

**URBAN FOREST WASTE GENERATION AND
UTILIZATION IN NORTH CAROLINA:
A SURVEY STUDY OF CURRENT
PRACTICES AND PERCEPTIONS**

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and Environmental Conservation*

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About this Report

In this report are the results of a survey study conducted in 2014 for the North Carolina Forest Service by the Virginia Tech Department of Forest Resources and Environmental Conservation. This study has not been peer-reviewed and should not be quoted or cited without permission of the principal investigator.

Funding for this study was provided by the USDA Forest Service. The survey was conducted with the oversight of the Institutional Review Board of Virginia Tech. All documentation for the survey is on file with Virginia Tech. Questions about the survey should be directed to the principal investigator. The authors thank Nancy Stairs and Eric Muecke with the North Carolina Forest Service for their assistance with compiling the contact lists for the municipalities and the Southern Chapter of International Society of Arboriculture for providing the contact list for certified arborists.

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Executive Summary

In 2014, a study was conducted to understand the current practices and perceptions of urban forest waste (UFW) generation and utilization in North Carolina. A web-based survey was administered to two professional groups directly involved in UFW generation and utilization: (1) employees of select North Carolina municipalities and (2) International Society of Arboriculture Certified Arborists with business addresses in North Carolina.

Overall response rate to the survey was 39% (municipal: 65%; certified arborist: 32%). Municipal respondents were primarily planners, managers, and administrators. About 22% were municipal arborists or urban foresters. Half of private sector certified arborists were employed by a tree care company or consulting firm, predominately in a managerial role. Nearly three-fourths of municipal and private respondents indicated that their local operation generates UFW. Of those operations that generate UFW, about three-fourths of private operations indicated that they could not provide an estimate of the amount of UFW they generate per unit time (weekly, monthly, yearly). Just over half of municipal operations indicated that they could estimate UFW generation.

Municipal UFW was reported as originating in roughly equal parts from private lands and from municipal lands. Curbside pickup of UFW generated by citizens accounts for nearly half of municipal UFW. Urban forest waste generated by private operations mostly originates from private residential and commercial lands and nearly all of this UFW comes from tree pruning and removal. Although the sample size was small, the most common fate for logs, wood chips, and brush generated by municipalities is disposal at a solid waste facility. What ultimately happens to this material could not be determined from the survey. Wood chip utilization is the most common in-house utilization practice of municipalities, the vast majority of which is processed into mulch and secondarily into compost. Private operations utilize the majority of their logs and wood chips, either in-house or by transfer to a 3rd party processor. When utilized in-house, their UFW is most commonly processed into firewood, mulch, or compost.

The strongest motivations and incentives for UFW utilization by municipal and private operations are environmental sustainability and avoidance of transportation and disposal costs. Neither group had a strong viewpoint that UFW utilization is a major issue for the urban forestry industry now or in the near future. Perceived barriers to UFW utilization were quite varied and no single barrier stood out amongst both groups. Logistical difficulties of transporting, stockpiling, and processing UFW were the most frequently cited barriers. Although lack of local processors of UFW was a common barrier, lack of local consumers for urban forest products was not perceived as a barrier relative to other issues.

Respondents did not express a strong interest in self-education or training about UFW utilization and were indifferent about the quality of existing educational or training programs. No clear interest was evident in any particular educational medium or venue. However, in terms of technical assistance, there was strong interest in a centralized facility for stockpiling and processing UFW and an urban forest product cooperative. Private sector arborists also favored an online database to network themselves with enterprises that process UFW and create urban forest products.

Introduction

Background

The Virginia Department of Forestry (VDof) and the North Carolina Forest Service (NCFS) partnered in a competitive grant proposal to provide information and education – as well as identify the current conditions and barriers – for utilization of interface and urban wood resources. VDof contracted with the Virginia Tech Department of Forest Resources and Environmental Conservation (VTFREC) to develop and conduct a survey to understand practices and perceptions of urban forest waste utilization in urban areas of Virginia. The Virginia survey was conducted in early 2014.

As was the original intent of its grant partnership with VDof, NCFS earmarked grant funds to conduct a similar survey in North Carolina. NCFS contracted with VTFREC and used the survey instrument developed by VTFREC for VDof (with minor modifications as deemed necessary by NCFS) to conduct a complimentary survey in urban areas of North Carolina during late 2014. By partnering with VTFREC to utilize survey work already underway in Virginia, this project was deemed to be an effective use of funds to provide information that NCFS can use in addressing the utilization of interface and urban wood resources in North Carolina.

Federal support of the North Carolina Urban and Community Forestry Program (NCUCF) is authorized by the Cooperative Forestry Assistance Act of 1978 (P.L. 95-313) as amended. The program operates as a cooperative partnership between the USDA Forest Service–Southern Region and NCFS. The mission of NCUCF is to develop, enhance, and support sustainable urban and community forestry programs throughout North Carolina by encouraging citizen and community involvement. The overall goal of the competitive grant that supported VTFREC’s survey study is to identify opportunities for outreach, education, and targeted messaging for communities, businesses, and other stakeholders with the goal of increasing awareness and subsequent utilization of wood resources that, more often than not, end up in the waste stream rather than the wood supply stream. In order to achieve this goal, outreach and education is necessary to increase community understanding of the benefits and opportunities for utilizing urban forest waste. The results of the survey study will provide baseline information for developing technical assistance and outreach programs to advance this programmatic goal in North Carolina.

Justification

The population of urban areas in North Carolina is growing. Although urban lands currently occupy only 9% of the state’s land base, 66% of the state’s inhabitants (6.3 million people) reside in urban areas (US Census Bureau 2010). In the 2000s, North Carolina’s population grew by about 1.5 million people (US Census Bureau 2011) and is projected to grow by about 2.04 million people between 2010 and 2030 (NC OSBM 2014). Most of these new inhabitants will reside in urban areas. With this growth in urban population will come growth of interface and urban forests.

North Carolina has a substantial urban tree resource. There are an estimated 663 thousand hectares of urban and community tree cover in the state (Nowak and Greenfield 2012a; Nowak and Greenfield 2012b), comprising nearly 203 million trees (Nowak and Greenfield 2009). As urban

areas grow, a substantial acreage of existing forest is urbanized and numerous trees are planted in new developments. In managed landscapes, urban trees are continually cut down and disposed as they die off, are destroyed by storms and pests, or are displaced by land development. As a result, there is the potential for substantial forest waste generation in North Carolina's urban areas.

Urban forest waste (UFW) can be described collectively as the logs, brush, and chips generated using arboricultural practices on an urban or community tree grown on residential or municipal lands (Tree Care Industry Association, Inc. 2013). Historically, much of this material has been shipped and disposed in landfills rather than utilized as a renewable natural resource (NEOS Corporation 1993; Nowak et al. 2001; Bratkovich et al. 2008). Urban forestry experts have identified UFW utilization in particular as an essential component of the sustainable urban forest management system (Clark et al. 1997), but little is known about the existing conditions and perceptions of utilization within North Carolina. It is believed that increased UFW utilization will improve the economic and environmental sustainability of the urban forestry industry, but more must be known about the state of UFW utilization in North Carolina before that belief can be confirmed. Therefore, there is a need to compile baseline data on UFW generation and utilization in North Carolina's urban areas.

The fate of UFW has come into question in recent years as localities grapple with the costs and logistics of dealing with the material. Localities that operate solid waste disposal programs process UFW primarily from private landowners and commercial tree care companies and secondarily from their own municipal trees and forests. Although much of this material has been historically landfilled, anecdotal evidence suggests that municipalities are moving away from landfilling for various regulatory reasons and instead are processing the material into products such as landscape mulch or compost. There are also some reports that these materials are finding their way into the forest products and biofuel supply chains. However, there is no empirical data on any of these utilization practices for UFW in North Carolina. Without this information, it is difficult for NCFS and NCUCF to provide municipalities and the green industry with targeted guidance on management options, regulatory policies, and utilization markets.

There are two primary producers of UFW in North Carolina – private arboricultural operations and municipal operations. Private operations consist of tree care companies, landscape companies, electric service providers, and various institutions such as universities and arboreta. Municipal operations vary by locality, but are typified by departments and divisions tasked with maintaining municipal trees and/or collecting/processing UFW generated by citizens. Private operations are often contracted by municipalities to perform work on municipal trees and electric service providers to manage vegetation in their rights-of-way. It is believed that the majority of UFW generated in North Carolina can be accounted for when combining the UFW generated by both private arboricultural operations and municipal operations.

Private arboricultural operations make a substantial contribution to urban forest waste as they prune and remove trees on their clients' properties. Anecdotal reports indicate that most operations view this material strictly as a cost of doing business. At best, they break even by transferring the material to a 3rd party that processes it for firewood, lumber, mulch, or compost. At worst, operations are paying exorbitant annual fees to dispose of material at either municipal or private facilities. There are infrequent reports of companies that have developed auxiliary businesses to utilize UFW for various

value-added products. At present, the amount and fate of UFW generated by commercial operations in North Carolina is not known. Moreover, it is unclear whether these operations are aware of or interested in the possible business opportunities that UFW utilization might afford them. This information is foundational to developing continuing education and technical assistance programs in UFW utilization and to managing the state's urban and community forests sustainably.

Given the inherent differences between municipal and private operations, it is important to distinguish between the two when investigating the practices and perceptions of UFW utilization in North Carolina. Municipal operations are government entities that must conform to regulatory and budgetary constraints, while private operations are largely focused on generating revenue. The incentives and barriers to UFW utilization are thought to be different between each sector, as are the opportunities for outreach and education for them. As a result, the study findings reported here are sub-divided by and compared between municipal and private operations.

Study Goals and Objectives

The goal of this study was to better understand UFW generation and utilization in urban areas of North Carolina. Specific objectives of the survey were to:

- Estimate the amount of UFW generated through municipal and private arboricultural operations in urban localities of North Carolina.
- Characterize the fate of UFW generated through municipal and private arboricultural operations in urban localities of North Carolina.
- Examine the perceptions of municipal administrators and private sector professionals about the needs, opportunities, and barriers to UFW utilization in urban localities of North Carolina.

Study Methods

Sampling Frame

This survey study focused on professionals whose work directly relates to generation and utilization of urban forest waste (UFW) in urbanized areas of North Carolina. The sampling frame to which the survey instrument was administered comprised two distinct groups – municipalities and private arboricultural operations.

A total of 69 urbanized municipalities were hand-selected by NCFS for inclusion in the sampling frame (Appendix I). For every municipality, a list of employees responsible for managing municipal UFW (i.e., tree debris generated by municipal forestry operations or collected from citizens) was obtained by NCFS and given to VTFREC. In instances where NCFS did not have an existing contact, an appropriate survey recipient was chosen by searching that municipality's website for the employee with the most relevant job title – often the Director of Public Works or Director of Parks and Recreation. In the survey solicitation, all municipal contacts were asked to forward the survey to another municipal employee if they felt they were not qualified to report on the municipality's generation or utilization of UFW. Only one employee was solicited for the survey for each municipality and was asked to report on the UFW generated by the entire municipal operation.

The second group in the sampling frame was private arboricultural operations. International Society of Arboriculture (ISA) Certified Arborists were selected to represent private arboricultural operations in the sampling frame. ISA Certified Arborists work in a variety of industries, ranging from tree care to landscaping to consulting. Although certified arborists do not account for all UFW generation in the private sector, they are a well-defined population that is easily enumerated through the ISA and is easily engaged for education, outreach, and technical assistance programs. Contact information for certified arborists with a mailing address in North Carolina (totaling 568 individuals) was obtained from the Southern Chapter of the ISA, and recipients were pre-notified of the upcoming survey through an assortment of organizational and agency media (e.g., email listservs, newsletters, etc.). To minimize double-reporting in the survey, certified arborists who responded to the survey were asked to be the sole respondent for their local operation.

Survey Instrument

Both groups were administered the same web-based survey instrument. There are several advantages to using electronic surveys instead of on-site, mail, or telephone surveys. Electronic surveys can be longer and more complex, yet still have high response rates and remain cost effective (Vaske 2008). The use of web-based survey software also makes data collection and analysis much more efficient (Griffis et al. 2003). Web-based surveys have been used successfully for conducting forestry research in the past (Poudyal et al. 2010; Fowler 2012; Kimball et al. 2014).

Before being distributed, the survey instrument was pilot-tested by both arborists and municipal employees in Virginia and revised for clarity and ease of use. The North Carolina survey was administered in late summer 2014 using a modified Tailored Design Method (Dillman 2000). This

study was limited to three personalized contacts per recipient and did not include a financial incentive for participation. The Qualtrics online survey platform (Qualtrics, Provo UT) was used to generate an individual survey web link for each survey recipient. Contrary to widely distributed anonymous links, individual links enable each survey response to be tied to that recipient's email address, thus reducing the chances of duplicate responses from an operation. Members of both groups received an email containing a formal invitation and a web link to the survey. Two email reminders were sent to non-respondents over the next few weeks.

Survey questions were presented in a variety of formats (Appendix II). First, respondents were asked to answer basic multiple-choice demographic questions about their age, gender, education, and professional experience. Further multiple-choice questions were used to classify the respondents' industry sector (i.e., municipality, business, or organization) and position within their local operation. Respondents were then asked whether their local operations conduct tree work in-house and directly generate UFW or hire contractors to complete this work. Those who responded "Yes" were forwarded to questions about their operation's characteristics, the amount and fate of UFW produced, and trends in past and future UFW generation and utilization.

Survey questions about operational characteristics classified each respondent's operation based on number of employees and municipal location of their operation. Respondents were then asked to report about their operation's UFW generation in terms of the land use origin (e.g., private residential, public greenspace, etc.) and tree management practices (e.g., pruning, tree removal, curbside debris pick-up, etc.). Because operations often do not monitor or track their UFW generation, a screening question was first asked of respondents about their ability to report on UFW generation by their operation. If the respondents confirmed that they had knowledge of UFW generation, then they were asked to estimate the amount of logs, brush, and chips that their operations generate. If the respondents were unable to provide an estimate, then they were forwarded to a series of similar questions about the fate of their operation's UFW. If one of the UFW fates selected was "utilized in-house", then the respondents were asked to specify what sort of urban forest products (UFPs) result from their UFW utilization. Finally, respondents were asked to report on their operation's trends in past and future UFW generation and utilization.

Perception questions prompted the respondents to select their level of agreement with various statements about UFW utilization. The first group of statements proposed *a priori* reasons for increasing UFW utilization, the second group of statements revolved around the importance of UFW utilization, and the third group of statements related to self-education and training opportunities on UFW utilization. Additional perception questions prompted the respondents to rank the most significant incentives and barriers to UFW utilization as well as certain educational or technical programs based on their potential to increase their capacity for UFW utilization. Respondents were asked to identify and rank at least three incentives, barriers, and educational or technical programs from an *a priori* list. A fill-in-the-blank for "other" was also provided.

After closing the survey, data were exported from Qualtrics, screened for errors and omissions, organized, and analyzed using Microsoft Excel and SPSS Statistics 22 (IBM, Armonk NY). Descriptive statistics were then generated for the survey data to report on respondent and operational characteristics. Further statistical analyses were used to examine the current conditions and

perceptions of UFW generation and utilization. Descriptive statistics were used to examine the project objectives of describing UFW amounts, fates, and perceptions, while inferential statistics were used to answer the associated research questions regarding any difference in responses between municipal and private operations.

For each survey question, responses from municipal employees and private arborists were tested for significant differences using a Chi-squared test. For categorical questions resulting in ordinal data, the null hypothesis was that the distributions of responses across all answer choices were the same for both municipal and private responses. For percentage or fill-in-the-blank questions resulting in scale data, the null hypothesis was that the distributions of responses for each answer choice were the same for both municipal and private responses. In Tables 1 – 9 of the Study Findings section, a single p-value is reported for questions resulting in ordinal data, while p-values for questions resulting in scale data are reported in a separate column next to each answer choice. Null hypotheses (no differences between study groups) were tested at the $\alpha = 0.05$ significance level.

Study Findings

Survey Response

Survey invitations were distributed to individual certified arborists and municipal employees using the Qualtrics web mailer. After importing ISA Southern Chapter's mailing list of all 568 certified arborists operating in North Carolina, the Qualtrics mailer generated individual links and an email invitation was manually mailed to each individual. Several of the email invitations were immediately returned because the email address of the recipient was invalid. In addition, several of the certified arborists were also the primary contact for municipalities in the sampling frame (and were therefore moved over into the municipality group). As a result, the effective sampling frame for certified arborists was 531 individuals. Of these, survey responses were received from 170 individuals, resulting in a response rate of 32% for certified arborists. Some of these respondents reported at the beginning of the survey that they were either not directly involved in the generation of UFW or not in a position to report on the generation of UFW by their local operation, so they were forwarded to the perceptions section of the survey, resulting in sample sizes lower than 170 for some of the survey questions about UFW waste generation and utilization. Sample sizes for certain questions also vary because of question forwarding and incomplete responses. Of the 69 solicited municipal employees, 45 responded to the survey, resulting in a response rate of 65%. Two responses were accepted from High Point, NC because this municipality also runs a stand-alone composting program.

Respondent and Operational Characteristics

Responses to demographic and operational survey questions were used to characterize the private sector arborist and municipal employee groups (Table 1). The majority of respondents tended to be male, between 30 and 60 years of age, have completed some level of higher education, and have more than 10 years of professional experience. Several demographic differences were observed between municipal employees and private sector arborists. Private arborists were younger ($p = 0.005$) while municipal employees were more highly educated ($p = 0.037$). In the private sector, over half of respondents reported being employed by a tree care company, landscape company, or consulting firm. The statistic that 13% of private arborists reported municipality as their industry sector is assumed to be a response error (clicked on wrong button) or a misunderstanding of the question (may have thought the question was asking whom do they contract for). Over three-fourths of the private sector arborists reported being the manager of either a local or regional operation. Municipal employees reported holding a wide range of positions – planners, managers, and public works administrators accounted for over half of respondents whereas arborists and urban foresters accounted for less than a quarter of respondents.

There was a strong dichotomy in the size of private operations; almost two-thirds of private operations reported 10 or fewer employees, yet one-quarter reported having over 20 employees (Table 2). Municipal operations had a similar dichotomy; over two-thirds reported having 10 or fewer employees, yet one-quarter reported having 16 or more employees. Operation size not only has an influence on the generation of UFW, but also may influence an operation's capacity to utilize UFW. Larger operations may have more diversified and specialized skill sets amongst employees for

Table 1: Characteristics of municipal employees and private sector certified arborists in North Carolina who responded to a survey on perceptions of urban forest waste (UFW). Where provided, p-values indicate the statistical probability that municipal and private operations do not differ for the characteristic of interest.

Age (p-value = 0.005)	Municipal (n=42)	Private (n=163)
18-30	5%	14%
31-44	26%	42%
45-60	64%	34%
61+	4%	10%
Gender (p-value = 0.094)	Municipal (n=42)	Private (n=164)
Female	17%	20%
Male	83%	80%
Education (p-value = 0.037)	Municipal (n=42)	Private (n=164)
High school or equivalent	10%	18%
Associate degree	14%	26%
Bachelor's degree	45%	41%
Graduate degree	31%	15%
Experience (p-value = 0.369)	Municipal (n=42)	Private (n=164)
0-10	24%	24%
11-20	33%	35%
21-30	33%	23%
31+	10%	18%
Industry Sector	Municipal (n=42)	Private (n=164)
Municipality	98%	13%
Tree care company	0%	40%
Landscape company	0%	4%
Consulting Firm	0%	10%
Institution	0%	15%
Electric service provider	0%	8%
NC Dept. of Transportation	2%	10%
Position within municipal sector	Municipal (n=40)	Private (n=0)
Arborist	12%	n/a
Horticulturist	0%	n/a
Urban Forester	10%	n/a
City/Town/County Manager	10%	n/a
City/Town/County Planner	32%	n/a
Public Works Administrator	15%	n/a
Parks and Recreation Administrator	8%	n/a
Solid Waste Administrator	8%	n/a
Other	5%	n/a
Position within private sector	Municipal (n=0)	Private (n=70)
Manager of regional operation	n/a	16%
Manager of local operation	n/a	63%
Manager of production crew	n/a	8%
Member of production crew	n/a	7%
Other	n/a	6%

processing UFW. Likewise, larger operations may have better physical assets such as specialized equipment or greater real estate space, allowing them to stockpile and process UFW more readily than small operations.

Urban Forest Waste Generation

Origins of Urban Forest Waste

Nearly three-quarters of respondents in both municipal and private operations reported that their local operation generates UFW (Table 2). As expected, the land use origin of UFW generated by private operations was mostly private residential (39%) and private commercial (16%) (Table 3). A substantial portion (28%) of private operation UFW also came from public and municipal lands, suggesting that many of the responding private operations hold municipal contracts. UFW generation on NCDOT and electric utility rights-of-way was comparatively low, but this may simply be a reflection of the private sector respondent pool.

Table 2: Characteristics of municipal and private sector operations in North Carolina that responded to a survey on urban forest waste (UFW) generation. Where provided, p-values indicate the statistical probability that municipal and private operations do not differ for the characteristic of interest.

Number of employees in the local operation (p-value = 0.367)	Municipal (n=31)	Private (n=120)
0-5	29%	42%
6-10	39%	21%
11-15	6%	7%
16-20	16%	4%
21+	10%	26%
The local operation generates UFW (p-value = 0.638)	Municipal (n=42)	Private (n=160)
Yes	71%	75%
No	29%	25%
Ability to estimate amount of UFW generated by the local operation (p-value ≤ 0.001)	Municipal (n=32)	Private (n=109)
Keep detailed records	22%	1%
Can provide an estimate	34%	24%
Cannot provide an estimate	44%	75%
Ability to identify fate of UFW generated by the local operation (p-value = 0.388)	Municipal (n=32)	Private (n=105)
Keep detailed records	19%	1%
Can provide an estimate	37%	50%
Cannot provide an estimate	44%	49%

Over 40% of municipal UFW was reported as originating on private lands (Table 3). This high percentage might be explained in part by the practice of municipal curbside pickup of citizen-generated UFW, which was reported as accounting for 44% of municipal UFW generation. As expected, about half of municipal UFW came from public greenspace and municipal street rights-of-way, both of which were statistically more frequent for municipalities than for private operations. The only other statistical difference between municipal and private operations was that private operations generated UFW on electric utility ROWs about twice as frequently as municipalities, which makes sense given that municipal utilities are relatively uncommon compared to private utilities.

Table 3: Generation of urban forest waste (UFW) by municipal and private sector operations in North Carolina based on self-reported survey data. Where provided, p-values indicate the statistical probability that municipal and private operations do not differ for the characteristic of interest.

Land use origin of the UFW generated by the operation	Municipal (n=32)	Private (n=114)	p-value
Private residential	36%	39%	0.418
Private commercial	6%	16%	0.873
Public greenspace	25%	18%	0.037
Municipal street ROW	24%	10%	≤ 0.001
NC DOT roadside ROW	6%	4%	0.225
Electric utility ROW	3%	8%	0.001
Other	0%	5%	0.447
Management practices that generate the operation's UFW	Municipal (n=32)	Private (n=111)	p-value
Tree pruning	23%	44%	0.271
Tree removal	22%	42%	0.226
Curbside pickup	44%	5%	≤ 0.001
Small woodlot logging	4%	3%	0.867
Land Clearing	6%	5%	0.666
Other	1%	1%	0.363

As expected, private operations reported that nearly all of their UFW is generated from tree pruning and removal (Table 3). Small woodlot logging was rarely reported by private arborists; this could be a possible growth area for arborists in the future and warrants further investigation. Tree pruning and removal accounted for nearly half of municipal UFW generation, which is consistent with the large volume of vegetation management they do in greenspaces and rights-of-way. The other half of their UFW generation was mostly curbside pickup of residential debris, which was the only practice that municipalities performed at a statistically higher frequency than private operations.

Amount of Urban Forest Waste

Respondents were asked if they could estimate the amount of UFW that their local operations generate. The majority of private operations (75%) indicated that they cannot estimate their UFW generation (Table 2). Municipal operations were much more familiar with their UFW generation; less

than half indicated that they cannot provide an estimate of UFW generation. Moreover, nearly one-fourth of municipal operations reported keeping detailed records of their UFW generation, which contrasted sharply with only 1% of private operations reporting that they keep detailed records. Municipalities may be required by law to more closely monitor the amount of UFW they generate compared to the private sector.

Because only about half of the respondents that actually generate UFW indicated that they could estimate the amount of UFW they generate, the sample sizes used for quantifying the amount of UFW generation were fairly low and the data were quite variable, even after adjusting the data for the number of employees in each operation (Table 4). The coefficient of variation is reported for the UFW type generated by each operation type. This statistic is computed by dividing the standard deviation by the mean and multiplying by 100. In every case, the coefficient of variation was well over 100% and ranged as high as 529%. This statistic is an indicator of highly variable data, and it is difficult to make any strong inferences from it. Extreme variability could be a consequence of at least two different scenarios. First of all, if operations are rarely keeping detailed records of UFW generation, then the estimates provided in this survey were likely just a “best guess” based on memory and day-to-day experience. This situation is very susceptible to reporting errors. Second, tree management operations vary considerably in the blend of work that they perform. For example, municipal or private operations that specialize in clearing vegetation on rights-of-way or hauling curbside debris would have a much higher UFW generation rate per employee than operations that specialize in pruning of street or residential trees, which is a very time-intensive process that generates relatively small amounts of debris per unit of employee time.

Based on the total amount of UFW generated by operations on an annual basis, a percentage breakdown of these UFW types was calculated (Table 4). From the reported data, about two-thirds of municipal UFW is chips and about one-quarter is brush. Logs were a very minor component of municipal UFW generation. Chip and log generation by private operations showed an opposite trend to municipalities; the majority of private sector UFW was from logs followed by brush. Unexpectedly, chips were a minor component of UFW generation. Given the small sample size and the extreme variability in the data, drawing firm conclusions from these data is inadvisable.

Urban Forest Waste Utilization

Familiarity with Fate of UFW

Once UFW is generated, it can end up in a lot of different places (termed “fate” here), and these endpoints may or may not result in utilization of the UFW. In this survey, respondents were asked to report the percentage breakdown of their UFW to various endpoints. Two of these endpoints likely result in no or limited UFW utilization: (1) disposed at a solid waste facility, or (2) left on-site without utilization. Three other endpoints are known to result in UFW utilization: (1) utilized in-house by the operation, (2) utilized on-site by the landowner, or (3) transferred to a 3rd party for utilization.

Respondents were asked if they could identify the fate of the UFW that their operations generate (i.e., where does their UFW end up and what happens to it). Private operations had a better understanding of the fate of their UFW than they did of the amount that they generate; just over half

said that they could identify where their UFW ends up (Table 2). Municipal operations were slightly more confident in knowing the fate of their UFW. As with the amount of UFW generation, municipalities more frequently kept detailed records of UFW fate compared to private operations (19% vs. 1%). Municipalities may be required by law to more closely monitor the fate of the UFW that they generate compared to the private sector.

Table 4: Amount of urban forest waste (UFW) generated by municipal and private sector operations in North Carolina based on self-reported survey data. Sample comprises only those operations that indicated they generate UFW and could provide an estimate. Where provided, p-values indicate the statistical probability that municipal and private operations do not differ for the characteristic of interest.

	Logs		Chips		Brush	
	----- tons year ⁻¹ employee ⁻¹ -----					
	Municipal Operations	Private Operations	Municipal Operations	Private Operations	Municipal Operations	Private Operations
Sample size (n)	17	30	17	30	17	30
Minimum	0	0	0	0	0	0
First quartile	0	0.5	0.1	0.3	0	0
Median	0	2.8	23.8	3.8	0.6	0.3
Third quartile	7.5	6.4	533.2	27.1	289.1	3.3
Maximum	500.0	3,333.3	3,125.0	333.3	1,222.2	533.3
Mean	40.7	114.9	459.2	33.1	180.3	47.5
Standard Deviation	123.8	607.9	879.6	70.8	314.4	130.5
Coefficient of Variation	304%	529%	192%	214%	174%	275%
Avg. % of total UFW	6%	59%	67%	17%	27%	24%

Fate and Utilization of Logs

Over two-thirds of logs generated by municipalities are disposed at a solid waste facility (Table 4). This finding was surprising because a high degree of log utilization was an expected outcome of the survey. It is quite possible that municipal respondents misinterpreted the meaning of disposal used in the survey although the survey question was worded such that disposal implied no utilization. This could also be an anomaly of the low sample size for this question (n=9). Compared to other UFW types, municipalities rarely generate logs and therefore the concept of log utilization may be unfamiliar. Likewise, it is often reported that utilization of logs from municipal forests is difficult due

to issues with wood quality and embedded objects that damage milling equipment. So municipalities may be foregoing utilization due to these concerns. Only three municipalities indicated that they utilize logs in-house, so generalizations are very difficult. With that said, the responses were as anticipated; the majority of log utilization goes to firewood, followed closely by lumber.

Table 4: Fate of the log component of UFW generated by municipal and private sector operations in North Carolina and the urban forest products (UFPs) created from these logs when utilized in-house by the operation (based on self-reported survey data). Where provided, p-values indicate the statistical probability that municipal and private operations do not differ for the characteristic of interest.

Fate of logs generated by the local operation	Municipal (n=9)	Private (n=45)	p-value
Utilized in-house to produce urban forest products	8%	25%	0.829
Transferred to a 3rd party for utilization as urban forest products	11%	34%	0.588
Disposed at a solid waste facility or elsewhere	68%	22%	0.118
Left on-site, resulting in no utilization	6%	8%	0.725
Left on-site for utilization by property owner	7%	11%	0.410
UFPs created from logs utilized in-house by the local operation	Municipal (n=3)	Private (n=27)	p-value
Firewood	46%	57%	0.431
Lumber	33%	19%	0.942
Pallets	7%	1%	0.145
Furniture	7%	1%	0.023
Cabinetry	7%	0%	0.050
Flooring	0%	0%	n/a
Veneer	0%	0%	n/a
Art/Novelty	0%	1%	0.916
Other	0%	21%	0.908

Log utilization by private operations conformed more closely with expectations. About 70% of private operation logs were utilized in some manner. The most common fate of logs was transfer to a 3rd party for utilization. About one-quarter of logs generated by arborists are utilized in-house, the majority of which end up being processed into firewood or lumber. Unexpectedly, about 21% of logs were reported as being processed into products in the “other” category. Examples of “other” products include pulp and railroad ties. Given that there is a high volume of southern yellow pines on the piedmont and coastal plain of North Carolina, it is not surprising that a lot of logs are processed as pulp, particularly in the urban interface. One positive observation is that both municipal and

private operations rarely leave logs on-site unutilized. This may more so be a cosmetic implication because logs left on site are often considered an eyesore or nuisance in urban areas.

Fate and Utilization of Wood Chips

As with logs, a higher than expected amount of wood chips generated by municipalities were reported to be disposed at a solid waste facility, although it was a minor portion of the chip volume (Table 5). Nearly a third of municipal wood chips are utilized in-house where the vast majority of them become mulch, which is often used on landscape beds, walking trails, and playgrounds in public areas. Municipalities transfer about 19% their wood chips to a 3rd party for utilization; presumably these chips are distributed to citizens for use as mulch, which is a common practice for municipalities.

Table 5: Fate of the wood chip component of UFW generated by municipal and private sector operations in North Carolina and the urban forest products (UFPs) created from these logs when utilized in-house by the operation (based on self-reported survey data). Where provided, p-values indicate the statistical probability that municipal and private operations do not differ for the characteristic of interest.

Fate of chips generated by the local operation	Municipal (n=13)	Private (n=43)	p-value
Utilized in-house to produce urban forest products	31%	46%	0.660
Transferred to a 3 rd party for utilization as urban forest products	19%	20%	0.795
Disposed at a solid waste facility or elsewhere	35%	12%	0.109
Left on-site, resulting in no utilization	6%	7%	0.863
Left on-site for utilization by property owner	8%	15%	0.732
UFPs created from chips utilized in-house by the local operation	Municipal (n=9)	Private (n=30)	p-value
Mulch	81%	73%	0.764
Compost	13%	18%	0.842
Biomass	3%	8%	0.843
Pellets	3%	1%	0.359
Other	0%	0%	n/a

Private operations have a very high utilization rate (over 80%) of their wood chips. Most of these chips are utilized in-house and almost all of them are utilized for mulch or compost. About 20% are transferred to a 3rd party for utilization. In-house and 3rd party transfers are probably a revenue stream for some operations. At the very least, it is a conscious cost-control measure because arborists rarely dispose their chips at a solid waste facility. A fairly active composting program for

chips is evident in both municipal (13%) and private (18%) operations, but chips are rarely used as biofuel by either group. Some chips are left on-site without utilization by both types of operations. This is probably most common for land clearing and rights-of-way maintenance operations where brush is run through a chipper and chips are strewn across the ground to decompose rather than incur the cost of hauling chips to a disposal facility.

Fate and Utilization of Brush

As with logs and wood chips, a high percentage of brush (46%) generated by municipalities is disposed at a solid waste facility (Table 6). It seems likely that much of this brush is being tub-grinded into mulch given regulations on landfilling vegetation. Also surprising was that almost half of municipal brush is being transferred to a 3rd party for utilization. In this case, it may be that a business is taking the brush from the municipality so that mulch or compost can be produced from it, but no data is available to support or refute this. Municipalities rarely process brush, as evidenced by the very low sample size; but in those cases, the majority of brush is being used for compost (59%), followed by biomass (26%), and mulch (15%).

Table 6: Fate of the brush component of UFW generated by municipal and private sector operations in North Carolina and the urban forest products (UFPs) created from these logs when utilized in-house by the operation (based on self-reported survey data). Where provided, p-values indicate the statistical probability that municipal and private operations do not differ for the characteristic of interest.

Fate of brush generated by the local operation	Municipal (n=11)	Private (n=32)	p-value
Utilized in-house to produce urban forest products	5%	33%	0.439
Transferred to a 3 rd party for utilization as urban forest products	41%	14%	0.083
Disposed at a solid waste facility or elsewhere	46%	33%	0.667
Left on-site, resulting in no utilization	4%	11%	0.812
Left on-site for utilization by property owner	4%	9%	0.730
UFPs created from brush utilized in-house by the local operation	Municipal (n=3)	Private (n=16)	p-value
Compost	59%	33%	0.362
Biomass	26%	1%	0.008
Mulch	15%	56%	0.596
Other	0%	10%	0.917

Private operations utilize about one-third of their brush with the majority of it being processed into mulch (56%) or compost (33%). Because brush is a fairly low-value raw material and is difficult to

handle, about one-third of private operation brush is disposed at a solid waste facility. For this reason, brush is rarely left on-site for by the property owner and is rarely left behind to decompose because it creates a mess and fire hazard in urban landscapes.

Perceptions of Urban Forest Waste Utilization

As has been pointed out throughout this report, the respondents to this survey represent a diversity of individuals employed by municipal and private operations of varying scale and scope. As a result, analyzing their perceptions of urban forest waste utilization in the aggregate may obscure some underlying beliefs or behaviors inherent to particular demographic groups. With that said, disaggregating the data into perilously small sample sizes can lead to bias or misrepresentation of sub-groups in the analysis. Because of this, the following sections treat the perceptions data in the aggregate, only distinguishing between municipal and private sector respondents. Still, caution must be taken with interpretation of the aggregated analysis, being careful not to over-generalize the findings to demographic sub-groups that are not well represented in the respondent pool of the survey.

Motivations and Perceptions

Respondents were asked to indicate their level of agreement with several *a priori* statements about motivations for UFW utilization. For the most part, municipal and private operations did not express a high level of agreement or disagreement with the statements (Table 7). In both cases, the most strongly agreed upon statement was increasing UFW utilization for environmental reasons. Both groups also slightly disagreed that regulatory compliance was a motivational factor. Financial and logistical reasons were slightly important motivations for both groups. There was no statistical difference between municipal and private operations in their responses to any of the statements about motivations for UFW utilization.

Both municipal and private operations felt that UFW utilization is not currently a major issue for urban forestry, but there was a slight indication that it might become an issue in the future (Table 7). Private operations agreed more strongly than municipalities that UFW utilization is important to their clients and that it represents a major disposal cost for their operations. In fact, UFW disposal cost was the most highly agreed upon statement of all among private operations. Sensitivity to clients' values may be greater within the private sector because they have more direct contact with their clientele than do municipalities, which may not interact with the public on a daily basis and thus be less attuned to their values. Municipal and private operations only slightly viewed UFW utilization as a major revenue source.

Table 7: Perceptions of municipal employees and private sector certified arborists about urban forest waste (UFW) utilization in North Carolina. Level of agreement questions are reported using this scale: 1 = strongly agree, 2 = somewhat agree, 3 = neither agree nor disagree, 4 = somewhat disagree, 5 = strongly disagree. Where provided, p-values indicate the statistical probability that municipal and private operations do not differ for the characteristic of interest.

My operation seeks to increase UFW utilization...	Municipal (n=42)	Private (n=143)	p-value
...for environmental reasons	2.60	1.61	0.509
...for financial reasons	2.76	2.66	0.301
...for logistical reasons	2.81	2.75	0.817
...for regulatory reasons	3.12	3.87	0.511
Urban forest waste...	Municipal (n=41)	Private (n=141)	p-value
...disposal is a major cost for my operation	2.39	1.90	0.066
...utilization is important to my clients	2.56	2.16	0.009
...utilization is a major revenue source for my operation	2.66	2.74	0.491
...utilization will be a major issue for the urban forestry industry in the future	2.93	2.91	0.332
...utilization is a major issue for the urban forestry industry currently	3.78	3.72	0.992

Incentives and Barriers

Respondents were then asked to identify both incentives and barriers to further UFW utilization. They were presented with a list of *a priori* incentives and barriers and asked to rank them from highest to lowest importance based on their perceptions.

The UFW utilization incentives most frequently ranked among the top-three incentives by municipal respondents were environmental sustainability (77%) and avoidance of transportation or shipping costs (72%) (Table 8). Beyond those two, there was no strong consensus amongst municipalities about incentives. Just under half of municipal respondents viewed UFW utilization as a value-added service (46%) or as a way to avoid disposal fees (46%). About one-third saw UFW utilization as an important means for additional revenue (31%) or to produce urban forest products (33%). Few municipalities considered UFW utilization to support local industries as being highly important to them.

Private operations favored similar UFW utilization incentives as the municipalities. About three-fourths of respondents viewed avoidance of transportation or shipping costs as an important incentive (Table 8). Also rated highly amongst arborists was UFW utilization for environmental reasons; about two-thirds of respondents ranked this incentive highly. Notably, nearly half of arborists rated additional revenue as a major incentive for UFW utilization. This suggests that private

operations might undertake UFW utilization if markets and networks could be profitably developed. About one-third of arborists concurred that avoidance of disposal fees is a major incentive for UFW utilization. This is roughly half the frequency reported for avoidance of transportation or shipping costs, which suggests that moving UFW around is more problematic than paying for its disposal.

Table 8: Perceptions of municipal employees and private sector certified arborists about incentives for further urban forest waste (UFW) utilization in North Carolina. Incentives are reported based on the percentage of respondents who ranked each incentive in their top three. Where provided, p-values indicate the statistical probability that municipal and private operations do not differ for the characteristic of interest.

Incentives for further urban forest waste utilization	Municipal (n=39)	Private (n=134)	p-value
Environmental sustainability of the operation/community	77%	66%	0.213
Avoidance of transportation or shipping costs	72%	74%	0.869
Value-added service to clients	46%	41%	0.570
Avoidance of disposal fees	46%	34%	0.178
Additional revenue	31%	46%	0.101
Opportunity to produce UFPs for use elsewhere within the operation/community	33%	40%	0.386
Support local industries or businesses	21%	31%	0.189
Other	0%	3%	0.275

There was no clear consensus amongst municipal respondents about the most important barriers to UFW utilization (Table 9). The most frequently cited barriers were lack of in-house equipment for processing UFW (44%) and lack of local processors of UFW (41%). Several different barriers were reported as important by about one-third of respondents: lack of stockpiling space, lack of processing knowledge or skill, lack of local consumers, and logistical difficulties with handling UFW.

Private operations also cited a broad mix of important barriers to UFW utilization. About half of respondents cited lack of local processors and lack of stockpiling space as important barriers (Table 9). It is interesting to note that arborists frequently viewed lack of local processors as a barrier, yet viewed lack of local consumers as a less important barrier. This suggests that there may be untapped demand for urban forest products that could be taken advantage of if more local processors could be brought into UFW utilization. About one-third of arborists noted that a lack of in-house equipment for processing UFW is a major barrier. Processing equipment is a major fixed cost for commercial operations and has a highly specialized application that many arborists cannot justify in their business model. Neither private nor municipal respondents viewed local regulations as being

a major barrier to UFW utilization relative to other barriers in the list. There was no statistical evidence that municipal and private operations differed in their viewpoints on the importance of incentives and barriers, with one exception: arborists much more frequently viewed transporting UFW to processors (45% of respondents) as a barrier compared to municipalities (18% of respondents). This may be because municipalities have trucking equipment specifically designed for hauling UFW generated by citizens or have better access to their processing destinations.

Table 9: Perceptions of municipal employees and private sector certified arborists about barriers to further urban forest waste (UFW) utilization in North Carolina. Barriers are reported based on the percentage of respondents who ranked each barrier in their top three. Where provided, p-values indicate the statistical probability that municipal and private operations do not differ for the characteristic of interest.

Barriers to further urban forest waste utilization	Municipal (n=39)	Private (n=132)	p-value
Lack of in-house equipment for processing UFW	44%	36%	0.383
Lack of local processors of UFW	41%	47%	0.513
Lack of in-house space for stockpiling UFW	38%	46%	0.392
Lack of in-house knowledge or skill for processing UFW or marketing UFPs	36%	40%	0.633
Logistical difficulties of handling UFW on tree service job sites	33%	37%	0.666
Lack of local consumers of UFPs	33%	24%	0.651
Lack of communication between UFW producers and UFP consumers	26%	27%	0.913
Local regulations or permitting requirements	23%	21%	0.804
Logistical difficulties of transporting UFW to processors	18%	45%	0.003
Other	8%	4%	0.310

Education and Technical Assistance

Respondents were asked to indicate their level of agreement with several *a priori* statements about their experiences with education and training on UFW utilization. Municipal and private operations had similar perspectives on these experiences. There was only a slight indication that respondents had sought self-education about UFW utilization in the past, with a bit more interest in such education in the future (Table 10). Respondents were largely ambivalent about their ability to find satisfactory education or training on UFW utilization when they sought it. This fairly neutral attitude towards education and training may result from the prevailing perception that UFW utilization is not a

major issue for urban forestry now or into the near future. Simply put, UFW utilization may not be an overall major concern for urban forestry professionals relative to other issues and therefore education on the topic is not a high priority for them.

Private and municipal operations were then asked to identify their preference for educational or technical programs on UFW utilization. Respondents were presented with a list of *a priori* programs and asked to rank them from highest to lowest importance based on their preferences. Preferences were similar among municipal and private operations, and no clear preference was shown for any particular program option by either group (Table 10). The strongest preference shown by municipal respondents was for hands-on workshops or field demonstrations (54% of respondents). Significantly fewer arborist respondents (34%) preferred this educational medium, perhaps because they feel comfortable with their technical abilities compared to other needs. It is not surprising that such a wide range of education programs were preferred by both groups given the diversity in municipal and private operations represented by the respondents. Additional investigation into educational preferences of these groups is warranted in order to better target and tailor educational programming to these diverse stakeholders.

Both groups showed a strong preference for a centralized UFW stockpiling facility, which reaffirms that space and logistical issues are often a barrier to UFW utilization. Most respondents did not view publications from Cooperative Extension or NCFS to be particularly useful for meeting their educational needs. Likewise, industry standards or BMPs were not highly preferred, which may reflect the overall limited importance that both groups place upon UFW utilization. The only other difference that stood out amongst municipal and private operations was that nearly half of arborists showed a preference for an online database to network UFW generators and processors with producers of urban forest products. Because arborists view UFW disposal as a major cost for their operations, they may likewise view a networking system as a useful means to curb their operational costs.

Table 10: Educational experiences and preferences of municipal employees and private sector certified arborists about urban forest waste (UFW) utilization in North Carolina. Level of agreement questions are reported using this scale: 1 = strongly agree, 2 = somewhat agree, 3 = neither agree nor disagree, 4 = somewhat disagree, 5 = strongly disagree. Preferences are reported based on the percentage of respondents who ranked each item in their top three. Where provided, p-values indicate the statistical probability that municipal and private operations do not differ for the characteristic of interest.

Experience with education and training	Municipal (n=42)	Private (n=140)	p-value
I have engaged in self-education or training about UFW utilization in the past year	2.83	2.62	0.442
I will engage in self-education or training about UFW utilization in the coming year	2.64	2.43	0.345
I have found satisfactory opportunities for education or training on UFW utilization when I have sought it	2.79	2.95	0.516
Preference for educational or technical programs about UFW utilization	Municipal (n=39)	Private (n=129)	p-value
Hands-on workshops or field demonstration	54%	34%	0.027
A local, centralized facility for receiving, sorting, and stockpiling UFW	46%	50%	0.705
A cooperative business facility for selling and/or producing UFPs	41%	37%	0.667
Educational seminars or conferences	36%	33%	0.767
An educational website	31%	34%	0.698
Cooperative Extension or North Carolina Forest Service publications	26%	27%	0.854
An online database that networks UFW generators, UFW processors, and UFP producers	23%	42%	0.034
Industry standards or best management practices	23%	23%	0.902
Online webinar	18%	15%	0.626
Other	0%	2%	0.337

Conclusions and Recommendations

This study has provided insight on the practices and perceptions of UFW generation and utilization by municipal and private arboricultural operations in North Carolina. Few studies, if any, have ever investigated UFW generation and utilization in the state on such a broad geographic scale and in such depth. The findings in this study provide a useful foundation to build education and technical assistance programs aimed at improving UFW utilization by municipalities and private arboricultural operations.

Many of the findings in this study corroborate long-held beliefs and anecdotal observations about UFW practices. For example, it was affirmed that tree pruning and removal on private residential and commercial lands account for the majority of UFW generated by private operations. And that firewood, lumber, mulch, and compost are the most frequent products of UFW utilization by both municipalities and private operations. Yet some findings were unexpected and contrary to the conventional wisdom about UFW. Perhaps most surprising was the limited grasp that private operations, and to a greater extent municipal operations, have on the amount of UFW that their operations generate. One of the key requirements for creating viable markets for UFW utilization and getting buy-in from industry is having a clear understanding of the raw material supply. It is evident from the data reported by respondents in this survey that there is much variability and uncertainty about the UFW being generated in North Carolina's urban forests. A survey instrument is clearly an insufficient means of gathering this data and further work needs to be done quantify UFW generation.

Perceptions of UFW generation and utilization by municipal and private arboricultural operations are difficult to summarize succinctly because no strong feelings seem to emerge about the subject in the data. There doesn't seem to be a single factor strongly motivating these operations to utilize UFW, but there is evidence that environmental sustainability resonates broadly. And with the exception of UFW disposal being viewed as a major cost to private operations, these groups do not seem to be pre-occupied with UFW generation or utilization in their day-to-day jobs. Environmental sustainability and cost avoidance are clearly the most important incentives for increasing UFW utilization to these groups, but they are not the only incentives that are important to them. A challenge going forward is to figure out which incentives most clearly resonate within the community of UFW generators so that proper mechanisms can be put into place to bolster those incentives.

Barriers to UFW utilization are much more difficult to pinpoint than incentives for municipal and private arboricultural operations. Their perspectives on barriers are quite varied and no single barrier rises clearly above the others. Lack of local processors and the general logistical difficulties of handling, hauling, and processing UFW seem to be the prevalent barriers. The take home message is that the barriers to UFW are numerous and none of them are particularly easy to overcome without significant investment in operational infrastructure and systems. Educational and technical programs are another facet to breaking down barriers to UFW utilization. Yet the survey results do not show a clear consensus for educational or technical needs. On the average, education and training do not appear to be in high demand for these groups, but undoubtedly there are certain cohorts within this population that are passionate about UFW utilization and would be responsive to

outreach programs. Given that UFW utilization is not yet a “mainstream” enterprise in urban forestry, UFW outreach may remain a niche program for the foreseeable future. What does seem clear is that these professionals do not need training on the technical process of utilizing UFW, but rather need mechanisms to connect the raw material that they generate with enterprises that create urban forest products and consumers that purchase urban forest products.

While surveys are an efficient means to collect data about practices and perceptions, there are inherent limitations that must be carefully considered when interpreting and applying information gathered from them. A key consideration is always how well the respondents represent the population of interest and whether any bias has been introduced to the survey by a low sample size or a non-representative respondent pool. This survey is believed to be an overall robust assessment of UFW practices and perceptions for several reasons. First, the response rate for the survey met our expectations (65% municipal; 32% certified arborist; 39% overall response rate) and was consistent with typical survey response rates. Second, the distribution of respondents across industry sectors and operational positions was consistent with the perceived industry segmentation of the population as a whole. Although an evaluation of non-response bias was not performed for this survey, the prior survey in Virginia was evaluated for non-response bias and no evidence was found for bias there. Given the high response rate, representativeness of industry sectors and operational positions, and lack of response bias in the prior Virginia survey, the North Carolina survey is viewed as a reliable instrument overall. With that said, there were certain survey items that had low sample sizes and/or high variance. For this reason, some survey items are less reliable than others and should be used with caution for drawing conclusions.

Based on the findings of this survey study, the following recommendations are made to North Carolina Forest Service with regard to their urban forest waste utilization programming:

1. Additional data are needed to accurately quantify the amount of urban forest waste generated by municipal and private operations. Because about one-half of municipal respondents and three-fourths of private respondents effectively precluded themselves from reporting on urban forest generation due to lack of knowledge about the subject, the data reported here are at very high risk for bias. The web survey format combined with elective reporting by respondents has been shown here not to be a reliable means to collect this type of data. Better options might include one-on-one intensive interviews with operations or an observational study in which a sample of operations is tracked over a period of time and their day-to-day urban forest generation is documented through direct observation.
2. Underlying demographic trends in the survey data should be further investigated. Although two well-defined demographic groups were targeted as respondents for this survey, broad diversity in the underlying industry sectors and professional positions represented in the respondent pool was still evident. This was to be expected and represents one of the ongoing challenges to making tangible progress with urban forest waste generation given the diversity of stakeholders. Moreover, there may be geographic or economic factors at play that could not be detected by the survey instrument. In planning this survey study, there was an *a priori* belief that municipal and private operations would differ in their urban forest waste practices and perceptions. Therefore, the instrument and the analysis were designed to

disaggregate these two distinct groups. However, there may be further demographic sub-groups within these two groups that also differ. Because the study was not designed to evaluate these sub-groups, there may not be sufficient sample sizes and therefore statistical power, to analyze these data at a deeper level without risk of bias.

3. A clearer understanding is needed about the fate of urban forest waste generated by municipal operations. In this survey, municipal respondents indicated that two-thirds of their logs, one-third of their wood chips, and half of their brush is disposed at a solid waste facility. In the context of this survey question, this implies that the waste is not utilized in any way, but this finding is contradictory to state prohibitions on landfilling “yard trash”. It seems likely that this survey question was misunderstood by municipal respondents, specifically those individuals who are not urban forestry professionals and are not familiar with the concepts and terminology of urban forest waste utilization. Regardless, the data only lead to speculation about how much municipal urban forest waste is being utilized and by whom, so this information warrants further study.
4. Opportunities for high-value utilization of logs need further study. Although the sample size was precariously small, the data suggest that when logs are being utilized in-house by municipal and private operations, the utilization is primarily for firewood. Although this is certainly favorable utilization, some experts would argue that the log resource is being under-utilized for high-value products such as flooring, cabinetry, and veneer, which were rarely reported in the survey. Since no data were collected about the quality of the urban forest waste, it is hard to judge under-utilization since finished wood products require a high-quality raw material that may be scarce in urban areas. Moreover, markets for high-value urban forest products may be insufficiently developed in North Carolina to make such enterprises viable at this time.

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Appendix I: Municipalities Solicited for the Survey

Listed below are the 69 localities in North Carolina that were selected for the sampling frame of the survey on urban forest waste generation and utilization. Municipalities that completed the survey are denoted with an asterisk (*). See “Study Findings” for details on survey response rate.

Albemarle*	Greensboro*	Monroe
Apex*	Greenville*	Mooresville
Asheboro*	Havelock	Morganton
Asheville*	Henderson	Morrisville*
Boone	Hendersonville*	Mount Holly*
Burlington*	Hickory	New Bern
Carrboro	High Point*	Newton*
Cary*	Holly Springs*	Pinehurst
Chapel Hill	Hope Mills*	Raleigh*
Charlotte	Huntersville*	Reidsville*
Clayton	Indian Trail*	Roanoke Rapids*
Clemmons*	Jacksonville*	Rocky Mount*
Concord*	Kannapolis*	Salisbury*
Cornelius*	Kernersville	Sanford*
Durham*	Kinston*	Shelby
Eden*	Laurinburg*	Southern Pines
Elizabeth City	Leland*	Stallings
Fayetteville*	Lenoir*	Statesville*
Fuquay-Varina*	Lewisville	Thomasville
Garner*	Lexington*	Wake Forest*
Gastonia	Lumberton*	Wilmington*
Goldsboro*	Matthews*	Wilson
Graham	Mint Hill	Winston-Salem

Appendix II: Survey Instrument

Printed below is a transcript of the survey instrument. Note that the survey was administered in an online format that used skip logic and branching to route respondents through the questions based on how they responded to certain questions. Thus the transcript does not reflect the actual flow of the survey experienced by the respondents.

Preamble

You are invited to participate in a survey conducted by Virginia Tech Department of Forest Resources and Environmental Conservation on the topic of urban forest waste generation, disposal, and utilization in North Carolina.

Your participation is voluntary. All responses will be confidential and not associated with you individually in any public dissemination of the results. Results will be used for a graduate thesis and publication.

The survey should require about 20 minutes to complete. Please read each question carefully and answer to the best of your ability.

Should you have any questions, please contact Jordan Endahl (urbanwood@vt.edu).

This study is conducted under the guidance of the Virginia Tech Institutional Review Board. If you have any concerns about the study's conduct or your rights as a research subject, please contact IRB via Dr. Moore (moored@vt.edu, 540-231-4991).

Please read the following definitions. They will help clarify certain terminology used in the survey questions.

Urban forest waste (UFW) – any woody material (i.e., logs, chips, or brush) generated from the pruning, felling, or removal of a tree.

Urban forest product (UFP) – any product produced via the utilization of urban forest waste.

Generated – created from arboricultural practices (e.g., pruning, felling, removal, land clearing, etc).

Utilized – used to produce an urban forest product.

Disposed – transported to a facility (e.g., landfill, dump site) or left on-site without the intention of producing an urban forest product.

Q1 Are you in a position to report on the urban forest waste (UFW) generated by the local operation of your business/organization/municipality? Local operation refers to an individual municipality, a locally-owned and operated business, or a local office of a larger company with multiple regional offices.

- Yes (1)
- No (2)

Please answer a few questions about yourself. Your answers are confidential and are intended to help us understand perceptions about urban forest waste utilization.

D1 What is your age?

- 18-30 (1)
- 31-44 (2)
- 45-60 (3)
- 61+ (4)

D2 What is your gender?

- Female (1)
- Male (2)

D3 What is your highest level of education attainment?

- High school or equivalent (1)
- Associate degree (2)
- Bachelor's degree (3)
- Graduate degree (4)

D4 How long have you worked in a profession related to trees or tree debris disposal?

- 0-10 (1)
- 11-20 (2)
- 21-30 (3)
- 31+ (4)

P1 Please indicate your level of agreement with the following statements:

	Strongly Agree (1)	Agree (2)	Neither Agree nor Disagree (3)	Disagree (4)	Strongly Disagree (5)	We do not generate UFW (6)
My operation seeks to increase UFW utilization for logistical reasons (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My operation seeks to increase UFW utilization for financial reasons (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My operation seeks to increase UFW utilization for regulatory reasons (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My operation seeks to increase UFW utilization for environmental reasons (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

P2 Please indicate your level of agreement with the following statements:

	Strongly Agree (1)	Agree (2)	Neither Agree nor Disagree (3)	Disagree (4)	Strongly Disagree (5)
UFW disposal is a major cost for my operation (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
UFW utilization is a major revenue source for my operation (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
UFW utilization is important to my clients (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
UFW utilization is a major issue for the urban forestry industry currently (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
UFW utilization will be a major issue for the urban forestry industry in the future (5)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

P3 Please indicate your level of agreement with the following:

	Strongly Agree (1)	Agree (2)	Neither Agree nor Disagree (3)	Disagree (4)	Strongly Disagree (5)
I have engaged in self-education or training about UFW utilization in the past year (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I will engage in self-education or training about UFW utilization in the coming year (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I have found satisfactory opportunities for education or training on UFW utilization when I have sought it (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

P4 Please rank the most significant incentives (existing or potential) for increasing utilization of urban forest waste (UFW) by the local operation of your business/organization/municipality: Rank at least 3 Items by dragging and dropping Items into the Rank box.

Rank
_____ Additional revenue (1)
_____ Value-added service to clients (2)
_____ Avoidance of disposal fees (3)
_____ Avoidance of transportation or shipping costs (4)
_____ Environmental sustainability of the operation/community (5)
_____ Support local industries or businesses (e.g., "Buy local" initiatives) (6)
_____ Opportunity to produce urban forest products for use elsewhere within the operation/community (7)
_____ Other: (8)
_____ Other: (9)
_____ Other: (10)

P5 Please rank the most significant barriers (existing or potential) for increasing utilization of urban forest waste (UFW) by the local operation of your business/organization/municipality: Rank at least 3 Items by dragging and dropping Items into the Rank box.

Rank
_____ Local regulations or permitting requirements (1)
_____ Lack of local processors of UFW (2)
_____ Lack of local consumers of UFP (3)
_____ Logistical difficulties of handling UFW on tree service job sites (4)
_____ Logistical difficulties of transporting UFW to processors (5)
_____ Lack of in-house space for stockpiling UFW (6)
_____ Lack of in-house equipment for processing UFW (7)
_____ Lack of in-house knowledge or skill for processing UFW or marketing UFP (8)
_____ Lack of communication between UFW producers and UFP consumers (9)
_____ Other: (10)
_____ Other: (11)
_____ Other: (12)

P6 Please rank the following educational or technical programs as a potential means for helping you increase your capacity for utilization of urban forest waste (UFW) or production of urban forest products (UFP): Rank at least 3 Items by dragging and dropping Items into the Rank box.

Rank
_____ Cooperative Extension or VDOF publications (1)
_____ Industry standards or best management practices (2)
_____ An educational website (3)
_____ Educational seminars or conferences (4)
_____ Hands-on workshops or field demonstrations (5)
_____ An online database that networks UFW generators, UFW processors, and UFP producers (6)
_____ A local, centralized facility for receiving, sorting, and stockpiling UFW (7)
_____ A cooperative business facility for selling and/or producing UFPs (8)
_____ Other: (9)
_____ Other: (10)
_____ Other: (11)
_____ An online course or webinar (12)

P7a May we contact you with follow-up questions based on your responses to this survey?

- Yes, my email is: (1) _____
- Yes, my phone number is: (2) _____

P7b Thank you for your time spent responding to this survey. If there is anything else you would like to contribute to our study of urban forest waste utilization, please use the comment box below.

Q2 Does the local operation of your business/organization/municipality directly generate urban forest waste (UFW)? If your local operation hires contractors who generate UFW rather than using your in-house staff, please select No.

- Yes (1)
- No (2)

Q3a Please indicate your industry sector:

- I am employed by a municipality (city, town, county) (1)
- I am employed by a tree care company (including contractors for utility service providers or NCDOT) (2)
- I am employed by a landscape company (3)
- I am employed by a consulting firm (4)
- I am employed by an institution (university, arboretum, estate, state/federal park, etc.) (5)
- I am employed by an electric utility service provider (6)
- I am employed by North Carolina Dept. of Transportation (NCDOT) (7)
- Other: (8) _____

Answer If: Please indicate your industry sector: I work for a municipality (city, town, county) is selected

Q3b Please indicate your position within your municipality:

- Arborist (1)
- Horticulturist (2)
- Urban Forester (3)
- City/Town/County Manager (4)
- City/Town/County Planner (5)
- Public Works Administrator (6)
- Parks and Recreation Administrator (7)
- Solid Waste Administrator (8)
- Other: (9) _____

Answer If: Please indicate your industry sector: I am employed by a tree care company (commercial, residential, utility) is selected Or Please indicate your industry sector: I am employed by a landscape company Is Selected

Q3c Please indicate your position within your business/organization:

- Manager/owner of a regional operation (1)
- Manager/owner of a local operation (2)
- Manager of a production crew (3)
- Member of a production crew (4)
- Other (5) _____

Q4 In the local operation of your business/organization/municipality, how many full-time employees are directly involved in activities that generate urban forest waste (UFW)?

- 0-5 (1)
- 6-10 (2)
- 11-15 (3)
- 16-20 (4)
- 21+ (5)

Q5a From the list provided below, select ALL of the localities in which the local operation of your business/organization/municipality generates urban forest waste (UFW). If you are employed by a larger company with multiple regional offices, please select only those localities where your local office operates and for which you can specifically answer questions about UFW generation. If you are employed by a municipality, please select only your municipality from the list.

- < 69 sample municipalities listed >
- None of these (1)

Answer If: Please indicate your industry sector: I work for a municipality (city, town, county) Is Not Selected

Q5b Please estimate the percentage of urban forest waste (UFW) that the local operation of your business/organization generates within each of your selected localities as a percentage of the total UFW generated in all of your selected localities: To set your percentages, drag each blue bar side to side or enter a specific percentage on the right side of the graph. Keep in mind your responses should add up to 100%. If you only selected one locality in the previous question, your percentage for that locality should be 100%.

< 69 sample municipalities listed >

Q6 Please indicate where the local operation of your business/organization/municipality generates urban forest waste (UFW) (as a percentage of total UFW generated): To set your percentages, drag each blue bar side to side or enter a specific percentage on the right side of the graph. Keep in mind your responses should add up to 100%.

- _____ Private residential (1)
- _____ Private commercial (2)
- _____ Public parks, grounds, and greenspaces (3)
- _____ Public street rights-of-way maintained by a municipality (4)
- _____ NCDOT roadside rights-of-way (5)
- _____ Electric utility rights-of-way (6)
- _____ Other: (7)
- _____ Other: (8)

Q7 The following arboricultural practices generate urban forest waste (UFW). Please indicate which types of work the local operation of your business/organization/municipality conducts (as a percentage of total UFW generated): To set your percentages, drag each blue bar side to side or enter a specific percent on the right side of the graph. Keep in mind your responses should add up to 100%.

- _____ Tree pruning (1)
- _____ Tree removal (2)
- _____ Curbside pickup of tree debris (3)
- _____ Small woodlot logging (4)
- _____ Land clearing (5)
- _____ Other: (6)
- _____ Other: (7)

AF1 Urban forest waste comprises logs, chips, or brush generated from the pruning, felling, or removal of a tree. Please describe how the local operation of your business/organization/municipality tracks the amount of urban forest waste (UFW) that it generates:

- We keep detailed records of the amount of UFW generated and can report based on these records (1)
- I can provide an estimate of the amount of UFW generated (2)
- I cannot provide an estimate of the amount of UFW generated (3)

If I cannot estimate the amount... Is Selected, Then Skip To Please describe how your business/org...

AF2 Please report or estimate the average amount of urban forest waste (UFW) that your local operation generates per unit of time. For each type of material, enter an amount, followed by the unit of measure, followed by the unit of time. It is understood that waste generation can be highly variable during the year. Please provide your best estimate for a typical time period.

	Amount (1)	Unit of Measure				Unit of Time				
		Tons (1)	Cubic Yards (2)	Board Feet (3)	N/A (4)	Day (1)	Week (2)	Month (3)	Year (4)	N/A (5)
Logs (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Chips (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Brush (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

AF3 Please describe how the local operation of your business/organization/municipality tracks the fate of urban forest waste (UFW) that it generates: Fate refers to what happens to UFW after it is generated and may include disposal and/or utilization on-site, in-house, or by a 3rd party.

- We keep detailed records of the fate of UFW generated and can report based on these records (1)
- I can provide an estimate of the fate of UFW generated (2)
- I cannot provide an estimate of the fate of UFW generated (3)

If I cannot estimate the fate ... Is Selected, Then Skip To End of Block

AF4a Urban forest waste comprises logs, brush, or chips generated from the pruning, felling, or removal of a tree. Please describe the fate of the logs generated by the local operation of your business/organization/municipality: To set your percentages, drag each blue bar side to side or enter a specific percent on the right side of the graph. Keep in mind your percentages should add up to 100%.

_____ Utilized in-house to produce urban forest products (firewood, lumber, furniture, art/novelty, etc.) (1)

_____ Transferred to a 3rd party for utilization as urban forest products (2)

_____ Disposed at a solid waste facility or elsewhere (3)

_____ Left on-site, resulting in no utilization (4)

_____ Left on-site for utilization by property owner (5)

Answer If: Please describe the fate of the logs you generate (Keep in mind your percentages should add up to 100%): Utilized in house to produce urban forest products (firewood, lumber, furniture, art/novelty, etc.) Is Greater Than 0

AF4b Of the logs that your local operation utilizes in-house, what percent are utilized to produce each of the following urban forest products (UFPs)? To set your percentages, drag each blue bar side to side or enter a specific percent on the right side of the graph. Keep in mind your percentages should add up to 100%.

_____ Firewood (1)

_____ Lumber (2)

_____ Pallets (3)

_____ Furniture (4)

_____ Cabinetry (5)

_____ Flooring (6)

_____ Veneer (7)

_____ Art/novelty (8)

_____ Other: (9)

_____ Other: (10)

AF5a Urban forest waste comprises logs, brush, or chips generated from the pruning, felling, or removal of a tree. Please describe the fate of the chips generated by the local operation of your business/organization/municipality: To set your percentages, drag each blue bar side to side or enter a specific percent on the right side of the graph. Keep in mind your percentages should add up to 100%.

- _____ Utilized in-house to produce urban forest products (mulch, compost, biomass, etc.) (1)
- _____ Transferred to a 3rd party for utilization as urban forest products (2)
- _____ Disposed at a solid waste facility or elsewhere (3)
- _____ Left on-site, resulting in no utilization (4)
- _____ Left on-site for utilization by property owner (5)

Answer If: Please describe the fate of the chips you generate (Keep in mind your percentages should add up to 100%): Utilized in house to create urban forest products (mulch, compost, biomass, etc.) Is Greater Than 0

AF5b Of the chips that your local operation utilizes in-house, what percent are utilized to produce each of the following urban forest products (UFPs)? To set your percentages, drag each blue bar side to side or enter a specific percent on the right side of the graph. Keep in mind your percentages should add up to 100%.

- _____ Mulch (1)
- _____ Compost (2)
- _____ Biomass for energy (3)
- _____ Pellets for wood stove burning (4)
- _____ Other: (5)
- _____ Other: (6)

AF6a Urban forest waste comprises logs, brush, or chips generated from the pruning, felling, or removal of a tree. Please describe the fate of the brush generated by the local operation of your business/organization/municipality: To set your percentages, drag each blue bar side to side or enter a specific percent on the right side of the graph. Keep in mind your percentages should add up to 100%.

- _____ Utilized in-house to produce urban forest products (chips, mulch, compost, biomass, etc.) (1)
- _____ Transferred to a 3rd party for utilization as urban forest products (2)
- _____ Disposed at a solid waste facility or elsewhere (3)
- _____ Left on-site, resulting in no utilization (4)
- _____ Left on-site for utilization by property owner (5)

Answer If: Please describe the fate of the brush you generate (Keep in mind your percentages should add up to 100%): Utilized in house to create urban forest products (chips, mulch, compost, biomass, etc.) Is Greater Than 0

AF6b Of the brush that your local operation utilizes in-house, what percent is utilized to produce each of the following urban forest products (UFPs)? To set your percentages, drag each blue bar side to side or enter a specific percent on the right side of the graph. Keep in mind your percentages should add up to 100%.

- _____ Mulch (1)
- _____ Compost (2)
- _____ Biomass for energy (3)
- _____ Other: (4)
- _____ Other: (5)

Answer If: Urban forest waste comprises logs, brush, or chips generated from the pruning, felling, or removal of a tree. Please describe the fate of the logs generated by your operation (keep in mind your perc... Disposed at a solid waste facility or elsewhere Is Greater Than 0 Or Urban forest waste comprises logs, brush, or chips generated from the pruning, felling, or removal of a tree. Please describe the fate of the chips generated by your operation (keep in mind your per... Disposed at a solid waste facility or dump, resulting in no utilization Is Greater Than 0 Or Urban forest waste comprises logs, brush, or chips generated from the pruning, felling, or removal of a tree. Please describe the fate of the brush generated by your operation (keep in mind your per... Disposed at a solid waste facility or elsewhere Is Greater Than 0

AF7 Please report or estimate the average expense of disposal of urban forest waste (UFW) generated by the local operation of your business/organization/municipality per unit of time. It is understood that waste generation and disposal fees can be highly variable during the year. Please provide your best estimate for a typical time period.

	Amount	Unit of Time			
	\$ (1)	Day (1)	Week (2)	Month (3)	Year (4)
Disposal Fees (1)		<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

PF1a In the past five years, the amount of urban forest waste (UFW) generated by the local operation of your business/organization/municipality has:

- Increased substantially (1)
- Increased moderately (2)
- Stayed about the same (3)
- Decreased moderately (4)
- Decreased substantially (5)
- I don't know (6)

PF1b In the past five years, the amount of urban forest waste (UFW) utilized as urban forest products (UFP) by the local operation of your business/organization/municipality has:

- Increased substantially (1)
- Increased moderately (2)
- Stayed about the same (3)
- Decreased moderately (4)
- Decreased substantially (5)
- I don't know (6)

PF2a In the next five years, the amount of urban forest waste (UFW) generated by the local operation of your business/organization/municipality will:

- Increase substantially (1)
- Increase moderately (2)
- Stay about the same (3)
- Decrease moderately (4)
- Decrease substantially (5)
- I don't know (6)

PF2b In the next five years, the amount of urban forest waste (UFW) utilized as urban forest products (UFP) by the local operation of your business/organization/municipality will:

- Increase substantially (1)
- Increase moderately (2)
- Stay about the same (3)
- Decrease moderately (4)
- Decrease substantially (5)
- I don't know (6)