaceous and woody material are generated as by-products of local agricultural production.

The broader goal of the study was to develop an understanding of local vegetative agricultural waste and related management strategies. The following objectives were established to guide the research:

- Assess the types of vegetative waste generated by farming operations in Metro Vancouver and produce an inventory;
- Provide details of waste management methods and strategies utilized for each type of vegetative waste;
- Identify existing barriers that prevent reducing, reusing or recycling of agricultural vegetative wastes; and

- Identify opportunities for waste reduction and avoidance of open-air burning of agricultural vegetative wastes in Metro Vancouver.

To meet these objectives, the study collected information through a literature review and a questionnaire. The questionnaire was formulated with the intent of enlisting participation from individuals who have been or are currently associated with the local agricultural sector. The literature review was conducted to collect information regarding the management methods and strategies, as well as fill any potential gaps in the questionnaire data.

An inventory of vegetative agricultural waste was developed with a significant reliance on the British Columbia Ministry of Agriculture's Agricultural Land Use Inventory for Metro Vancouver. With a collection of academic and peer-reviewed articles from the literature review, details regarding management strategies were collected and summarized. The study found two technologies that may contribute to the transition to a circular economy: anaerobic digestion and pyrolysis. Final recommendations were made and include:

- Further research into waste management technologies that have the potential to reduce vegetative waste, provide green energy, and well as improve economic viability for producers in Metro Vancouver;
- Development of regional programs that support matching programs and provide management rebates; and
- A quantitative study of vegetative waste generated in the region.

Introduction

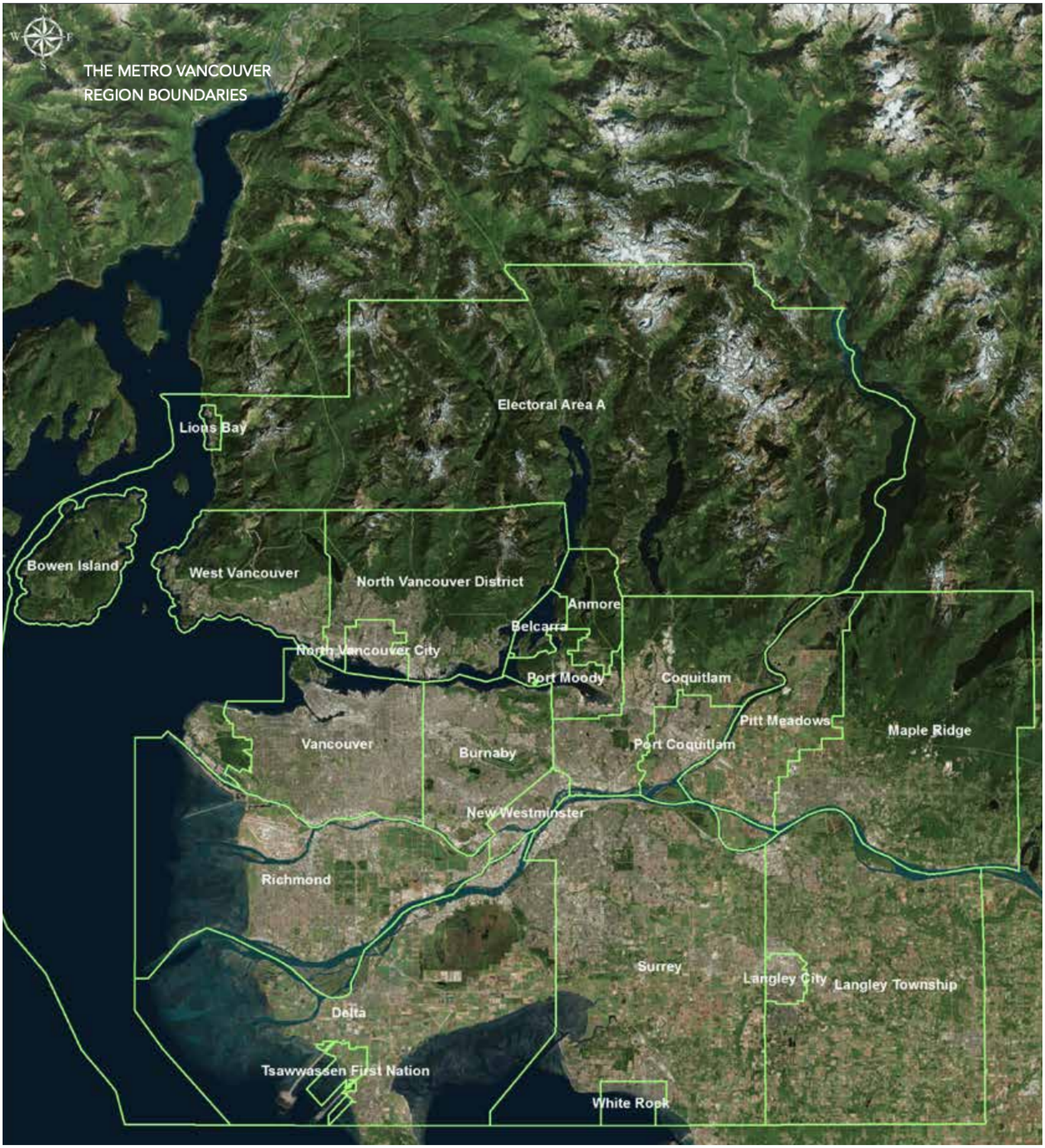
1. Introduction

Agricultural waste management is an integral, sometimes under-regarded, aspect of farming. Agricultural systems tend to be more commonly associated with the generation of products such as vegetables, fruits, dairy and meat; yet, there are important environmental and financial considerations associated with the management of the vast quantities and types of vegetative waste produced as by-products in agricultural production systems. In order to continue to foster growth and enhance the sustainability of agriculture locally, it is essential to understand the current context of agricultural vegetative waste management in the Metro Vancouver region. With this in mind, a study was initiated with the goal of better understanding the types of vegetative agricultural waste generated, how it is managed, and existing barriers that prevent reducing, reusing or recycling these waste streams in order to avoid open-air burning.

The Board Strategic Plan 2019-2022

Metro Vancouver is a federation of 21 municipalities, Tsawwassen First Nation and an Electoral Area (see Figure 1). The Metro Vancouver Board Strategic Plan 2019 to 2022 provides a framework for the decisions taken to address regional priorities. The plan is built on five central themes that guide the development of Metro Vancouver: Regional Growth, Environmental Sustainability, Financial Sustainability, System Stewardship, Regulatory and Legislative Environment. Environmental sustainability is a theme that acknowledges the importance of taking action to reduce pollutants, including greenhouse gases, prevent waste, and conserve ecosystems. With this in mind, the project aligns with the shared municipal goal of ‘Strengthening Our Livable Region’ by being leaders in environmental stewardship. With the deepening reality of climate change comes the necessity to strengthen resilient and adaptable economies. Within the component of waste management in agriculture, this concept involves the transformation to, and the strengthening of, a circular economy — one which optimizes efficiencies and partakes in the prominent 3R precept: reduce, reuse, and recycle. What’s more, the study supports the Board Strategic Plan for ‘Taking Leadership on Climate Action Through Climate 2050’ by deepening the understanding of barriers that prevent adopting waste management practices which could replace high emission activities that contribute to GHG emissions and air contaminants such as the practice of open-air burning.

Figure 1. Boundary map of Metro Vancouver. Image source: (Metro Vancouver, 2019)



By removing or reducing barriers to implementing the 3Rs with respect to vegetative waste management in production systems, progression towards goals of 'Climate Action Through Climate 2050' can be achieved. As an exploratory study, the main focus is to deepen our understanding of complex issues that producers face daily when choosing management strategies for vegetative waste and debris. Furthermore, the long-term objective of this research is to ease potential barriers producers face in order to enhance efficiency in the circular economy, improve air quality by reducing emissions and contaminants originating as a result of agricultural vegetative waste management, and to progress the overall sustainability of local agricultural production systems.

1.1 Background

Current context

Metro Vancouver is home to a bustling agricultural industry with the most recent 2016 census reporting $954 million in gross annual farm receipts, up by $165 million from the previous census of 2011 (Metro Vancouver, 2014, 2017). The region produces 26 percent of British Columbia's gross annual farm receipts despite farming only 1.5 percent of the province's agricultural land (Metro Vancouver, 2017). The remarkable agricultural capacity in the Metro Vancouver region is partly made possible by the quality of the soil[1] (a large portion of which are fertile alluvial deposits in the Fraser River Delta) and by the moderate climate. Additionally, the close proximity to urban areas and diverse markets provides further support for local agriculture by enabling added income through direct marketing. However, growing farmland prices in the region have led to the increased cost of production for producers. According to a report conducted by Vancity, the price of farmland in "Metro Vancouver ranges from $150,000 to $350,000 per acre for parcels up to 40 acres, and $50,000 to $80,000 per acre for parcels more than 40 acres" (2016, pp. 2). The growing price of farmland forces producers to intensify production on less land in order to remain economically viable which might partially account for the trend of reduction in area farmed alongside the growth in gross farm receipts in the past 20 years (see Table 1).

[1] Visit the government of BC's webpage Soil Mapping and Classification for more information on soil in the Metro Vancouver region (https://www2.gov.bc.ca/gov/content/industry/agriculture-seafood/agricultural-land-and-environment/soil-nutrients/mapping-and-classification)

Table 1 Total area farmed in Metro Vancouver from 2006 to 2016[2]

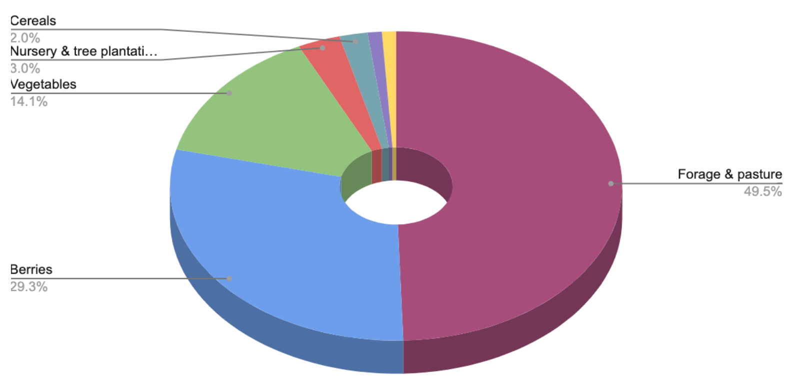
Region	Total Farm Area (Ha)		
	2006	2011	2016
Burnaby	1,397	501	277
Delta	7,520	6,988	9,090
Greater Vancouver A[1]	1,102	955	692
Langley	12,970	14,978	10,807
Maple Ridge	1,923	1,509	2,446
Pitt Meadows	3,086	6,275	4,785
Richmond	3,730	3,072	3,122
Surrey	9,307	6,368	7,007
Vancouver[2]	--	46	154
Metro Vancouver	**41,035**	**40,692**	**38,380**

[1]Greater Vancouver A includes Barnston Island, Port Coquitlam, and other municipalities of which were not specified in the census report.
[2]Prior to the 2011 Census period, data regarding farming in Vancouver was not reported.

Agricultural activities

The most recent estimates report between 31,000 and 38,000 ha of farmland within the Metro Vancouver region[3] with a diversity of agricultural activities possible due in part to the fertile soil and moderate climate conditions which allows for a wide array of crops to be cultivated. According to the most recent Agricultural Land Use Inventory (ALUI) by the BC Ministry of Agriculture, cultivated field crops make up 90 percent of total agricultural land cover in the region of which approximately half is classified as forage & pasture and 29 percent as berries (Figure 2) (B.C. Ministry of Agriculture, 2014c). As for livestock, equine is listed as the most common type of livestock activity accounting for 1,585 activities out 2,676 total (59 percent). Poultry

Figure 3. Cultivated field crops in Metro Vancouver



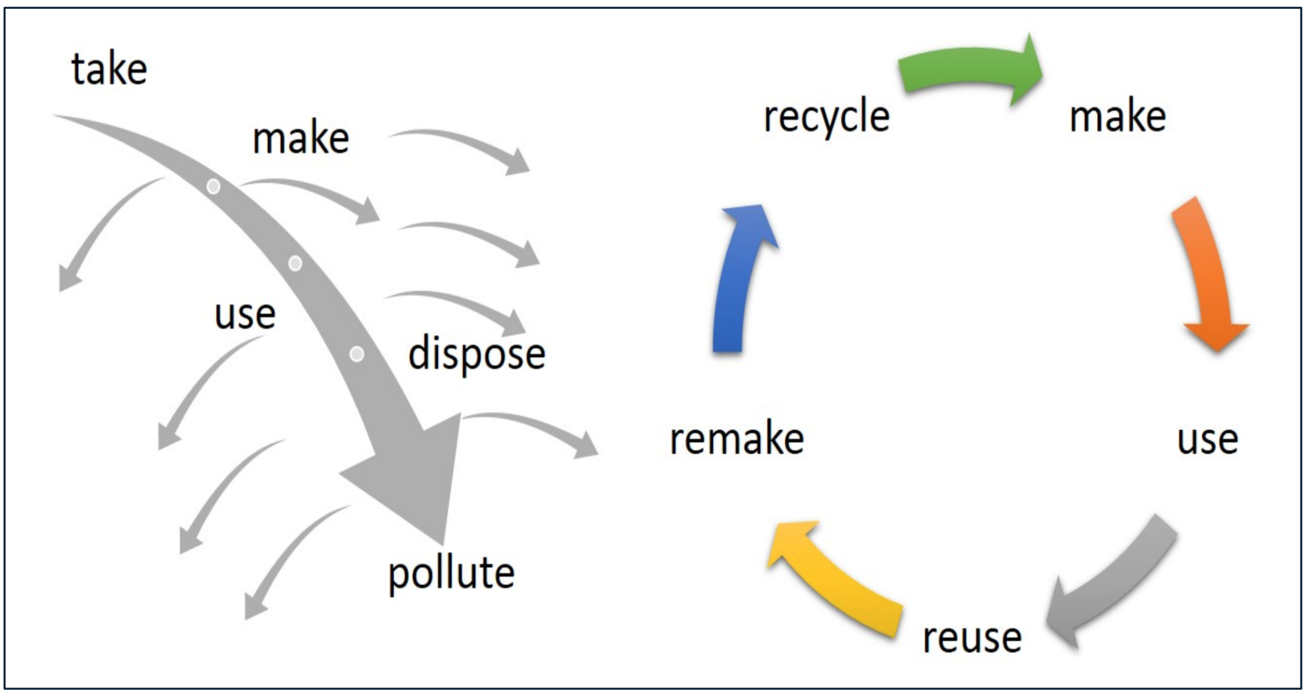
[2] Table 1 is modified from the 2016 Census of Agriculture Bulletin and varies from the reported ALUI estimate of farmland due to differing parameters of inclusion. Source: (Metro Vancouver, 2017).
[3] Difference in estimates is due to disparate definitions of agricultural land cover between the reports.

is the second most common making up 13 percent of all livestock activities.

Circular economy

The concept of a circular economy is defined by Geissdoerfer et al. as "a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling" (2017, pp. 759). Thus, a circular economy is based on the principle of eliminating both pollution and the production of waste materials from a system by enhancing interconnectedness. In regard to agriculture, this can be viewed as minimizing or eliminating waste from production and by building a system that connects agricultural by-products to appropriate sectors for direct use or processing to yield value-added products. Transitioning to a circular economy within the agricultural sector requires the uncovering of sometimes inconspicuous barriers that prevent the reduction of waste as a by-product and the transformation of waste to a value-added product.

Figure 6. Linear versus circular economy. This figure illustrates a linear economy (left) in which materials are produced and consumed and a circular economy (right) in which materials are reused and recycled. Source: Catherine Weetman, CC 3.0

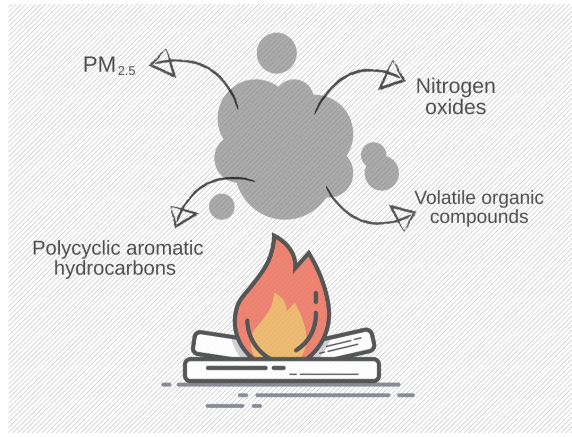


1.2 Open-air burning

Open-air burning is one of the management tools used for disposing of vegetative waste produced as a by-product of agricultural activities. It is broadly defined as the combustion of material that is conducted outside a structure and does not vent to a stack or chimney (Metro Vancouver, 2019b). Open-air burning is used to dispose of organic material such as woody residues (e.g. prunings from orchards, berries, or vines), debris from land clearing, crop residues, weeds, diseased materials and to control vegetation on pasture and non-crop areas (B.C. Ministry of Agriculture, 2014b). However, open-air burning of organic material is typically inefficient and leads to the emission of smoke which contains a wide range of pollutants that are released into the air and environment, as illustrated in Figure 4.

The chemical composition of smoke depends on the material and the conditions of combustion. If there is an adequate supply of air, complete combustion occurs, and organic material is transformed into carbon dioxide (CO_2) and water vapour. However, due to inefficient conditions inherent to typical open-air burning activities, much of the organic material is transformed by incomplete combustion. This is visually indicated by the presence of smoke.

Figure 9. Potential pollutants produced from burning organic material



Health and environmental impact

Smoke contains a complex mixture of fine particles and compounds that have potential adverse effects on human health and the environment. Constituents of smoke include: fine particulate matter ($PM_{2.5}$), nitrogen oxides (NO_x), volatile organic compounds (VOC), and polycyclic aromatic hydrocarbons (PAH) (CCME, 2016; Metro Vancouver, 2019b). Numerous illnesses are associated with exposure to smoke with short-term exposure linked to diseases such as acute bronchitis, asthma attacks and increased susceptibility to respiratory infections with young children and older adults being more vulnerable to these health effects (CCME, 2016). Research has shown that fine particles present in smoke are non-threshold pollutants, meaning there is a health risk regardless of the level of exposure (CCME, 2016; Metro Vancouver, 2019b). Smoke emissions also impact the environment by reducing visibility at the local level, and by contributing to climate change at the global level from the release of black carbon, a short-lived climate forcer[4] (CCME, 2016). In addition to the health impacts, smoke can also cause irritation in the eyes and respiratory pathway, which can affect residents' use and enjoyment of their environment.

Due to the high population density of Metro Vancouver, smoke emissions from open-air burning in the region tend to have a larger impact on a greater number of people compared to less densely populated areas of British Columbia.

Agricultural burning legislations

The BC *Open Burning Smoke Control Regulation* (OBSCR), a regulation under the provincial *Environmental Management Act* (EMA), places restrictions on open-air burning of vegetative debris. However, under Section 31 of the EMA, Metro Vancouver has delegated authority for air pollution control and air quality management within the Metro Vancouver region, including on industrial and agricultural land. Metro Vancouver does not currently have a regulation to manage emissions from open-air burning of vegetative debris. Open-air burning activities of vegetative debris are currently authorized using the system of permits and approvals under *Greater Vancouver Regional District Air Quality Management Bylaw No. 1082, 2008 (Bylaw 1082)*.

1.3 Research objectives

This study aims to meet the following objectives:

- Assess the types of vegetative waste generated by farming operations located in Metro Vancouver and produce an inventory;
- Provide details of waste management methods utilized for each type of vegetative waste;
- Identify existing barriers that prevent reducing, reusing or recycling of agricultural vegetative wastes; and
- Identify opportunities for waste reduction and avoidance of open-air burning of agricultural vegetative wastes in Metro Vancouver.

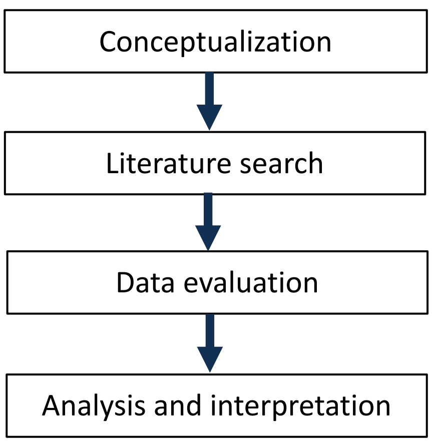
[4] For more information on black carbon and its climate impact, read the Nature article *Black carbon radiative effects highly sensitive to emitted particle size when resolving mixing-state diversity* by Matsui, Hamilton, & Mahowald

Research Approach

2. Research Approach

2.1 Literature review

The main research approach for this study is a literature review. This is a mixed research technique in which both qualitative and quantitative data are collected and analyzed. The literature review consisted of four phases to answer the research objectives. The phases included[5]:



The first phase involved conceptualizing the aim and objectives of the topic under examination. The primary goal of the project was to gain a deeper understanding of vegetative agricultural waste and its management in the Metro Vancouver region. From there, discrete objectives related to the overarching theme were developed to achieve a broader goal. Once the study objectives were defined, a literature review was conducted by scanning and collecting data from both academic databases and grey literature including from governmental, industrial and/or agricultural organizations. In the third phase of data evaluation, information was assessed for quality by reviewing the credibility of authorship and content. Preference was given to data originating and directly pertaining to the Metro Vancouver region; however, for example, in the case of possible alternative management strategies, a lack of data relating directly to the region led to less stringent conditions during data evaluation. The last phase of the literature review comprised analyzing and interpreting the data collected by organizing the information into sections relating to a distinct objective.

2.2 Questionnaire

A questionnaire was designed to collect primary data to accompany the literature review. This research approach was aimed to collect information from individuals affiliated to and experienced in the Metro Vancouver agricultural sector in order to uncover pertinent information regarding the objectives of the study.

[5] This literature review technique was adapted from the University of Southern California Libraries research guide and can be accessed at https://libguides.usc.edu/writingguide/literaturereview

Aim and goal

Waste management decisions are dependent on a multitude of factors, including the type, quantity, and quality of the waste product. The questionnaire was developed to collect information regarding the type of vegetative waste, barriers to avoiding open-air burning, and factors involved in management decision. The aim was to collect information and insight as a preliminary gauge for further research.

Research questions

The following research questions (RQ) were formulated to meet the objectives of the questionnaire.

- RQ1: What are the most significant types of vegetative agricultural waste generated in Metro Vancouver?
- RQ2: What are the most significant barriers to avoiding open-air burning in Metro Vancouver?
- RQ3: What are the most significant barriers to avoiding reducing, reusing, and recycling vegetative waste?

Participants

In order to meet the objectives of the project, the questionnaire was developed with the goal of collecting insight relating to vegetative agricultural waste management in Metro Vancouver directly from individuals associated with the local agricultural industry. Participants were chosen based on two prerequisites:

1) experience in the agricultural industry
2) affiliated with agricultural production in the Metro Vancouver region

In order to participate, it was mandatory for the respondents to have either a current or past affiliation to the agricultural industry in the Metro Vancouver region. The pool of appropriate participants was from positions such as producers (farm owner, manager, employee), staff from agricultural organizations (including governmental and non-profit), and natural resource professionals.

Questionnaire platform

The questionnaire to address the RQs was developed using Qualtrics as an online survey tool. Qualtrics was chosen for its user-friendly platform, ease in disseminating anonymous links via email, and its low cost.

Eight questions were developed to address the 3 RQs[6]; the questions were separated into 3 sections of which one was optional.

The sections are as follows:

1) Agricultural system details
2) Waste management
3) Optional: statement on barriers

[6] Refer to Appendix A for the content of the questionnaire.

Findings

3.1 Questionnaire demographics

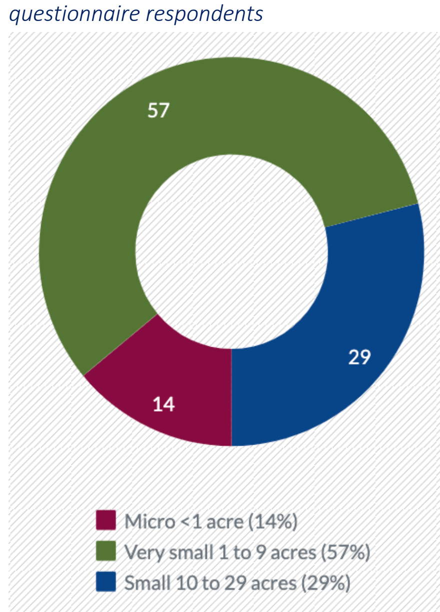
The questionnaire provided responses from 10 individual participants. The results showed the demographics of the respondents to be predominantly employing market garden[7] systems and no respondents reporting livestock (with the exception of poultry), timber, or fodder/forage production. Agricultural products generated were reported as annual crops, bush fruit, floriculture products and tree fruits and nuts. All respondents reported affiliation to small-scale agricultural systems, with 57 percent of the respondents reporting a production scale between 1 and 9 acres and no participants reporting a production scale exceeding 29 acres (see Figure 5).

3.2 Vegetative waste inventory[8]

Of the ten participants, 7 reported post-harvest crop residues and culled or unmarketable produce as a vegetative waste generated. The next most commonly reported waste was (in descending order) post-processing residue and unused seeds or seedlings; tree pruning and leaves/grass clippings; land clearing debris; and bedding.

According to the ALUI, the two most prominent field crops[9] in the Metro Vancouver region are 'forage and pasture' with approximately 14,000 ha in production and 'berries' with approximately 8,500 ha (see Figure 6). When compared to the total farmland in the region, 'forage and pasture' and 'berries' account for 45 and 27 percent respectively. Other categories of land cover[10] include farm infrastructure, crop barns, and greenhouses which account for 8 percent of the total, a relatively small proportion.

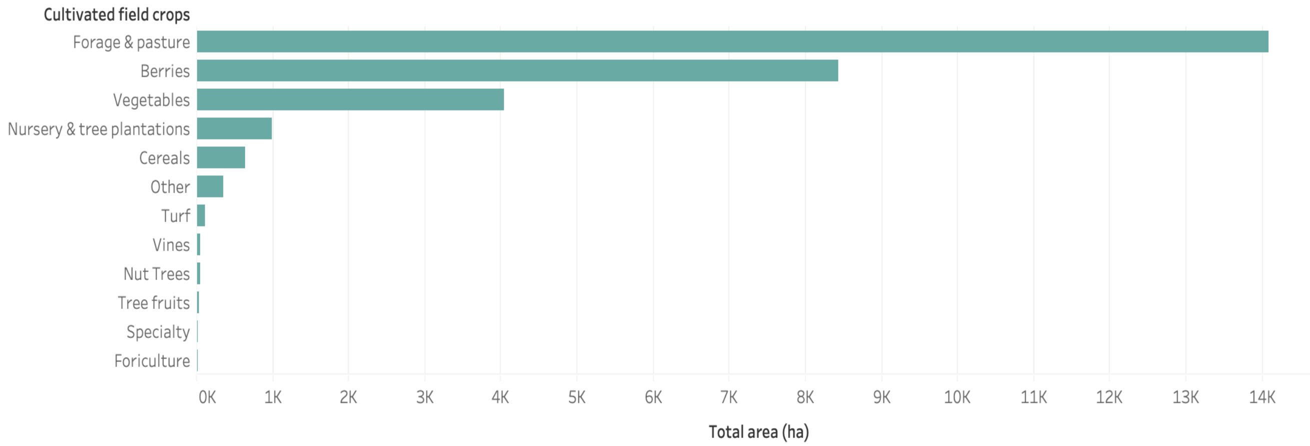
Figure 12. Proportion of production scale of questionnaire respondents



[7] A market garden is generally a small-scale production of vegetables, fruits, and/or flowers as cash crops with the majority of profits being made from direct to consumer markets such as farmer's markets, community-supported agriculture (CSA), and direct to restaurants. Market garden production supplies local populations with fresh produce throughout the growing season.
[8] See Table 3 in Appendix B for a complete inventory of waste organized by crop type and waste characteristics.
[9] Refer to Appendix C for a definition of field crop categories included in Figure 6.

[10] See Table 4 in Appendix B for details

Figure 15. Hectares of cultivated field crops farming by category. Source: modified from BC Ministry of Agriculture (2014c)



Waste generated as a by-product of forage and pasture field crops varies depending on the crop species and variety, system goals, management and growing conditions. Forage crops include grasses, legumes, and brassicas[11] that may be sown independently or as a mixture with the general purpose of feeding livestock as either fodder (e.g. hay) or for direct grazing. The ALUI also included forage corn[12] when accounting for forage and pasture. Possible vegetative waste produced from forage and pasture includes wasted feed, leftover residue from harvest, and diseased vegetation.

The category of berry production in the Metro Vancouver region includes blueberries, cranberries, strawberries, raspberries, and blackberries.

The ALUI noted this category as the second most prolific land cover within cultivated field crops, with blueberries being the most commonly grown type.

The type of vegetative waste produced as a result of berry production varies significantly between berry crops and is mostly dependent on the plant species. For example, raspberries and blackberries share the same genus (*Rubus*) and therefore have similar plant structure and pruning requirements. Both berry species generate woody canes that are normally pruned annually.

Blueberries are the most prolific berry crop grown in Metro Vancouver making up 65 percent of the land cover in the category. There exist two species of blueberries: highbush and lowbush (sometimes referred

[11] Brassicas are known to be incorporated into forage seed or cover crop mixes; however, the ALUI did not include brassica in their definition of forage and pasture. The brassica family are more commonly known within vegetable production (e.g. kale, cabbage, radish).
[12] As a result of mild summer temperatures in the Lower Mainland, it is inefficient to grow corn to maturity. Cattle and hog farmers will grow corn to ferment the biomass and produce a nutritious feed referred to as corn silage.

to as wild blueberries). As the name suggests, these two species differ greatly in size with the highbush reaching heights of 3 to 4 meters and the lowbush 0.6 meters. According to the B.C. Blueberry Council, the predominant species grown in B.C. is highbush[13]. Due to their large size, pruning can result in a considerable quantity of woody biomass.

Cranberries are the second most prolific berry crop grown in Metro Vancouver comprising 31 percent of the total berry land cover. Ideally, cranberries are grown in a manner that does not require pruning. This is more often the case in regions with hot summer climates such as Quebec and Ontario. In the Lower Mainland, where the climate is cooler, cranberry farmers will run machinery over the crop in order to remove the top of the runners and open the canopy and avoid fruit rot. Vegetative waste generated as a by-product of local cranberry production includes woody runners and leaves, culls, diseased vegetation, post-harvest debris, and post-processing debris.

Strawberry production makes up 2 percent of the berry land cover in Metro Vancouver. Strawberry crops do not require heavy maintenance as is the case for other berry species. Producers may decide to remove runners and/or mow foliage, however, this may not always the case. The waste generated from this type of maintenance may be minimal when compared to blueberries and cranberries. Additionally, the waste generated from strawberry maintenance is herbaceous as the crop does not produce woody material.

The ALUI category of vegetables, which accounts for 16 percent of land cover within cultivated field crops, is a broad category with a large range of crops[14] and cultivars. As a result, it is difficult to generalize types of vegetative waste produced within this category due to the variability of plant structure and biomass between crops and their cultivars. For example, carrot crops may be grown and harvested with little post-harvest debris left within the field. Whereas lettuce heads are generally harvested by cutting the crop at its base and leaving a portion of the stem and roots in the ground. Generally speaking, vegetable production generates non-woody herbaceous wastes such as post-harvest debris within the field, waste from weed removal within the production field, post-processing waste, and culled products.

Although estimates vary among sources and production types, a significant quantity of culled produce contributes to on-farm vegetative waste. Thus, culls are a ubiquitous and inevitable source of vegetative waste on farms irrespective of the production system.

[13] Visit https://www.bcblueberry.com/ for more information.
[14] See Appendix C for the list of crops under the ALUI vegetable category.

Land clearing debris is another form of vegetative waste generated in agricultural systems. This debris is often the result of expanding farmland for production and may include woody material from tree and bush removal, invasive species, and leaves and grass clippings. According to the questionnaire results, 3 participants reported land clearing debris as a type of vegetative waste generated on-farm. While this accounts for a relatively low proportion of the overall respondents, it can be accounted for by the garden market demographic who generally work minimal and confined land. Additionally, as a consequence of high farmland prices, there is an assumption that land clearing is not frequent or intensive (i.e. prime arable farmland in the region has since been cleared of mature forest stands). Despite that, the vegetative waste inventory assumed that all agricultural systems partake in some form of land clearing—be it removal of invasive species on marginal land, or the removal of senesced trees or perennial crops.

As a consequence of the study parameters, it is difficult to quantify the vegetative waste generated in the Metro Vancouver region. However, it can be assumed due to the area of land cover and information gleaned from the literature review, that a large portion of the vegetative waste originates from spent forage crops, berry prunings, culls, post-harvest residues, post-processing residues and diseased vegetation. Nonetheless, further studies would be required to garner information regarding the volume and weight of vegetative wastes in their individual categories.

3.3 Vegetative waste management practices

Methods chosen for managing vegetative wastes are dependent on several variables. These include quality, quantity, and type of material, and may be affected by additional factors such as environmental conditions (e.g. weather or climate conditions), logistical issues, infrastructure, and capital availability. Consequently, vegetative waste management requires complex deliberation.

The literature review found the most common types of vegetative agricultural waste management practices in the Metro Vancouver region to be:

- Burning
- Composting
- Reincorporating into soil
- Reusing on farm (e.g. mulch)
- Transporting to green waste facility or transfer station
- Sending to other sector for use
- Feeding to livestock

The questionnaire found that a major management practice to be on-farm composting (choice count: 32%) and reincorporating into the soil (choice count: 27%). These prevalent strategies are likely a result of the participants' affiliation to market garden production system which tends to produce high volumes of products using succession planting on minimal land thereby relying on on-site nutrient cycling as a strategy for maintaining soil quality. On larger farms, methods such as on-farm composting may not always be possible due to logistical issues and physical constraints.

Composting[15]

Composting is an aerobic process in which microorganisms work to decompose organic material into a humus-like form that can be returned to the soil as an amendment to improve soil quality. It is an active process that can be done in many ways with a variety of systems, equipment, and scales (Upland Agriculture Consulting, 2019). Farms may practice what is thought of as "passive composting" in which organic material is piled up and left to decompose without management; however, this may lead to several problems involving environmental and air quality (e.g. leachate, strong odour) as well as the quality concerns with the final product. Composting is a well-managed process that requires know-how, infrastructure, and continual maintenance.

The major reasons why farmers should consider incorporating composting on-farm as a practice have been summarized by the Upland Agriculture Consulting firm's compost guide (2019):

- Reduces farm waste
- Improves soil quality
- Kills pests and pathogens
- Can be sold for profit

However, composting as a method for managing vegetation waste has several

Table 3. Benefits and challenges of composting. Source: Modified from Martin (2015).

ADVANTAGES	DISADVANTAGES
Reduces and/or eliminate pathogens	Pathogen control requires high temperatures and adequate aeration
Reduces volume and moisture of waste	Often requires additional bulking material
Minimizes viable weed seeds	Long processing time
Reduces insect larvae, minimizing potential pests	Poorly run process achieves very little
Reduces odour	Land and infrastructure required for processing and storage
Stabilizes organic components and nutrients	May require initial investment
Produces a soil amendment/fertilizer	Requires maintenance

[15] Visit http://www.rdosmaps.bc.ca/min_bylaws/PublicWorks/SolidWaste/BC_Agriculture_Composting_Guide.pdf for the comprehensive BC On-Farm Composting Guide by Upland Agriculture Consulting (2019)

advantages and challenges which are summarized in Table 2.

Composting is a microbiological process and therefore requires a relatively low carbon to nitrogen ratio (C:N) for optimal decomposition[16] (Upland Agriculture Consulting, 2019). Therefore, a fastidious accounting of the compost feedstock is mandatory. Feedstock that is high in carbon, such as from woody material, may slow the composting process. In certain production systems (for example, ones that are dominated by woody perennials such as blueberries or apples) composting may not be a viable option. The on-farm composting process may be most viable in systems where there is access to a substantial quantity of herbaceous materials and some woody materials to act as a bulking agent or to raise a low C:N (Upland Agriculture Consulting, 2019).

Reincorporating into the soil

Reincorporating residue into the soil was the second most prevalent practice for managing vegetative waste after composting with 6 respondents reporting using this method.

A significant volume of vegetative waste is produced by crop residues remaining post-harvest. For example, stubble left in the field after silage corn or hay is cut and harvested, plant structures left with roots in the ground after the growing season has ended, and bolted[17] crops that are no longer suitable for harvest.

A viable method for managing this waste is to incorporate it into the soil by use of a plough. Re-incorporating vegetation into the soil is an agroecological practice sometimes referred to as green manuring which has the goal of improving soil quality (Sullivan, 2003). The vegetation is broken up and overturned into the soil where microorganisms work to decompose the material over time. This is not equivalent to amending soil with matured compost since compost comes decomposed with readily available nutrients for plants; however, the reincorporated vegetation can contribute to soil quality over time by conserving organic matter and nutrients within the soil. This method, however, may only be efficient when the vegetative residue is not significant in quantity (e.g. stubble from hay or leftover roots from lettuce) and has a low C:N (e.g. herbaceous material). Woody material and large residual plant structures (e.g. tomatoes or cucumbers after the growing season) generally require removal.

[16] The Upland Agriculture Consulting (2019) compost guide recommends a target C:N ratio of 25:1 to 35:1 for optimal results.

[17] A term used to describe a plant that has begun growing flowering stems. This generally implies a diminished value due to a change in crop quality (e.g. structure and taste of edible parts).

Open-air burning

Open-air burning is used as a management tool for disposing of vegetative agricultural waste generated such as land clearing debris, crop residues, prunings, invasive species, and/or diseased crop material. It is often perceived as the most feasible option for disposing of woody, diseased, or invasive vegetative waste that cannot be composted easily.

Although open-air burning releases air pollutants through incomplete combustion, it may be permitted by the Metro Vancouver Regional District (MVRD) under individually assessed circumstances. In order to carry out open-air burning, a permit or approval must be granted by Metro Vancouver, and municipal or other bylaws and restrictions (e.g. burn bans) must be consulted and followed.

Based on the information gathered in the questionnaire, market garden producers are likely not significantly contributing to open-air burning practices in the region (2 respondents reported using this method). This could be related to the nature of the production system in which mostly herbaceous crops are grown that can more feasibly be reincorporated into the soil or composted on-site. Additionally, area may be limited within this system for growing large perennials such as fruit and nut trees and/or large berry bushes which would require regular pruning of woody material that is not easily composted.

According to a small dataset gathered from past open-air burning permits and approvals of vegetative agricultural waste in the Metro Vancouver region, the most abundant requests for burning agricultural materials in the region are berry crop residues and land clearing debris (e.g. trees and invasive species such as the Himalayan blackberry).

Reusing on farm

Producers will often find inventive ways to reuse vegetative material in order to minimize waste and save on costs. For example, producers from a Vancouver urban farm use fallen deciduous leaves in the fall as a mulch to conserve soil from erosion during the winter. Other examples include chipping woody prunings for reuse as a mulch, using twigs as stakes, and building trellises out of pruned sticks or cleared trees.

These methods reduce waste and/or prolong the transition of a material to waste and are especially useful for small to medium scale farmers with tight financial margins. However, according to the questionnaire, only 2 respondents reported using this method suggesting that this method is not widely employed.

Feeding to livestock

Certain livestock provides the benefit of an additional opportunity for nutrient cycling. For example, a small-scale mixed market garden and hog farm in Delta utilizes vegetative waste from their vegetable and fruit production to feed the hogs with fresh and nutritious feed. In turn, the hogs, which are also set out to till fallow fields, incorporate the nutrients into the field that will be used for production in subsequent years. A farm in Vancouver employs a similar system with laying hens, in which a harvested field is left with post-harvest residues for the chickens to ingest in addition to foraging for soil insects. Numerous closed-loop cycles may be employed on a mixed farm.

One respondent reported practicing this method as a waste management strategy. This low number could be accounted for the low number of reported livestock production (3 respondents reported poultry production as either laying hens or broiler chickens).

Transporting to a waste facility

Transfer stations in Metro Vancouver will accept yard and garden trimmings as green waste. The fees associated to this service are dependent on the municipality[18]. This may not be an effective method for disposing vegetative waste for farms that have over an acre in production or that are located a significant distance from facilities that accept green waste.

3.4 Barriers

The final question in the questionnaire was an open-ended inquiry into perceived barriers for reducing, reusing, and recycling vegetative waste generated on-site. Out of 10 participants, 6 responded to the question and provided valuable insight.

The most common perceived barrier regarded upfront costs associated with both infrastructure (e.g. storing) and equipment required. Additional costs associated are related to the labour required for 'environmentally sound' methods of waste management such as composting. The method of composting was also regarded as a logistical issue (e.g. transporting), especially during heavy production times. Other barriers included transportation costs and associated tipping fees at transfer facilities.

Question 7 asked participants to rank the most important consideration when choosing a management strategy using time, logistics, cost, and environment as considerations. According to the responses, time was the most important factors, followed by cost, environment, and finally logistics. From this preliminary data, it can be inferred that time is regarded as both a cost and lost opportunity. Producers would therefore benefit financially from technology that

[18] Please consult the transfer station website in your municipality before transporting yard and garden trimmings.

allowed for efficient waste management and required minimal on-going costs.

3.5 Opportunities for waste reduction

The following opportunities for agricultural vegetative waste reduction have been identified based on responses from the questionnaire and information gathered from the literature review.

Regionally sponsored programs

Programs have been created within other British Columbian regional districts to reduce agricultural vegetative waste and minimize open-air burning. One pertinent example is the Agricultural Wood Waste Chipping Program[19] in the Regional District of Central Okanagan (RDCO). This program provides free chipping for orchardists wishing to remove crops for either replanting or other agricultural use. Additionally, the program provides producers with rebates for renting mowing and chipping equipment to minimize the amount of burned woody debris in the region. According to the RDCO website, the program has resulted in the avoidance of 77 tonnes of particulate matter (including $PM_{2.5}$ and PM_{10}), 312 tonnes of carbon monoxide, and 27 tonnes of volatile organic compounds being released into the air as a consequence of open-air burning.

Although this example displays a positive outcome regarding a regional district program, the agricultural context of a region must first be understood before developing a program for the MVRD. Central Okanagan is home to an abundance of fruit orchards and wineries which comprise 41 percent and 9 percent of the cultivated land respectively (B.C. Ministry of Agriculture, 2014a). This predominant production leads to large quantities of woody vegetative waste generated and require adequate management. As discussed, woody material is not ideal for compositing in large quantities due to high C:N. The program was put forward to minimize waste and encourage reuse in addition to reducing open-air burning. Open-air burning is a great concern in the region; smoke produced from burning may be trapped in the valley bottom by temperature inversions and poor wind dispersion leading to diminished air quality and increasing the possibility of negative health effects for the communities (Johnson, 2011). As a result, the program established to assist producers in managing their vegetative waste and improve air quality was appropriate within the agricultural context of the RDCO.

In the Metro Vancouver region, there is a significant amount of herbaceous waste generated as a result of forage/pasture

[19] Visit http://www.rdosmaps.bc.ca/min_bylaws/ES/AQ/2013/General_Information_ProgramSteps-web.2013_4pgpdf.pdf for more information regarding the program.

production and vegetable production. This waste can be feasibly and largely managed by composting and reincorporating into the soil. However, as discussed previously, the region has also had a large land cover of woody perennials such as berries that generate prunings as a result of crop management requirements which may not always be appropriate for composting. In this case, a chipping program could be useful for minimizing emitted pollutants from open-air burning.

Other possibilities include matching programs in which producers that are clearing land or have collected a large quantity of woody prunings, are matched with business that process wood to produce mulch for commercial sale. However, this may be a challenging task due to uncertain, or undeveloped, markets for output products.

The MVRD may benefit from vegetative waste reduction by organizing extension services with the British Columbia Institute of Agrologist as collaborators to educate producers about on-farm composting to optimize composting viability through regionally appropriate and accessible knowledge. This service may also be supported by offering grants through a regional vegetative waste reduction initiative to facilitate covering start-up costs (i.e. composting infrastructure).

Sent to other sector for use

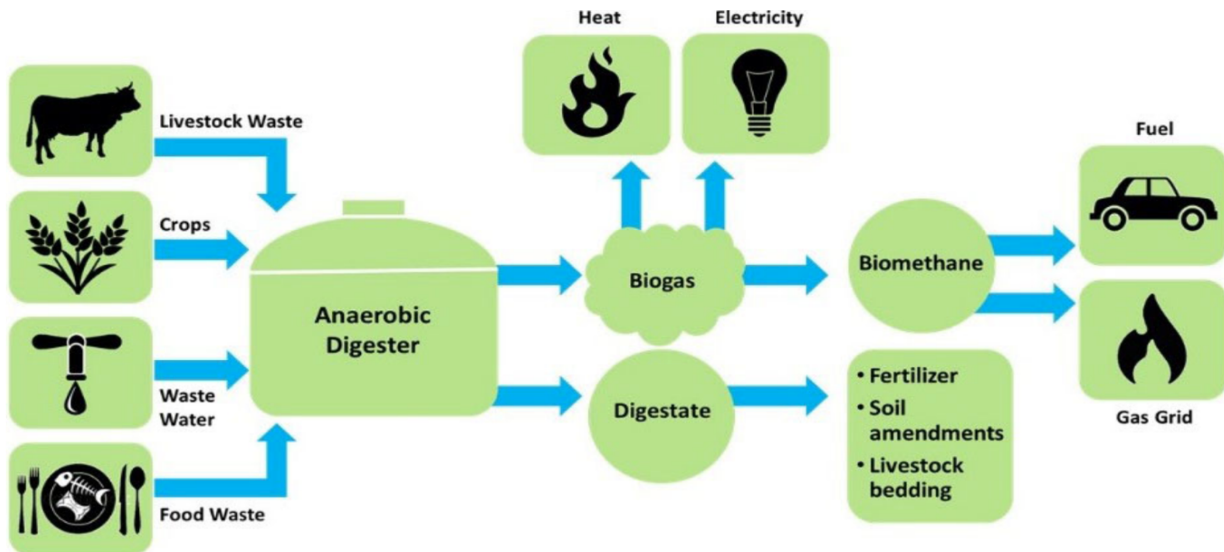
Local companies provide a pick-up service for woody debris. Producers who generate a large quantity of wood waste can dispose of it by handing it over to these companies who, in turn, grind it for resale as mulch, wood shavings, wood waste, hog fuel, or sawdust. These companies also provide grinding services and at a cost will process wood waste into the previously mentioned products for direct reuse in the production system.

3.6 Alternative waste management technologies

Anaerobic digestion

Organic wastes (i.e. from plants and animals) harness the potential to produce a compound mixture similar to the composition of natural gas (Environmental and Energy Study Institute, 2017). Biogas is generated from an anaerobic digestion process where thermophilic microorganisms break down organic wastes (Broitman et al., 2018) to produce a gaseous mixture of methane (CH_4) and carbon dioxide (CO_2). The biogas can be used for heat and power production. Additionally, this process yields a digestate (sludge residue) by-product that may be used as a soil amendment or compost starter (Scano et al., 2014). The organic

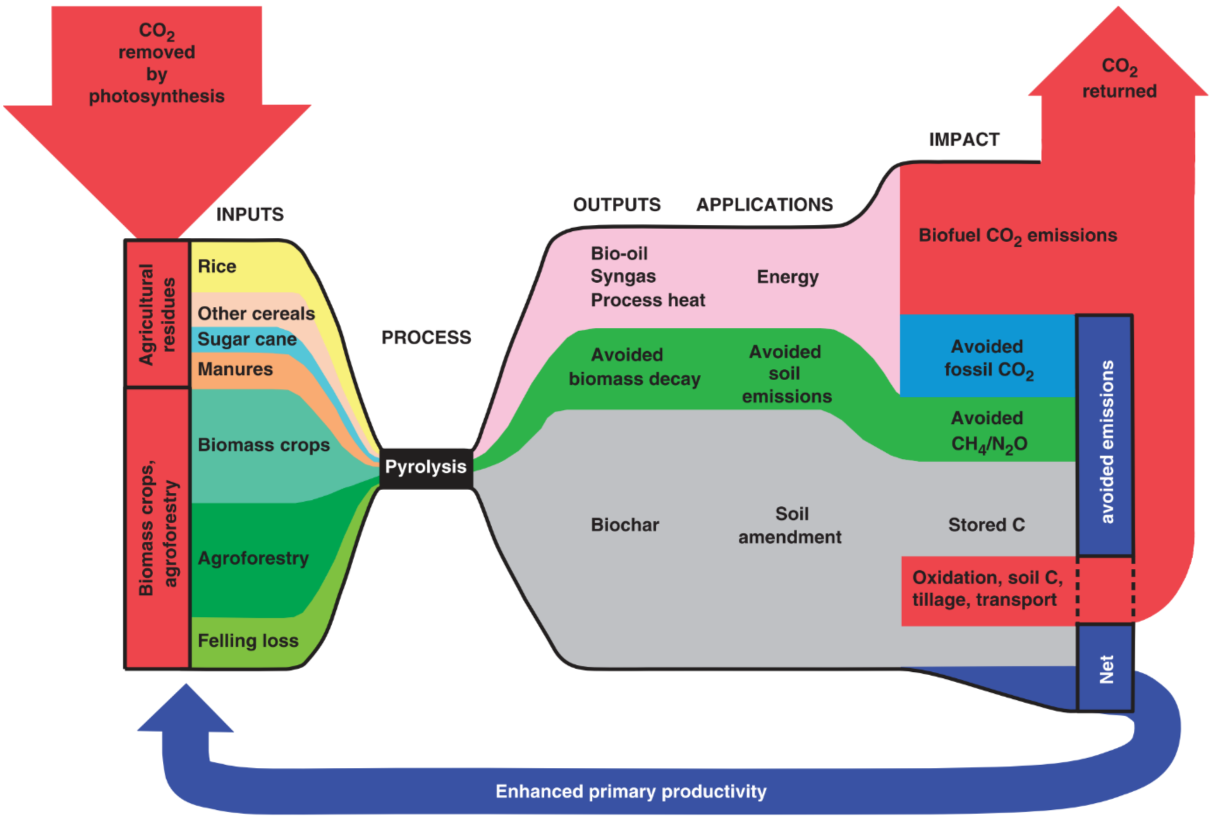
Figure 18. Inputs and outputs of anaerobic digestion. Source: (Woolf et al., 2010)



biomass used as feedstock for this process includes crop residues, food waste, and livestock waste (Environmental and Energy Study Institute, 2017). This process does not efficiently digest recalcitrant compounds such as those found in woody material; consequently, anaerobic digestion would be best suited to production systems with access to livestock manure and herbaceous waste material as an on-farm waste management strategy.

Anaerobic digestion provides producers with an opportunity to manage wastes while capturing additional value from waste by-products. While this may be the case, several factors must be considered before implementation. Much like the challenges of a well-run composting system, producing biogas using anaerobic digestion requires considerable upfront costs, continual maintenance, and plan of action for avoiding air quality problems from odour. A strong understanding of the equipment and biochemical process is also required for efficient production, as well as access to feedstock with the appropriate biochemical balance. These are challenges that may lead to inaccessibility for many producers. Additionally, a study regarding the economic value of several organic waste treatment outputs found that anaerobic digestion resulted in the lowest profit (after assessing fixed and variable costs) when compared to other promising treatment technologies (Broitman et al., 2018). Nonetheless, anaerobic digestion has potential to provide a suitable and profitable waste-treatment method for producers in the Metro Vancouver region and further research should be conducted to explore this as an option (including on-farm processing and transporting for industrial processing) for green energy production.

Figure 21. Illustration of the associated inputs and outputs of pyrolysis. Source: Environmental and Energy Study Institute (2017). Image credit: Sara Tanigawa.



Pyrolysis

Pyrolysis is an anaerobic thermo-chemical process that digests biomass (Broitman et al., 2018) and produces valuable resources as outputs (see Figure 8). The process uses high temperatures (400-600°C) and absence of oxygen to transform the material into a char, referred to as biochar, while generating energy in the form of bio-oil and heat for energy production (Obi et al., 2016; Woolf et al., 2010). In addition to the benefits of providing value-added outputs, pyrolysis has been suggested as a potential solution to mitigating climate change by sequestering carbon (Woolf et al., 2010).

Much like anaerobic digestion, pyrolysis generates an opportunity for producers to both manage on-farm wastes[20] and enhance profits with the formation of value-added products. Biochar can be used as a soil amendment or applied as a bio-sorbent to mitigate soil or liquid contamination (Broitman et al., 2018; Woolf et al., 2010). However, it should be noted that the biochar

[20] Figure 8 shows the relative proportion of inputs and outputs in the process based on width and height of each category. The most important feedstock is woody material.

market is currently underdeveloped[21] which may pose a future financial risk to producers. Despite the absence of a well-established market, a study conducted by Broitman et al. evaluated the economic potential for outputs generated from pyrolysis and provided optimism (2018). Albeit, further research and feasibility studies to support the development of this technology in the Metro Vancouver region as both on-farm processing and industrial processing of farm generated waste is needed.

Funding through governmental programs

Federal and provincial funding options currently exist to support the adoption of clean energy technologies such as anaerobic digestion and pyrolysis. For instance, the Government of Canada's Agricultural Clean Technology Program[22] has dedicated $25 million to assist businesses with the costs associated to implementing green technology. Additional support can be acquired from tax savings for eligible start-up expenses that qualify as Canadian Renewable and Conservation Expenses[23] which may result in up to 50 percent deductions. The funding acquired from participating in these programs supports improving the economic viability of local production systems while simultaneously reducing agricultural waste and providing a source of renewable energy.

[21] For more information regarding the market for biochar in BC, read the Pacific Institute for Climate Solutions report *Industrial and Market Development of Biochar in British Columbia* by de Ruiter, Helle, and Rutherford (2014).
[22] Visit https://www.agr.gc.ca/eng/agricultural-programs-and-services/agricultural-clean-technology-program/?id=1521202868490 for more information
[23] Read the Technical Guide to Class 43.1 and 43.2 for more information at https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/Class_431-432_Technical_Guide_en.pdf

Summary and Concluding Remarks

4. Summary

Understanding vegetative agricultural waste management in Metro Vancouver is important for advancing policy, improving local air quality, fostering agricultural production viability, and facilitating the transition to a circular economy. The first step to improving vegetative waste management in the agricultural industry is understanding what type of waste is produced. This information can be used to facilitate the transfer of agricultural residual materials across industry in an effort to reduce waste and encourage recycling by producing value-added products. Additionally, an inventory of vegetative waste can aid in developing a comprehensive picture of possible management decisions. This information can help facilitate innovation in vegetative agricultural waste management by improving on current management strategies or by providing auxiliary outlets for residual materials.

This report developed an inventory of vegetative waste generated in agricultural production systems in the Metro Vancouver region using a literature review and questionnaire as research methods to collect information. Details concerning strategies implemented in the region to manage vegetative waste were also researched and summarized within the Findings section. In addition to regularly employed strategies for waste management, relatively new and unestablished methods were discussed. These management technologies may assist in the transition to a circular economy by providing sustainable solutions for managing waste by generating value-added outputs that may provide additional income for producers.

4.1 Recommendations

- Future research in vegetative agricultural waste in the Metro Vancouver region should consider collecting quantitative data about waste generated on-site (including volume, weight, and carbon estimates) and perceived barriers.
- Consideration should be given to conducting a feasibility study on the incorporation of anaerobic digestion and pyrolysis for varying scales of agricultural production in the region to assess their viability.
- Additional research into the development of vegetative waste reduction initiatives and funding to support producers in managing their waste with the goal of reducing open-air burning should be further explored.

4.2 COVID-19: Impact on study

The project initially set out to meet its objectives using the questionnaire as a predominant method for collecting primary and qualitative data relating to the study goals. The intent was to disseminate the questionnaire as either an online survey or as an interview, depending on the participants preference. The strategy for accumulating questionnaire respondent data incorporated sending emails to producers and affiliates from a contact list, visiting farmers market for direct first contact, and cold calling. However, due to the co-occurrence of the COVID-19 pandemic, the reliance on primary data collection as a means for meeting the objectives had to be modified. This was in part due to the physical distances measures that were set in place during the project and in recognition of the potential strain on members of the agricultural community who in particular may have been experiencing immense demands on their resources during the pandemic. To mitigate affording producers and affiliates an extra task, the majority of the data required to meet the study goals and objectives were collected from grey literature such as the B.C. Ministry of Agriculture's ALUI.

References

B.C. Ministry of Agriculture. (2014a). *Agricultural Land Use Inventory: City of Kelowna, Regional District of Central Okanagan, Summer 2014*.

B.C. Ministry of Agriculture. (2014b). *Farm Practice: Burning* (Issues 870.218-28). https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/agricultural-land-and-environment/strengthening-farming/farm-practices/870218-28_burning.pdf

B.C. Ministry of Agriculture. (2014c). *Metro Vancouver Regional District Land Use Inventory*. 74. https://doi.org/800.510-29.2014

Broitman, D., Raviv, O., Ayalon, O., & Kan, I. (2018). Designing an agricultural vegetative waste-management system under uncertain prices of treatment-technology output products. *Waste Management*, *75*, 37–43. https://doi.org/10.1016/j.wasman.2018.01.041

de Ruiter, G., Helle, S., & Rutherford, M. (2014). *Industrial and Market Development of Biochar in British Columbia*. *February*, 20.

Environmental and Energy Study Institute. (2017). *Fact sheet - biogas: converting waste to energy*.

Geissdoerfer, M., Savaget, P., Bocken, N. M. P., & Hultink, E. J. (2017). The Circular Economy – A new sustainability paradigm? *Journal of Cleaner Production*, *143*, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Johnson, J. (2011). *Agricultural Waste Disposal: Best Practice Guide*. http://www.rdosmaps.bc.ca/min_bylaws/PublicWorks/AirQuality/Best_Practices_Guide-Ag_Waste.pdf

Martin, H. (OMAFRA). (2015). *Agricultural composting basics*. *05*. http://www.omafra.gov.on.ca/english/engineer/facts/05-023.htm

Metro Vancouver. (2014). *Farming in Metro Vancouver*. http://www.metrovancouver.org/services/regional-planning/PlanningPublications/Farming_In_Metro_Vancouver_Oct_2014.pdf

Metro Vancouver. (2017). *2016 Census of Agriculture* (p. 21). http://www.metrovancouver.org/services/regional-planning/PlanningPublications/2016CensusofAgricultureBulletin.pdf

Metro Vancouver. (2019a). *Board Strategic Plan*. http://www.metrovancouver.org/about/aboutuspublications/BoardStrategicPlan2019-2022.pdf

Metro Vancouver. (2019b). *Open-Air Burning*. *October*.

Obi, F., Ugwuishiwu, B., & Nwakaire, J. (2016). Agricultural Waste Concept, Generation, Utilization and Management. *Nigerian Journal of Technology*, *35*(4), 957. https://doi.org/10.4314/njt.v35i4.34

Scano, E. A., Asquer, C., Pistis, A., Ortu, L., Demontis, V., & Cocco, D. (2014). Biogas from anaerobic digestion of fruit and vegetable wastes: Experimental results on pilot-scale and preliminary performance evaluation of a full-scale power plant. *Energy Conversion and Management*, *77*, 22–30. https://doi.org/10.1016/j.enconman.2013.09.004

Sullivan, P. (2003). Overview of Cover Crops and Green Manures. *Attra*, 16. https://cpb-us-e1.wpmucdn.com/blogs.cornell.edu/dist/e/4211/files/2014/04/Overview-of-Cover-Crops-and-Green-Manures-19wvmad.pdf

Upland Agriculture Consulting. (2019). *On-Farm Composting in British Columbia*. *December*. http://www.rdosmaps.bc.ca/min_bylaws/PublicWorks/SolidWaste/BC_Agriculture_Composting_Guide.pdf

Vancity. (2016). *Home on the Range: Cost pressures and the price of farmland in Metro Vancouver*. https://www.vancity.com/SharedContent/documents/pdfs/News/Vancity-Report-Cost-Pressures-and-the-Price-of-Farmland-in-Metro-Vancouver-2016.pdf

Woolf, D., Amonette, J. E., Street-Perrott, F. A., Lehmann, J., & Joseph, S. (2010). Sustainable biochar to mitigate global climate change. *Nature Communications*, *1*(5). https://doi.org/10.1038/ncomms1053

Appendices

Appendices

Appendix A

Questionnaire: Vegetative Agricultural Waste Management in Metro Vancouver

Landing Page

The goal of this questionnaire is to gather information on the types of vegetative wastes generated on agricultural sites in Metro Vancouver and how they are managed.

The questionnaire should take 5 to 10 minutes to complete.
[Privacy Statement]
Responses will be treated as strictly confidential and all comments will remain anonymous.
Your participation in this survey is greatly appreciated. If you have any questions regarding the questionnaire or your role as a participant, please contact the Project Manager, Amy Sigsworth.
Select 'Next' to continue

Section 1: Agricultural System Details [New Page]

Questions
Q1 What best describes your current or most recent affiliation to the agricultural sector in Metro Vancouver? Select all that apply.

◯ Farm owner or manager

◯ Farm employee

◯ Agricultural organization/society employee

◯ Natural resource professional (e.g. agrologist, biologist, forester)

◯ Government employee

◯ Non-profit organization employee

◯ Other (please specify) ____

◯ Not applicable: all affiliations are outside Metro Vancouver region

Q2 What agricultural products are generated in the production system that you are currently or were most recently associated with? Select all that apply.

◯ Annual crops (vegetables, herbs)

◯ Bush fruits (blueberries, cranberries, blackberries, raspberries)

◯ Floriculture products (flowers and ornamentals)

◯ Christmas trees

◯ Tree fruits and nuts

◯ Forage or fodder crops

◯ Timber or wood products

◯ Beef

◯ Pork

◯ Dairy

◯ Poultry and/or egg

◯ Mushroom

◯ Other (please specify) ____

Q3 What scale of production is the system that you are or were most recently associated with? You may skip this question if it is not applicable.

○ Micro (< 1 acre)

○ Very Small (1 to 9 acres)

○ Small (10 to 29 acres)

○ Medium (30 to 229 acres)

○ Large (230+ acres)

Section 2: Waste Management [New Page]

Q4 What type of vegetative waste is generated in the agricultural production system you are or were most recently associated with? Select all that apply.

- ◯ Tree prunings
- ◯ Bush fruit prunings
- ◯ Land clearing debris
- ◯ Invasive or unwanted species
- ◯ Post-harvest crop residues
- ◯ Culled or unmarketable produce
- ◯ Post-processing residue
- ◯ Diseased vegetation
- ◯ Unused seeds or seedlings
- ◯ Leaves and grass clippings
- ◯ Wasted feed
- ◯ Bedding
- ◯ Other (please specify) ____

Q5 What strategies are used to manage the vegetative waste generated? Select all that apply.

- ◯ Burn
- ◯ Compost
- ◯ Reincorporate into soil
- ◯ Reuse on farm (e.g. mulch)
- ◯ Transport to green waste facility or transfer station
- ◯ Send to other sector for reuse
- ◯ Land spread
- ◯ Livestock feed
- ◯ Bury
- ◯ Other (please specify) ____

Q6 In your opinion, what is the overall most effective method for managing agricultural vegetative waste?

○ Burn

○ Compost

○ Reincorporate into soil

○ Reuse on farm (e.g. mulch)

○ Transport to green waste facility or transfer station

○ Send to other sector for reuse

○ Land spread

○ Livestock feed

○ Bury

○ Other (please specify) ____

Q7 Based on the answer given above, what is the most important consideration when choosing a management strategy? Rank by order of importance (1 = most important; 4 = least important).
_______ Cost
_______ Time
_______ Logistics
_______ Environment

Section 3: Optional: Statement on Barriers [New Page]

Q8 If desired, please leave a comment on what you believe to be significant barriers to reducing, reusing, and/or recycling vegetative agricultural waste in Metro Vancouver. (optional)

[Concluding Statement]

Thank you for taking the time to complete this questionnaire.

Please help distribute the questionnaire by forwarding the following anonymous link to potential participants: https://ubc.ca1.qualtrics.com/jfe/form/SV_a01OxcL9Tnpr6YJ

Appendix B

Table 5. Vegetative agricultural waste inventory based on author's assumptions, observations and firsthand information from practitioners. Categories and crop type included in this table were obtained and modified from the B.C. Ministry of Agriculture (2014c).

Category	Crop type	Waste characteristics							Material type
		Cull	Pruning	Post-harvest residue	Post-processing residue	Diseased vegetation	Unused seed/seedling	Wasted feed	Woody or herbaceous
Forage	Hay			X		X		X	H
	Silage			X		X	X	X	H
Pasture						X			H
Berries	blueberries	X	X		X	X	X		W
	cranberries	X	X	X	X	X	X		W
	strawberries	X	X	X	X	X	X		H
	raspberries	X	X		X	X	X		W
	blackberries	X	X		X	X	X		W
Vegetables	*Solanaceae* (nightshades)	X	X	X	X	X	X		H
	Fabaceae (legumes)	X		X	X	X	X		H
	Brassicaceae (brassicas)	X		X	X	X	X		H
	Apiaceae (root crops)	X			X	X	X		H
	Alliaceae (onion)	X			X	X	X		H
	Amaranthaceae (leafy greens)	X		X	X	X	X		H
	Cucurbitaceae (cucumbers, squash, melon)	X	X	X	X	X	X		H
	Asteraceae (lettuce)	X		X	X	X	X		H
Nursery & tree plantations	Nursery	X	X	X	X	X	X		W/H
	Tree plantations	X	X	X	X	X	X		W
Cereals		X		X	X	X	X		H
Other	Fallow land					X			W/H
	Cover crop			X	X	X	X		H
Turf		X			X	X	X		H
Vines	Grapes	X	X		X	X	X		W
	Kiwis	X	X		X	X	X		W
Nut trees	Hazelnut/filbert	X	X		X	X	X		W
	Walnut	X	X		X	X	X		W
Tree fruits	Apples	X	X						W
	Cherries	X	X						W
	Pears	X	X						W
	Plums	X	X						W
Specialty	Herbs	X	X						W/H
	Rhubarb	X			X	X	X		H
Floriculture		X	X	X	X	X	X		W/H

Table 6. Percent of agricultural land cover in Metro Vancouver. Data was modified from the ALUI report (B.C. Ministry of Agriculture, 2014c)

Land cover		Total area (ha)	Percent total
Actively farmed	Cultivated field crops	27,984	90.23
	Farm infrastructure	1,732	5.58
	Greenhouses	453	1.46
	Crop barns	23	0.07
Inactively farmed	Unused forage or pasture	680	2.19
	Unmaintained field crops	128	0.41
	Unmaintained greenhouses	13	0.04
	Unmaintained crop barn	2	0.01
Farmed total		**31,015**	**100.00**

Appendix C

Definition of terms included within the "cultivated field crop" grouping. These terms and their definition were taken directly from the Metro Vancouver Regional District ALUI by the B.C. Ministry of Agriculture (2014).

Forage & pasture	Grass, legumes, forage corn
Berries	Blueberries, cranberries, strawberries, raspberries, mixed berries, blackberries
Vegetables	Potatoes, mixed vegetables, legumes, sweet corn, cucurbits, cole crops (brassicas), root vegetables (other), Asian vegetables, carrots, miscellaneous vegetables, leafy vegetables
Nursery & tree plantations	Nursery (ornamentals & shrubs, cedar hedging, forestry stock, mixed), tree plantations (Christmas trees, fibre/pulp/veneer trees)
Cereals	Barley, oats, wheat, mixed
Other	Bare cultivated land, fallow land, land in crop transition, land planted in cover crops to manage soil moisture/erosion associated with a cultivated crop
Turf	Lawn grass
Vines	Grapes, kiwis
Nut trees	Hazelnut/filbert, walnut
Tree fruits	Apples, cherries, pears, plums, mixed
Specialty	Herbs, rhubarb
Floriculture	Flowering and ornamental plants