

**An Analysis of Consumer Preferences for Gardening Products with
Environmentally Friendly Attributes**

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DEDICATION

I would like to dedicate this thesis with immense gratitude to my parents, Bill and Audra Thomas, for their unyielding support and faith in me. Additionally, I dedicate this paper to my younger sister, for whom I aspire to be the best sister, role model and friend.

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ABSTRACT

Consumers have expressed preferences for gardening products that have environmental benefits or ecofriendly attributes. These products can utilize fewer resources in production, reduce the need for further inputs as well as return nutrients back to the earth. Utilizing a survey of Tennessee indoor and outdoor gardeners, the following two papers estimate how consumer demographics, behaviors and attitudinal variables influence the propensity of a consumer to prefer environmentally friendly gardening products and their use of a specific ecofriendly gardening product, potting mix with biochar.

Some key findings from the first paper include that consumer gardening practices and demographic characteristics influence the overall propensity to prefer gardening products with environmental attributes. The tendency to be involved in environmental or gardening clubs as well as the practice of gardening to grow food were among the largest influences on the propensity to prefer gardening products with environmental benefits. In the second paper, analysis of consumer preferences for a specific product with environmental attributes, potting mix containing 25% biochar, was conducted. A mean willingness to pay of \$8.52 was estimated for an 8-quart bag of potting mix with biochar (compared with a base price of \$4.99). Results from this study suggest that consumer demographics and attitude variables regarding the environment and biofuel production were influential in the determination of willingness to pay and the probability of purchasing the potting mix with biochar.

The results from both studies further understanding about consumer preferences for environmentally conscious gardening product attributes. These studies can inform decisions and product development in the gardening and lawn care industry as well as contribute to the development of valuable coproducts in bioenergy production.

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INTRODUCTION

According to the 2017 National Gardening Survey (Garden Research 2018), 74% of American households participated in gardening activities in 2016, resulting in an over 36.9 billion dollar (USD) yard and garden industry. These gardening consumers stem from myriad backgrounds with varying interests and motivations from growing food to outlets for better physical and mental health (Hall and Dickson 2011). Studies aimed at differentiating gardening consumers into segments have been done in order to better target groups of consumers with more effective marketing campaigns. Behe, et al. (2010) use cluster analysis to find that there is a substantial segment of gardeners who prefer ecofriendly gardening supplies and products with attributes that are environmentally conscious. The use of gardening supplies and products with environmental benefits have the potential to decrease water use, reduce greenhouse gas emissions, and prevent soil erosion. The development of these products and the research of the consumers that would purchase them is, therefore, beneficial to both the industry itself and the environment.

One such gardening product with both environmental and economic benefits is biochar. Biochar, as defined by a report from the International Biochar Initiative, is a, “solid material obtained from thermochemical conversion of biomass in an oxygen-limited environment” (Jirka and Tomlinson 2014). Biochar can be created as a result of fast or slow pyrolysis and gasification, all of which are methods of producing biofuels. Of these three procedures, slow pyrolysis yields the most biochar and optimizes quantities of both biooil and biochar (Downie

and Van Zwieten 2013). Slow pyrolysis of corn stover, for example, has been shown to produce up to 40% biochar per ton of dry weight (Brown, Wright and Brown 2010). This biochar can be produced from various sources, including food, agricultural and forestry wastes (the use of which has the added benefit of waste diversion from landfills), in addition to dedicated energy crops (Downie and Van Zweiten 2013). Biochar has been shown to be effective in the areas of carbon sequestration, waste mitigation, and soil amending (Lehmann and Joseph 2009). Biochar is the subject of the second study, focusing on its use as a soil amendment and therefore, its subsequent capacity as a gardening product.

The impetus behind the development of biochar and other biofuel co-products begins with the energy policies of the early 2000s. The Energy Policy Act of 2005, the Energy Independence and Security Act of 2007 and the subsequent creation of the Renewable Fuel Standard (RFS) have made the production of renewable fuels and their integration into the conventional energy mix a requirement (U.S. Dept. of Energy 2018). As we strive to meet these targets set forth by the RFS, interest in the economic viability of the coproducts of advanced biofuel production is growing. To this end, the further development of products containing coproducts, like biochar, could contribute significantly to the attainment of these renewable energy goals.

Biochar was chosen as the coproduct of interest largely because of its versatility. For products containing biochar, it is anticipated that consumers with environmental concerns and preferences that reflect those concerns may be the target market. It is the intent of this study to both determine what environmental attributes consumers prefer as well as their willingness to

pay for an environmentally conscious product, biochar. For this project, biochar has been incorporated into the gardening supply market, justified by the increasing awareness of and demand for green products and supplies.

The overall goal of the research is to provide additional information on consumer preferences for gardening supplies with environmental benefits. There are two papers in this thesis that contribute to this end. The first paper examines the overall propensity of a consumer to choose products with environmentally friendly attributes and utilizes a Multiple Indicator Multiple Causation (MIMIC) model to analyze which demographic factors influence consumer preferences for ecofriendly products. The second paper utilizes survey data to estimate consumer willingness to pay (WTP) for a potting mix that contains biochar in a 25% mixture. The Appendix contains a copy of the survey instrument.¹

¹ The UTK Human Research Protections Program (HRPP) determined that this research was application is eligible for exempt review under 45 CFR 46.101, Category 2 and the application was determined to comply with proper consideration for the rights and welfare of human subjects and the regulatory requirements for the protection of human subjects. The approval number was UTK IRB-18-04526-XM.

PART I

MIMIC MODEL OF CONSUMER PREFERENCES FOR ENVIRONMENTAL ATTRIBUTES IN GARDENING SUPPLIES

McKenzie Thomas is the main author of this article. The study used was conducted under the direction and supervision of Dr. Kimberly Jensen with input by Dr. Christopher Clark, Dr. Burton English and Dr. Dayton Lambert. The study used a dataset that was obtained through a survey directed by the aforementioned faculty in July 2018.

Abstract

The purpose of this study is to understand the factors influencing home gardener preferences for six ecofriendly attributes (decreased fertilizer needs, decreased pesticide needs, decreased water needs, native species, organically produced, and recyclable packaging) associated with gardening products. Utilizing demographics, attitudes and shopping preferences gathered from survey data, market segments of consumers that are more likely to purchase environmentally friendly garden products can be identified. A Multiple Indicator Multiple Causation (MIMIC) Model was used to analyze which demographic factors influence consumer preferences for ecofriendly products. In this model framework, indicators and causal variables are linked by a latent, unobservable variable. In this case, the latent variable is the propensity of consumers to prefer environmentally friendly gardening products (ENVIR). The results from this study help identify characteristics of market segments that have a low, medium, and high propensity to prefer gardening products with environmental benefits. Compared with those in the low propensity group, consumers in the high propensity group are more likely to be female, younger, garden outdoors, grow their own food and have strong environmental beliefs. Our findings will supplement efforts made to develop gardening products with ecofriendly attributes with the intention of marketing these products to specific segments of consumers.

Chapter 1: Introduction and Objectives

Consumers are increasingly demanding products that possess environmentally friendly attributes, products that are deemed environmentally sustainable. In the context of this research, a product or behavior that is “environmentally sustainable” is defined as, “meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them” (Morelli 2011). Similarly, “green” is used in this research and when referring to a product, indicates that this product, “offers a significant eco-advantage over the incumbents” (Grant 2005). Products that tout this modifier include products that require fewer inputs in production and manufacturing or align with environmental goals like water conservation or energy-savings. This trend has transcended into the lawn and gardening industry (Garden Research 2018), providing incentive to research and develop sustainable products.

Gardening is one of the most common pastimes in the United States, and it is estimated that roughly 75% of all American households participate in some do-it-yourself lawn and gardening activity (Garden Research 2018). As of 2017, the average gardening household spent \$503 USD annually on gardening supplies – an increase of nearly \$100 USD from the previous year (Garden Research 2018). There are many motivations for gardening including gains to physical and mental health, the formation of social connections, the provision of food and nutrition as well as benefits to the environment (McFarland 2018, Hall and Dickson 2011).

Due to its popularity and direct reliance on natural resources, gardening and lawn care practices can have significant environmental impacts. In 2012, 59 million pounds of pesticides were applied by consumers for their gardens and homes (Atwood and Jones 2017). While they have their uses, the misuse or abuse of pesticides and fertilizers place pressures on the natural

systems upon which gardening relies. Additionally, the planting of nonnative or invasive plants can alter the local ecosystem in major and potentially irreversible ways, including extinction of local plant and animal species and alterations to ecological function (Crowl, et al 2008).

However, as consumers have become more aware of environmental and social issues, attention to environmental problems is becoming more typical of consumers (Chen 2010). Subsequently, as this environmental knowledge makes its way through the population, consumers are showing more favorable attitudes towards brands and companies that are thought to be better for the environment (Hartman, Ibanez and Sainz 2005). As consumer preferences reflect more environmentally friendly perspectives, sustainable gardening practices and products are supplanting their conventional equivalents.

If the gardening and lawn care industry hope to see a continued increase in household gardening expenditures and/or engagement, it is important that consumer preferences are understood and that the products reflecting them are made available. An example of this is the desire to purchase products and supplies that generate lower environmental impacts or reduce resource use (Hall, et al. 2010; Yue, et al. 2012; Behe, et al. 2010; Behe, et al. 2013).

Environmental Trends in Gardening

According to a 2015 Home Depot survey of 1,735 gardeners (Kellner 2015), low-maintenance plants and organics were among the top gardening trends. More than one quarter of gardeners over 35 years old stated that they used rain barrels and other similar rainfall collection systems. Over 40% of millennials (persons age 35 and under) in the Northeast, South, and Midwest expressed interest in learning how to grow food using organic methods (Kellner 2015).

Additionally, according to the latest National Gardening Survey (2018), millennials comprise 29% of the gardening segment. As the demographics of the average gardener begin to shift, we are also seeing a shift in preferences and accompanying behaviors, namely a concern for environmental problems and impacts. Products boasting reduced input needs (like water, fertilizers, pesticides, etc.), conservation of resources like water and energy in production or organic production methods are among the top choices for a segment of consumers (Behe, et al. 2013; Khachatryan, et al. 2014).

Several studies show that consumers are willing to pay a price premium for gardening products that boast environmental attributes (Khachatryan, et al. 2014; Yue, et al. 2010; Yue, et al. 2016). Khachatryan and colleagues studied several sustainable plant attributes and found that consumers were willing to pay premiums for energy-saving production methods (\$0.131); non-plastic containers, like compostable (\$0.227), recyclable (\$0.155) and plantable (\$0.122); and locally grown plants (\$0.222). They also found that those consumers scoring higher on the Environmental Concern (EC) scale (Schultz 2001) were willing to pay even higher premiums for those same attributes. Similarly, Yue, et al. (2010) find that consumers were willing to pay higher price premiums for rice hull and wheat straw plant containers.

Additionally, consumers are also showing preferences for companies that uphold higher levels of corporate social responsibility and operate sustainably (Choi and Ng 2011), indicating that higher consumer purchase intent levels can be awarded to companies with greater levels of environmental care. Choi and Ng (2011) show that consumers respond more negatively to a corporation with a lack of concern for environmental sustainability than for economic

sustainability. Moreover, a lower price does not guarantee higher consumer purchase rates when they are aware of low corporate attention to environmental sustainability, suggesting that companies cognizant of limiting resource use can be favored in the eyes of some consumers.

Environmental Benefits of Gardening

There are numerous environmental benefits associated with gardening. The ground cover can absorb water, reducing water runoff and the resulting pressures on storm water systems. In doing this, it also reduces the emissions produced from treating and processing wastewater. Trees in gardens are especially helpful in water retention in the canopy, temporarily reducing the impacts of heavy precipitation and associated flood risks (Xiao and McPherson 2002). Additionally, ground vegetation can aid in reducing ambient temperatures, resulting in a lowered need for cooling. Rooftop gardens have the capacity to both reduce the temperatures of buildings in hot months as well as insulate them in cooler temperatures (EPA 2007).

Gaston, et al. (2005) find that gardens, trees and lawns can provide extensive ecosystem services to both urban and rural areas, including a contribution to biodiversity, nutrient cycling and capacity to fix CO₂. Carbon sequestration has been recommended as an important feature to manage and build resilience to risks associated with climate change by the Intergovernmental Panel on Climate Change (Field, et al. 2014), validating urban and community gardening as options for small scale climate change mitigation in cities. Landscape design can also impact the ecosystem services provided by gardens and can drastically improve the capacity when design mirrors natural ecological functions (Ghosh 2010).

Gardening for food can also reduce the emissions associated with largescale agricultural production, including those associated with the transport, processing, heating and cooling of produce (Okvat and Zautra 2011). Vávra, Daněk and Jehlička (2018) find that while the emissions reductions of gardening rely largely on the methods used in production and transport, the emissions reductions are comparable to other residential efficiency practices, like efficient appliances and less variable heating and cooling temperatures in the home.

Research Objective

This study extends previous research through its comparison of attributes that have not been previously combined and analyzed. The Multiple Indicators, Multiple Causation (MIMIC) Model allows for the use of demographic characteristics, consumer attitudes and shopping patterns as causal variables and preferences for environmental attributes as indicator variables in our effort to determine consumer propensity to prefer products with environmentally friendly attributes.

The overarching objective of this study is to understand the factors associated with home gardener preferences for six attributes of some gardening products. The attributes considered are decreased need for fertilizer, decreased need for pesticides, decreased need for water, native species, the use of recyclable packaging and the quality of being organic. The association between home gardener demographics, attitudes, and shopping patterns on consumer preferences are measured. These measurements support the identification and definition of market segments on the basis of likelihood of purchasing ecofriendly gardening products. The specific objectives for this paper are to:

- Measure effects of home gardener demographics, attitudes and shopping patterns on preferences for six ecofriendly attributes associated with gardening products; and
- Develop profiles for consumer segments that would have low, medium and high propensity to purchase gardening products and supplies with environmentally friendly attributes.

Chapter 2: Review of Literature

This chapter presents an overview of the current findings relevant to consumer preferences for environmentally friendly products and product attributes. Consumer preferences for biochar are not known, so ecofriendly gardening products are used as a proxy to indicate consumer preference for green products and attributes, a market that would be well suited to biochar products. This chapter focuses on socio-economic characteristics, consumer attitudes and influences that may impact the propensity to prefer and purchase environmentally friendly gardening products and supplies.

Consumer Demographics

Females are, on average, more likely to take environmentally friendly attributes into consideration when making purchasing decisions. With respect to packaging of garden products, Yue, et al. (2010) found that women were willing to pay higher premiums for biodegradable packaging than men, relative to plastic or conventional packaging. An analysis of consumer adoption of drought-resistant plants as a way to combat climate change through reduced water use, indicates that households led by males were 20% less likely to adopt this practice than households led by females (Fan and McCann 2015).

Females are also shown to be more likely than males to participate in environmentally conscious practices. As an example, Grebitus, Printezis and Printezis (2017) find that female respondents were more likely to grow food at urban farms, a practice deemed to be sustainable and better for the environment. Similarly, Behe et al. (2010) analyze the differences in ecofriendly behavior among segments of gardening consumers using survey data and find that female respondents were more likely to practice ecofriendly behaviors (like recycling and

composting) than male respondents. They also found that females were more likely to both spend more money on plants and purchase them more frequently than males. Based on past studies, we hypothesize that gender (female) will also have a positive association with the propensity to prefer products with ecofriendly traits.

Age has also been found to play a role in consumer behavior, practices and preferences. In this case, it can be seen that gardeners tend to be older in age (Yue and Behe 2008; Behe et al. 2010; Yue et al 2010). A study of over 435,000 monetary transactions made in 48 states on floral products from 1992 to 2005, shows that over 70% of buyers were 40 years of age or older (Yue and Behe 2008). Age also has been shown to correlate with types of plant(s) purchased (i.e. herbaceous, woody, etc.) (Behe et al. 2010). As an example, Behe, et al (2010) find that those that purchase primarily vegetable plants and flowering perennials were, on average, six years older than their sample average. Consumer willingness to pay can and is also impacted by the age of the consumer, particularly in environmentally friendly products. Using a regional survey to analyze the preferences of gardening consumers for packaging materials, Yue, et al. (2010) find that as age increases, willingness to pay for certain products with biodegradable packaging does as well. Additionally, the results of an experimental auction study done on US and Canadian consumers to determine willingness to pay for sustainable attributes in plants, finds that those consumers with more eco-centric values toward plants tend to be older (Yue et al. 2016). We expect that the respondents' age will be positively associated with the propensity to prefer gardening products with environmentally friendly attributes.

Education has been found to have a positive impact on the probability of a consumer practicing environmentally friendly behaviors and habits (Park, Lamons and Roberts 1998; Behe, et al. 2010; Yue, et al. 2010; Yue, et al. 2016). Compiling county data, it was found that those with higher education (a college degree) were more likely to compost, exhibiting ecofriendly behavior (Park, Lamons and Roberts 1998). Correspondingly, Behe (2010) finds that more ecocentric segments of gardeners are composed of more college graduates than those that exhibit less ecofriendly behaviors. Multiple studies indicate that higher educational attainment positively influences both the willingness to pay for products with biodegradable attributes (Yue, et al 2010) and the tendency to make more environmentally conscious purchasing decisions (Yue, et al. 2016). Finally, Khachatryan et al. (2018) find that more highly educated consumers were less likely to purchase conventional products in the presence of products with advertised attributes showing environmental benefits (pollinator friendly, sustainably sourced, water/energy-saving, organic). As such, we expect that higher educational attainment will have a positive influence on the propensity to prefer gardening products with environmentally friendly attributes.

Income is also expected to have a positive impact on the likelihood of respondents in this study to prefer and purchase products with environmentally friendly attributes. It can be seen that higher incomes positively impact environmentally friendly behaviors, like composting or recycling (Park, Lamons and Roberts 1998), while decreasing likelihood of consumers purchasing conventionally grown florals when environmentally friendly alternatives are present and advertised (Khachatryan, et al 2018). When sustainable options were available (e.g. organic, certified organic, domestic vs. imported plants), consumers with greater incomes were more

likely to choose the plants with greater aspects of sustainability (Rihn, et al. 2016). Similarly, Yue et al. (2010) found that respondents with higher incomes had a greater WTP for biodegradable packaging methods of florals. All of these are consistent with a study of consumer choice in retail outlets for florals, indicating that consumers with higher incomes frequent floral retailers with higher prices (Yue and Behe 2008).

Consumer Beliefs and Attitudes

The belief systems and attitudes held by consumers greatly influence purchase and expenditure decisions. Attitudes on the environment, such as the acknowledgement that consumer behavior can effect climate change, has been shown to influence purchasing decisions (Hugie, Yue and Watkins 2012). Hugie and colleagues (2012) use cluster analysis to determine differing preferences among consumers for low-input turfgrasses. The cluster analysis revealed four segments of respondents, including a “Water Conscious segment”. This cluster identified that mowing behavior, namely a reduction in frequency, can positively impact the environment and were the cluster most likely to purchase turfgrasses with reduced resource needs (Hugie, Yue and Watkins 2012). Ghimire, et al. (2016) similarly find that among several attributes, drought-tolerant grasses were among the most preferred characteristics of sod (following low average maintenance costs and shade-tolerant turf). It is important to note here that while there are environmental benefits to drought resistance, there are also other benefits (like cost savings) that are at least as likely to influence consumer behavior.

Recent literature has attempted to identify social influences or personally held convictions that would motivate the practice of gardening in consumers. McFarland, et al. (2018)

utilized a general inductive approach to categorize survey data with responses identifying why the consumer gardened, any associated feelings with gardening, what it meant for them to be a gardener as well as their first memory related to gardening. Themes across the study included environmental aspects, economics, aesthetics, food availability/health/nutritional components and the capacity of gardening to be therapeutic. Ninety-two percent of respondents indicated a primary motivation for gardening was its therapeutic effects, validating that gardening as a practice is perceived to positively contribute to mental health.

Underlying, or latent, identities can also influence consumer behavior. Kiesling and Manning (2010) explore the influence of the “environmental gardening identity” on the practices and behavior of gardeners. Utilizing a validated environmental identity scale (EID, Clayton 2003) as a predictor of ecological gardening behavior, it was seen that those who identify themselves as environmentally-friendly and measure higher on the scale demonstrably behave more ecologically in the garden, including the tendency to avoid pesticides and choose natural fertilizers (Kiesling and Manning 2010). In an analysis of the contribution of food self-provisioning by active gardeners (“active” here is meant to indicate a gardener that produces at least some of the fruit, vegetables and potatoes, s/he consumes) in the Czech Republic to overall sustainability, Vávra, Daněk and Jechlička (2018) note that while the largest motivation for food self-provision was for access to fresh food, Czech active gardeners, in large part, act ecologically in their gardens. Forty-four percent of these gardeners use only organic fertilizers (compost, manure, etc.) and sixty-four percent have garden plots adjacent to their homes, eliminating the need for transportation to access their gardens (Vávra, Daněk and Jechlička (2018). Though the

motivation to grow their own food is different than a concern for environmental sustainability (only 6% of respondents indicated that they gardened for environmental reasons), the preference for fresh foods may be an underlying attitude that can promote sustainable practices in some segments of consumers. However, consumers may also be motivated to grow their food due to perceived or real benefits to health and nutrition, concerns for food safety or some combination including benefits to the environment.

The MIMIC Model

A Multiple Indicator Multiple Causation (MIMIC) Model was used to analyze which demographic factors influence consumer preferences for ecofriendly products. The MIMIC model is a multi-factor latent variable model that enables simultaneous modeling of discrete variables in a general linear model framework (Skrondel and Rabe-Hesketh 2004). MIMIC models consist of two components: i) a measurement model defining the relationships between an unobservable latent variable and its indicators, and ii) a structural model capturing the effects of causal variables on the unobservable latent variable.

Separate logit models for preferences for each of the individual environmental gardening attributes could have been estimated as a function of the demographic, expenditure, and attitude variables. However, estimation of individual logit models fails to capture that there is any common underlying factor that may represent these preferences (in this case preferences for environmental gardening supplies). Additionally, a multivariate probit model with correlations across the error terms could also have been used. In this case and with this type of model, the number of coefficients can become quite large as well as the associated marginal effects. For

these reasons, the MIMIC model was used and allows for both a measurable latent variable as well as interpretable marginal effects.

The MIMIC model has been used rather extensively in psychology and human behavior studies (Proitsi, et al. 2011; Brailean, et al. 2015; Ward, Ray and Fox 2018). The MIMIC model allows for the joint modeling of multiple indicator variables influenced by multiple causal variables in the estimation of an unobservable latent variable. As an example, Martin (2007) used a MIMIC approach to assess the impacts of demographic variables on eleven behavioral and cognitive factors in an attempt to estimate motivation and engagement of high school students.

Though adopted with less frequency, agricultural research has implemented the MIMIC model for several applications (Patterson and Richards 2000; Richards and Jeffrey 2000; Acharya and Molina 2014). Patterson and Richards (2000) analyze the impacts of newspaper ads on consumer preferences for seven varieties of apples. Using ad characteristics as the causal variables and brand share and profit margins as the indicator variables, they were able to estimate consumer preferences or “brand attraction”, the latent variable. In a study measuring “performance” as the latent variable of a dairy producer in Alberta, Canada (Richards and Jeffrey 2000), the MIMIC model was able to measure which causal variables were more influential to performance levels and could indicate which technologies, practices and the like could be focused on to further increase economic returns.

Additionally, the MIMIC model has been used in agricultural economic studies to measure the unobservable consumer taste and preference variable (Acharya and Molina 2004; Gao, Wailes and Cramer 1997). Acharya and Molina (2004) utilized a MIMIC model in their

study of changes in consumption of several fruits and vegetables. The indicator variables consisted of per capita expenditures on food spent away from home and on eggs, poultry and low fat milk, while the causal variables included several demographic and attitudinal variables. Their MIMIC model discerned that both priority of convenience and attention to health were important factors in shaping consumer preferences for fresh fruits and vegetables. Similarly, Gao, Wailes and Cramer (1997) utilize a MIMIC model to analyze consumer taste change for beef products. They sought to determine how household demographics and characteristics (causal variables) impacted taste and preference (the latent variable) as expressed through the residual of the household's demand for beef, the indicator variable.

The MIMIC model has also been used in assessing product or design attributes that are preferred by consumers (Lim, Heinrichs and Lim 2008; Bliemel and Hassanein 2007; Žabkar, Brenčič and Dmitrović 2008). Lim, Heinrichs and Lim (2008) use MIMIC analysis has been used to measure the impacts of e-shopping web design attributes on e-shopping web site usage. Finding that security was the most important attribute to the sample population, followed by content quality, this study was able to provide e-shopping firms with recommendations on which attributes to stress for successful e-shopping websites. Similarly, Bliemel and Hassanein (2007) use MIMIC analysis to identify the attributes of online health websites that incite consumer traffic for health information. They find that content quality and technical adequacy had the largest influence on overall consumer satisfaction, the latent variable. Žabkar, Brenčič and Dmitrović (2008) use MIMIC modeling to reveal which attributes of travel destinations promote the highest levels of consumer satisfaction. Their model tested the impacts of several destination

attributes on perceived quality of the destination by the consumer through their impacts on the indicator variables, including behavioral intentions (like visiting again) and visitor satisfaction. Their study provides operators of travel destinations with information on how to improve their sites to better serve and retain their consumers. These three studies validate the use of the MIMIC model to determine attributes of products that are most attractive to consumers.

Chapter 3: Methods and Procedures

Data Collection and Survey Instrument

A survey of home gardeners was conducted using the Qualtrics online survey platform. The list frame was comprised of Tennessee residents aged 18 years or older who self-identified as gardeners (either indoor, outdoor, or both). The sample frame was provided by Qualtrics. A pre-test survey of 108 respondents was fielded in June 2018. The survey was modified based on the pre-test results, with a full version of the survey fielded in July 2018 and yielded 771 responses.

The survey instrument used for this study was part of a larger willingness to pay study for potting mix containing biochar in a 25% mix, the results of which are discussed and analyzed in the second paper of this thesis. The survey included informational slides as well as questions asking about respondents' preferences for a potting mix with or without biochar, preferences for different characteristics of biochar, gardening supply purchasing patterns and demographic information.

The first and second sections were related to biochar and will be elucidated in the second paper. The subsequent sections asked respondents about their potting mix purchase patterns, including frequency and volume of purchases, where they normally purchase potting mix, and their intended uses for potting mix. Respondents were also asked about their overall gardening habits, expenditures, and gardening practices. The last section of survey included questions soliciting respondent views on various topics related to the environment and gardening as well as demographic and household characteristics.

Economic Modeling of the Adoption Decision – The MIMIC Model

The MIMIC model is a type of structural latent variable econometric model used to estimate an unobserved, or latent, variable using indicator and explanatory/causal variables (Richards and Jeffrey, 2000). Indicator variables are imperfect measures of the latent variable, or measures of the effect the latent variable has on observable quantities. In the case of this study, the indicator variables are ecofriendly attributes in garden supplies (see Table 1.1 for complete list of variables). The use of the MIMIC model here extends binary choice models by allowing the indicator variables to serve as indicators of propensity to prefer environmentally beneficial attributes in gardening supplies. The causal, or explanatory, variables are exogenous factors like age, education, environmental attitudes, or gardening expenditure, that are hypothesized to influence propensity to prefer environmentally friendly attributes in gardening supplies (the latent variable, *ENVIR*). Figure 1.1 shows the relationships between the causal variables, the latent variable (*ENVIR*), and the indicator variables.

It should be noted here that the sample size utilized in the model is smaller than that responses gathered from the survey. This accounts for 46 respondent surveys that were not complete (i.e. not all questions were answered) and therefore omitted from the model. Additionally, the means estimated from the model, while not representative of the Tennessee population, are representative of the population of consumers that garden. According to the National Gardening Association in 2014, the average U.S. gardener was female, female, over forty-five years old, and had a college degree or some college education. Hence, our sample is similar to these statistics from the national survey (White 2014).

Table 1.1. Variable Names, Definitions and Means

Variable Name	Variable Description	Mean (N=725)
<i>Environmentally Friendly Gardening Product Attributes (Indicator Variables)</i>		
Decreased Fertilizer Needed	1 if believes decreased fertilizer needed is important product attribute, 0 otherwise	0.75
Decreased Pesticide Needed	1 if believes decreased pesticides needed is important product attribute, 0 otherwise	0.87
Decreased Water Needed	1 if believes decreased water needed is important product attribute, 0 otherwise	0.67
Native Plant Species	1 if believes native species is important product attribute, 0 otherwise	0.57
Organically Produced	1 if believes organically produced is important product attribute, 0 otherwise	0.60
Recyclable Packaging	1 if believes recyclable packaging is important product attribute, 0 otherwise	0.62
<i>Explanatory Variables (Causal Variables)</i>		
AGE	Respondent age in years	44.00
FEMALE	1 if female, 0 otherwise	0.79
COLLGRAD	1 if college graduate, 0 otherwise	0.40
RURAL	1 if rural, 0 otherwise	0.33
HHINC	2017 household income, in \$1,000	73.03
PCTGARDEN	Percent of income spent on gardening supplies	0.49
OUTDOOR	1 if primarily an outdoor gardener, 0 otherwise	0.71
ENVIROORG	1 if environmental organization member, 0 otherwise	0.16
GARDENCL	1 if garden club member, 0 otherwise	0.08
INFOEXT	1 if use information from Extension Services, 0 otherwise	0.24
INFOOG	1 if use information from other gardeners, 0 otherwise	0.50
INFOTVMAG	1 if use information from TV/Magazines, 0 otherwise	0.38
INFOSOCINT	1 if use information from social media/internet, 0 otherwise	0.56
RESPFUTGEN	Responsible to future generations for environment, 1=strongly disagree, ..., 5=strongly agree	4.51
LENVKNOW	Lack environmental knowledge, 1=strongly disagree, ..., 5=strong agree	2.80
SACRIFICENV	People will sacrifice for the environment, 1=strongly disagree, ..., 5=strongly agree	3.82
HGARDENV	Home gardeners impact the environment, 1=strongly disagree, ..., 5=strongly agree	4.27
GROWFOOD	Like to grow own food, 1=strongly disagree, ..., 5=strongly agree	3.87

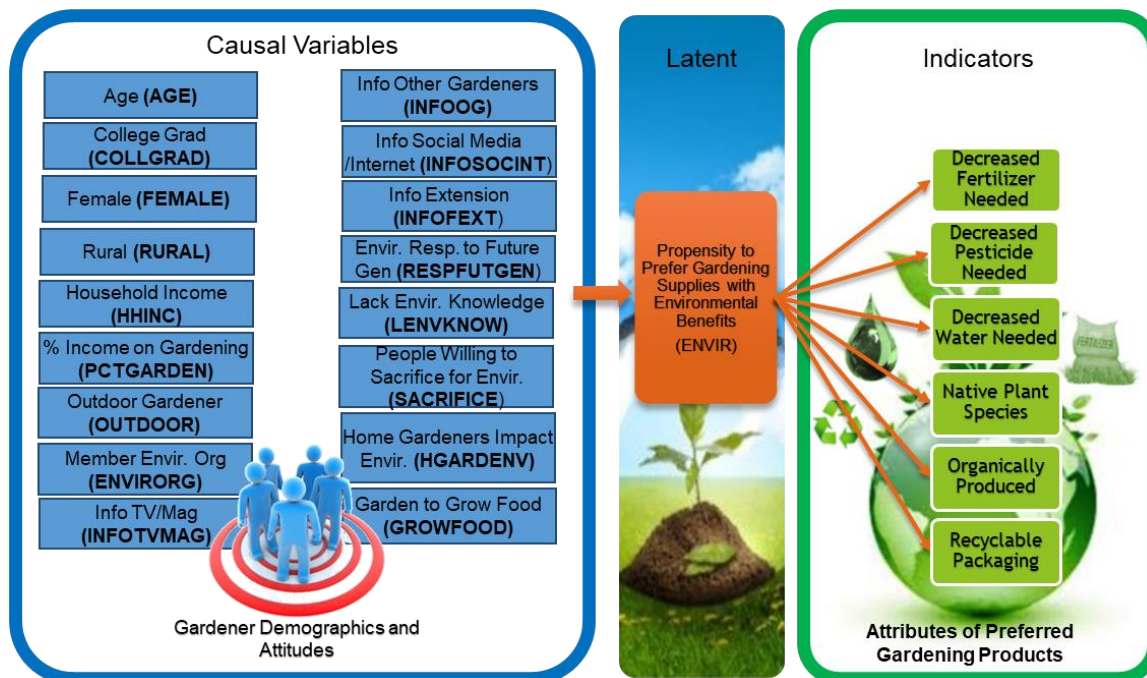


Figure 1.1. The MIMIC Model of Consumer Preferences for Gardening Products with Environmentally Friendly Attributes.

The MIMIC model consists of two types of equations, the structural equations and the measurement equations, used to describe the relationships between the indicator and latent variables and the explanatory and latent variables (Richards and Jeffrey 2000). In this study, the propensity to prefer ecofriendly attributes in gardening products, a latent unobservable variable labeled *ENVIR* is hypothesized to be a function of consumer demographics, shopping patterns, and environmental attitudes, $\mathbf{X}$, where

$$ENVIR = \gamma' \mathbf{X} + \varsigma \quad (4)$$

The structural equation in (4) identifies a relationship between the latent variable *ENVIR*, the matrix of observable causes $\mathbf{X}$, where γ is a matrix of parameters to be estimated, and the random error term, ς .

The measurement equation specifies the relationship between the vector of indicator variables, $\mathbf{y}$, and the unobserved latent variable, *ENVIR*. The λ are parameters to be estimated and ε are the error terms from each indicator equation (Bollen 1989):

$$y_k = \lambda' ENVIR + \varepsilon \quad (5)$$

The propensity to prefer the k th environmental gardening attribute y_k^* , (k =decreased pesticides needed, decreased fertilizer needed, decreased water needed, native species, organically produced and recyclable packaging) can be expressed as:

$$y_k^* = \lambda' ENVIR + \varepsilon_k \quad (6)$$

The ε_k represents the measurement error for the k th indicator equation (Bollen 1989). Hence, if we write equation (6) for each of the k indicator variables in this study, it would appear as:

$$\text{Decreased Fertilizer Needed}^* = \alpha_1 + \lambda_1 * ENVIR + \varepsilon_1 \quad (7a)$$

$$\text{Decreased Pesticide Needed}^* = \alpha_2 + \lambda_2 * ENVIR + \varepsilon_2 \quad (7b)$$

$$\text{Decreased Water Needed}^* = \alpha_3 + \lambda_3 * ENVIR + \varepsilon_3 \quad (7c)$$

$$\text{Native Species}^* = \alpha_4 + \lambda_4 * ENVIR + \varepsilon_4 \quad (7d)$$

$$\text{Organically Produced}^* = \alpha_5 + \lambda_5 * ENVIR + \varepsilon_5 \quad (7e)$$

$$\text{Recyclable Packaging}^* = \alpha_6 + \lambda_6 * ENVIR + \varepsilon_6 \quad (7f)$$

where α_k is a constant for each of the k ecofriendly attributes, the λ_k are factor loadings correlating each of the indicators with *ENVIR* (Skrondal and Rabe-Hesketh 2004). If kth λ is significant, this suggests preferring the kth ecofriendly attribute is a good indicator of the propensity to prefer environmentally friendly attributes in gardening supplies (Maddala and Trost 1981).

Using equations (4) and (6), the reduced form for the indicator variables as a function of the structural explanatory variables can be written as:

$$y_k = \lambda_k (\gamma' X + \varsigma) + \varepsilon_k. \quad (8)$$

The model is estimated with generalized structural equations modeling (GSEM) in STATA. In keeping with the GSEM modeling framework, the structural equations are estimated as OLS regressions, while the measurement equations are estimated as logit models. The estimates are obtained using maximum likelihood estimation.

Using the logistic distribution, the probability that gardeners will prefer the kth environmental attribute as a function of *ENVIR* can be expressed as:

$$\Pr(y_{k=1}) = \exp[\alpha_k + \lambda_k * ENVIR] / (1 + \exp[\alpha_k + \lambda_k * ENVIR]). \quad (9)$$

Furthermore, for the i th individual, using the logistic distribution, the probability that a gardener will prefer the k th environmental attribute as a function of their demographics, expenditure patterns, and attitudes can be expressed as:

$$\Pr(y_{i,k}=1) = \exp[\alpha_k + \lambda_k (\gamma' X_i)] / (1 + \exp[\alpha_k + \lambda_k (\gamma' X_i)]). \quad (10)$$

The probabilities of preferring the gardening products with each of the environmental attributes (Decreased Fertilizer Needed, Decreased Pesticide Needed, Decreased Water Needed, Native Plant Species, Organically Produced, and Recyclable Packaging) are calculated using the estimated coefficients of the MIMIC model and the predicted values for ENVIR (using the regression and the demographic, spending patterns, and other causal variables). To illustrate potential market segments and their demographics/characteristics, three segments were developed, one with low propensity to prefer environmentally gardening products (lowest third of ENVIR), medium propensity (middle third of ENVIR), and high propensity (highest third of ENVIR). For the three segments, means of the respondent demographics, spending patterns, and attitudes reflect differences across the three market segments.

Chapter 5: Results and Discussion

Results

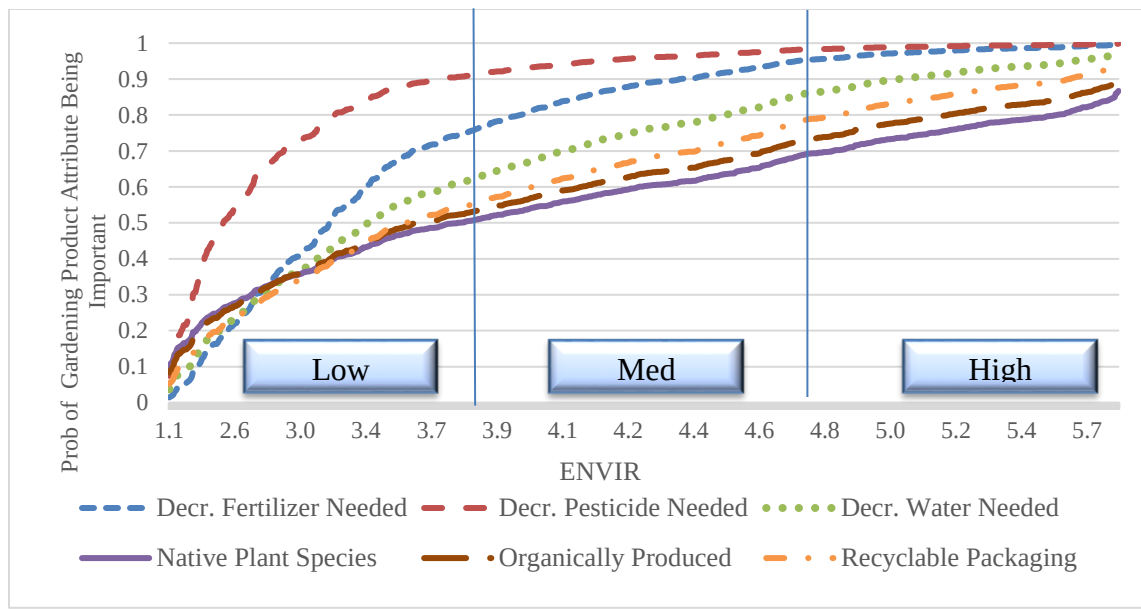
Results for the estimated MIMIC model are presented in Table 1.2. As can be seen in Table 1.2, a total of 725 responded to all questions needed for the analysis. The remaining sample with incomplete survey responses (n=46) were not included in the model. The Log Likelihood Ratio test (LLR Test) indicated the model was significantly different from zero (426.4 with 18 df > $\chi^2=28.87$) at the 95 percent confidence level. The percent correctly classified for each dummy variable representing preferences for environmental attributes in gardening products ranges from 91.59% for decreased need for pesticide (Decreased Pesticides Needed) to 68.28% for native plants (Native Plant Species). Respondents who are older (AGE), female (FEMALE), members of environmental organizations (ENVIRORG) and garden clubs (GARDENCL), along with those who like to garden to grow their own food (GROWFOOD) and consider themselves more knowledgeable about the environment (LENVKNOW) are more likely to prefer gardening products with the environmentally friendly attributes considered in this analysis (ENVIR). Similarly, gardeners who feel a greater responsibility to care for the environment for future generations (RESPFUTGEN) and believe that home gardeners impact the environment (HGARDENV) have a higher propensity to prefer these products. The probabilities of preferring product attributes are calculated using Equation 9 and the estimates from the model in Table 1.2

In Figure 1.2, the predicted probability of preferring each of the gardening product attributes is plotted against ENVIR – the propensity to prefer gardening products with environmental attributes. The scale of the propensity score ENVIR indicates the degree of

Table 1.2. Estimated MIMIC Model of Tennessee Home Gardeners' Probability of Preferring Gardening Supplies with Environmental Attributes^a

	Estimated Coefficients		% Correctly Classified
Model	α	λ_{ENVIR}	
Logit Models of Prob. of Preferring Attribute of			
Decreased Fertilizer Needed	-6.329 ***	1.961 ***	89.24%
Decreased Pesticide Needed	-4.427 ***	1.774 ***	91.59%
Decreased Water Needed	-4.737 ***	1.374 ***	81.79%
Native Plant Species	-3.045 ***	0.807 ***	68.28%
Organically Produced	-3.382 ***	0.921 ***	70.48%
Recyclable Packaging	-4.139 ***	1.142 ***	72.00%
Regression on Latent Variable (ENVIR)			
	γ		
AGE	0.011 ***		
FEMALE	0.265 ***		
COLLGRAD	-0.006		
RURAL	-0.115		
HHINC	-0.001		
SHRGARDEN	0.037		
OUTDOOR	0.111		
ENVIRORG	0.342 ***		
GARDENCL	0.374 *		
INFOEXT	-0.081		
INFOOG	0.081		
INFOTVMAG	0.074		
INFOSOCINT	0.096		
RESPFUTGEN	0.372 ***		
LENVKNOW	-0.103 **		
SACRIFICENV	0.008		
HGARDENV	0.343 ***		
GROWFOOD	0.109 **		
LLR Test (18 df)	-426.4 ***		
N=725			

^a***=significant at $\alpha=.01$, **=significant at $\alpha=.05$, and *=significant at $\alpha=.10$.



^a Groups of respondents were formed across their level of ENVIR. The lowest third of ENVIR fell below 3.845. The middle third was $3.845 \leq \text{ENVIR} < 4.757$, and the top third was $\text{ENVIR} \geq 4.757$.

Figure 1.2. Probabilities of Preferring Gardening Products with Environmentally Friendly Attributes Across ENVIR^a.

preference a consumer has for garden products with environmentally friendly attributes.

Consumers who are relatively indifferent to ecofriendly garden products (lowest ENVIR levels) are less likely to prefer these goods. For example, complete indifference corresponds with an ENVIR of 0.

The probability of considering a decreased need for pesticides as an important attribute in the product the respondent purchases emerges first, followed by organically produced and native plant species (Figure 1.2). However, as ENVIR increases, the rankings cross, and products that reduce inputs (“Decreased Pesticide Needed”, “Decreased Fertilizer Needed” and “Decreased Water Needed”) emerge as the attributes with the largest probabilities of attribute importance to consumers. While all product attributes have increased probabilities of importance to consumers.

as ENVIR increases, the “Native Plant Species”, “Recyclable Packaging” and “Organically Produced” attributes appear to have the highest probabilities in consumers with the greatest levels of ENVIR. This may suggest that these products are preferred by a more specialized group of consumers with relatively higher environmental concern, while products that reduce inputs are more widely preferred by consumers with varying perceptions of environmental importance.

Table 1.3 illustrates market segments, the respondents were divided into groups based upon levels of the propensity to prefer gardening products with environmentally friendly attributes (ENVIR). These groups are described as Low (lowest third), Medium (middle third), and High (highest third) and correspond with increasing levels of ENVIR. The mean demographic attributes, expenditure patterns, and attitudes are calculated to illustrate characteristics of market segments for gardening products with environmentally friendly attributes. The variables in bold signify those found to be significant in the model. Compared with the Low Propensity group, the High Propensity group members are more likely to be older as well as female. These High Propensity group members also tend to be involved in of environmental organizations and/or gardening clubs and are motivated to garden by a desire to grow their own food. Respondents in this group also consider themselves more knowledgeable about the environment, feel more strongly about a responsibility to future generations to protect the environment and are more likely to believe that home gardeners can impact the environment with their actions.

Table 1.3. Demographics of Three Market Profiles (Low, Medium and High) Across ENVIR^a

Variable	Low ENVIR	Med ENVIR	High ENVIR
AGE	42.54	43.81	45.64
FEMALE	0.75	0.79	0.85
COLLGRAD	0.41	0.39	0.41
RURAL	0.37	0.33	0.31
HHINC (\$1,000)	73.24	72.15	73.72
SHRGARDEN	0.46	0.46	0.54
OUTDOOR	0.66	0.72	0.76
ENVIRORG	0.08	0.14	0.25
GARDENCL	0.07	0.06	0.11
INFOEXT	0.21	0.20	0.30
INFOOG	0.46	0.47	0.57
INFOTVMAG	0.28	0.40	0.45
INFOSOCINT	0.54	0.57	0.57
RESPFUTGEN	4.09	4.58	4.86
LENVKNOW	3.05	2.94	2.40
SACRIFICENV	3.71	3.86	3.89
HGARDENV	3.85	4.29	4.67
GROWFOOD	3.62	3.94	4.05

^a Groups of respondents were formed across their level of ENVIR. The lowest third of ENVIR fell below 3.845. The middle third was $3.845 \leq \text{ENVIR} < 4.757$, and the top third was $\text{ENVIR} \geq 4.757$.

Discussion

Based on the results of the MIMIC model, there are several variables of importance, from a marketing perspective. Age and gender were significant and positively influential in the analysis as was membership in an environmental organization or gardening club. These group activities may be an effective marketing tool to engage with these types of consumers.

Additionally, consumer belief that they were knowledgeable about the environmental and stronger agreement with protecting the environment for future use coincide with previous research that those with greater environmental concern or awareness of environmental issues (real or perceived) is associated with the preference for products with environmentally friendly attributes. Additionally, gardening to grow food is significant and positively impacts the likelihood to prefer products with environmentally friendly attributes, which may suggest that targeting fruit and vegetable gardeners may increase sales of these types of products.

Based on Figure 2.1., gardening products requiring less pesticides are adopted by Tennessee gardening consumers with lower levels of propensity to prefer gardening products that have ecofriendly attributes, followed by produced organically, and native plant species. However, as the propensity increases, the probability of preferring products that require less fertilizer also increases rapidly. These results could indicate that products with a decreased need for pesticides and fertilizers may have broader appeal to Tennessee's gardening community, while only the most committed to environmental values have preferences for those products that are native species, organically grown or come in recyclable packaging.

Table 2.2 identifies some characteristics of the market segments that have low, medium, and high propensity to prefer gardening products with environmental benefits and may contribute to existing research that supports consumer segments that favor products with environmental attributes. While products with decreased need for fertilizer and pesticides appeal to those consumers across each of the three segments, other gardening product attributes, such as organically produced and native plant species, seem to be most likely favored by those of Tennessee's gardeners that have medium and high propensity to purchase ecofriendly gardening products.

Chapter 6: Conclusions

The purpose of this study was to provide a better understanding of Tennessee home gardeners' preferences for six environmentally friendly attributes of gardening supplies and the influences on the probabilities of preferring each of these attributes. The results suggest that among Tennessee gardeners, the marketing of products with decreased pesticide needs, decreased water needs and decreased fertilizer needs will appeal to a wider segment of consumers. Products that are native species, produced organically or have recyclable packaging are likely to appeal to a more specialized segment of consumers, those with a greater commitment to environmental sustainability. Thus, investing the resources necessary to identify and target consumer segments would seem more justified for products with recyclable packaging or that are native species than for those that decrease pesticide use. Conversely, untargeted approaches would be more likely to motivate a diverse set of Tennessee's gardening consumers with preferences for products that reduce need for pesticide, fertilizer and water.

Membership in gardening clubs and environmental organizations both positively influenced the propensity of Tennessee gardeners to prefer environmental gardening products. This could suggest that these organizations might provide a means of marketing environmental friendly gardening products to their participants and member gardeners. Additionally, gardening to grow food had a significant and positive influence on levels of ENVIR. This may indicate that food gardeners could be a gardening consumer segment worth targeting with garden products and supplies that possess environmentally friendly attributes.

Future research may involve a greater study area, perhaps on a regional or even national level. Regional characteristics could play a role in the preference for attributes, changing the

overall market segment structure. As an example, it is likely that the preference for products that reduced water needs would be more popular in the American Southwest than in Tennessee. Impending research might also examine reasons for preferring certain environmental attributes in an effort to discern any economic drivers that may be masked as environmental. The cost benefits associated with products that require fewer inputs may be driving consumer preference for gardening products that reduce fertilizers, pesticides, water among others. Further, because gardening for food production has a positive and significant effect on ENVIR, is also possible that consumer concerns for food safety or health and nutrition purposes may be contributing to the propensity to prefer environmentally friendly gardening products. Additionally, it is possible that the use of different indicator variables may yield different results, so the inclusion of other environmentally friendly attributes associated with some garden products is necessary to better understand consumer preferences.

PART II

CONSUMER PREFERENCES FOR POTTING MIX WITH BIOCHAR

McKenzie Thomas is the main author of this article. The study used was conducted under the direction and supervision of Dr. Kimberly Jensen with input by Dr. Christopher Clark, Dr. Burton English and Dr. Dayton Lambert. The study used a dataset that was obtained through a survey directed by the aforementioned faculty in July 2018.

Abstract

Marketing co-products could significantly improve the cost effectiveness of biofuel production. One such co-product, biochar, can serve as an effective soil amendment. Markets for soil amendments with biochar are emerging, but consumer willingness to pay (WTP) is uncertain. This study uses results from a survey of 577 Tennessee home gardeners to estimate WTP for a potting mix that is 25% biochar. Estimated WTP for an 8-quart bag with the 25% biochar mix was \$8.52 compared with \$4.99 for the same sized bag with no biochar. Consumer demographics and attitudes toward both the environment and biofuel production were associated with WTP a premium for the biochar-supplemented potting mix.

Chapter 1: Introduction and Objectives

The Renewable Fuel Standard (RFS), established by the Energy Policy Act of 2005 and expanded by the Energy Independence and Security Act of 2007, requires the blending of renewable fuels into petroleum-based transportation fuel in increasing amounts, culminating in 36 billion gallons annually by the year 2022 (U.S. Department of Energy 2018). The RFS also requires that 21 of those 36 billion gallons be advanced biofuels (U.S. Department of Energy 2018). Advanced biofuels derive from either cellulosic or advanced feedstock materials and must achieve at least a 50 percent reduction in the emission of greenhouse gases (GHGs) in relation to petrol-based fuels. However, the production of advanced biofuel has not kept pace with the targets established by the RFS, due in part to a lack of investment in advanced biofuel technologies (Bracmourt 2018). Additionally, the Department of Energy has identified a lack of high-value co-products as a leading barrier to large-scale production of biofuels (Bozell and Peterson 2010).

Lignocellulose, the basis of advanced biofuel, can be converted into bio-oil, a precursor to advanced biofuels, through pyrolysis (Garcia-Perez, Lewis, and Kruger, 2011; Garcia-Perez et al., 2009). Biochar is a co-product of pyrolysis, the output of which is between 20 and 50 percent biochar, depending on the pyrolysis technology used (Winsley 2007). Biochar has many potential uses, which, if developed and marketed, could increase the profit margins of advanced biofuel production. The physical and chemical properties of biochar suggest its use as an effective soil amendment. The porosity of the carbon in biochar is thought to increase soil surface area and water retention (Reddy, Nagender, and Yerasi 2013). This porosity also reduces soil density, increases the aeration of the soil, and allows for increased habitat for beneficial

microbial growth (Chalker-Scott 2014). Biochar's chemical properties are stable, meaning it has the potential to remain in the ground as a carbon sink for many years and therefore reduce GHG emissions (Reddy, Nagender, and Yerasi 2013). The use of biochar has also been shown to reduce the emissions of nitrous oxide from soils treated with nitrogen fertilizers (Grutzmacher et al. 2018), indicating the potential for further environmental benefits.

There is increasing evidence of the positive attributes of biochar as a soil amendment, but little is known about its market potential as a retail gardening product or about consumer preferences for biochar as a soil amendment. As a coproduct of pyrolysis, developing a better understanding of consumer preferences for biochar-based products is important for increasing the profitability of advanced biofuel production.

Objectives

The objective of this research is to ascertain consumer preferences and willingness to pay (WTP) a premium for a gardening product – potting mix – containing biochar. Potting mix was chosen, in part, because the sales of products related to container gardening have been one of the fastest growing lawn and garden categories (Mason, et al. 2008). Additionally, potting mix is a retail gardening product commonly used by both indoor and outdoor gardeners, and a premixed blend of potting mix with twenty-five percent biochar adds convenience to the product (Walker 2017). As part of achieving the overall objective, sub-objectives include:

- Estimating WTP for a potting mix with twenty-five percent biochar compared to a base (conventional) product with no biochar;

- Determining the relationship between consumer WTP for potting mix with twenty-five percent biochar and consumer demographics and attitudes for possible use in marketing biochar as a soil amendment; and
- Projecting the market potential for a twenty-five percent biochar potting mix product based on the results of the WTP analysis and respondents' potting mix expenditures.

Chapter 2: Review of Literature

No previous research on consumer awareness of, or attitudes toward, the use of biochar as a soil amendment or of biochar-based gardening products, more generally, could be found. However, studies focusing on consumer preferences and WTP for environmentally friendly gardening products may provide useful guidance for analyzing consumer interest in biochar products.

Gender (female) has been found to be positively correlated with a preference for environmentally friendly packaging of garden products (Behe et al. 2010; Yue et al. 2010; Fan and McCann 2015). Utilizing survey data from sample populations in Minnesota, Michigan, Indiana and Texas, Behe et al. (2010) found that female respondents were more likely to practice ecofriendly gardening behaviors (like recycling and composting), purchase plants more frequently, and spend more, in total, on plant purchases. Fan and McCann (2015) found that Midwestern women were more likely than men to purchase drought-resistant plants, while Yue (2010) found that women were willing to pay higher premiums for biodegradable packaging than men. These results suggest that females are likely to have a greater WTP than men for a potting mix-biochar blend.

In a study of over 435,000 monetary transactions made in 48 states on floral products from 1992 to 2005, Yue and Behe (2008) found that over 70 percent of the buyers were 40 years of age or older. Similarly, Yue et al. (2010) determined that age has a positive impact on WTP for environmentally friendly gardening products. Behe et al. (2010) used cluster analysis to separate consumers in the gardening segment based on purchase frequency and plant purchase type. Their study found age was positively correlated with the frequency of floral purchases.

Additionally, the results of an experimental auction study to determine WTP for sustainable attributes in plants found age was positively correlated with eco-centric values toward plants (Yue et al. 2016). All these findings suggest that age is likely to be positively correlated with WTP a premium for a potting mix-biochar blend.

A number of studies have found that educational attainment was positively correlated with the probability of a consumer exhibiting environmentally friendly gardening behaviors and performing ecofriendly gardening practices (e.g., Park, Lamons and Roberts 1998; Behe, et al. 2010; Yue, et al. 2010; Yue, et al. 2016). For example, Park, Lamons and Roberts (1998) found that those with a college degree were more likely to compost. Correspondingly, Behe (2010) found that more eco-centric segments of gardeners were more likely to contain college graduates than segments that exhibit less ecofriendly behaviors. In a WTP study of consumer preferences of floral pot materials, Yue et al. (2010) also found education to be positively correlated with WTP for products with a biodegradable attribute. In a study of Canadian and U.S. gardening consumers, Yue, et al. (2016) found that consumers possessing higher levels of educational attainment were more likely to make environmentally conscious purchasing decisions. Khachatryan et al. (2018) found that more highly educated consumers were less likely to purchase conventional products in the presence of products with advertised attributes showing environmental benefits. Thus, education is expected to be positively correlated with a premium for a potting mix-biochar blend.

Income has also been found to be positively correlated with environmentally friendly behavior, such as composting or recycling (e.g., Park, Lamons and Roberts 1998). Purchases of

organic plants are more likely among consumers with greater incomes (Rihn 2018) as are decreased likelihoods of purchasing conventionally grown florals when environmentally friendly alternatives are available (Khachatryan 2018). Willingness to pay for plant containers that are environmentally friendly (i.e. recyclable, compostable, etc.) is higher in consumer groups with higher incomes (Yue, et al. 2010). Similarly, Yue and Behe (2008) found that consumers with higher incomes frequent floral retailers with higher prices. With these studies in mind, it is anticipated that the WTP a premium for a potting mix-biochar blend is expected to be positively correlated with income.

Several studies suggest that gardening consumers favor environmentally friendly packaging and behaviors (Khachatryan, et al. 2018; Yue 2010; Behe 2010). A two-part study analyzing consumer behavior and buyer impulsivity when purchasing florals found that more environmentally friendly attributes have a positive impact on the likelihood of purchase (Khachatryan, et al. 2018). Similarly, utilizing hypothetical and non-hypothetical auction analysis methods, Yue et al. (2010) found that consumers were willing to pay significant premiums for biodegradable packaging (rice hull, wheat starch and straw pots) in relation to conventional plastic packaging. Behe et al. (2010) found similar results in their regional survey comparing ecofriendly practices among different segments of gardening consumers, finding that the clusters that regularly purchased plants regarded plastic containers as the least attractive packaging type. For the consumer segment that generally practiced the most ecofriendly behaviors, price and type of plant container were the most important factors in determining floral purchasing decisions. Findings from these studies suggest that consumers with stronger views

about the importance of the environment may be willing to pay a premium for a potting mix-biochar blend.

Additional studies indicate greater consumer awareness of environmentally friendly products and those products that embody sustainability and resource-conscious production methods (e.g. Rihn et al. 2016; Yue et al. 2016; Fan and McCann 2015; Hugie, Yue and Watkins 2012). Rihn, et al. (2016) used eye-tracking experiments, finding that for both fruit-producing plants and indoor foliage, being produced using organic methods was positively associated with the likelihood of product purchase relative to conventional alternatives. Yue et al. (2016) used an experimental auction to find that plants grown utilizing less water or energy have premiums over plants that are conventionally grown (Yue et al. 2016). Similarly, a study of consumers in Minnesota revealed that low-input turfgrass species, specifically those that require less irrigation, were preferred over conventional turfgrass (Hugie, Yue and Watkins 2012).

While other characteristics will also likely influence the preferences of our sampled consumers, previous research repeatedly finds the aforementioned variables to be correlated with consumer preferences for gardening products with environmentally friendly attributes.

Chapter 3: Data

The pre-test and survey were administered online through Qualtrics, an online hosting service. A pre-test of the survey instrument was conducted with 108 respondents in June 2018. The pre-test results were used to modify the survey instrument (See Appendix for survey instrument), and the revised survey was fielded in late July 2018 with 771 responding. Qualtrics solicited respondents until a designated sample size was achieved. Both the pre-test and the survey sampled Tennessee residents aged 18 years or older who self-identified as gardeners (either indoor, outdoor, or both).

The survey instrument included informational slides as well as questions asking about respondents' preferences for a potting mix with or without biochar, preferences for different characteristics of biochar gardening supply purchasing patterns and demographic information. The first section provided participants with information about biochar. A single information screen provided the following information:

Biochar is a charcoal-like material that can be added to soil to promote plant growth and reduce the amount of water and fertilizer needed. Biochar can also help with carbon sequestration, or the storage of carbon in soils, to help mitigate climate change. Biochar is made by burning biomass, such as crop residues, wood wastes or other organic matter, in an oxygen-starved environment through a process known as pyrolysis.

Following the biochar information screen, a second screen provided respondents with information on the choice set. This screen also included language designed to diminish ‘yea saying’ (Blamey, Bennett, and Morrison 1999) and hypothetical bias (Cummings and Taylor 1999). The language was as follows:

*The next screen is going to ask you to choose which of two 8-quart bags of potting mix you might purchase if given the opportunity. Responses to questions like this one can sometimes be biased. For example, sometimes people respond how they believe is socially responsible instead of how they would actually behave. So, in answering this question, **we ask that you take a moment to consider your household budget and the fact that paying more for the bag of potting mix would mean you would have less to spend on other items.** Remember, it is possible to support an issue related to a product without being willing to pay more for the product itself.*

In the second section, participants were asked to choose between two potting mix products, the first a conventional, 8-quart bag of potting mix priced at \$4.99 and the second an 8-quart potting mix bag with 25 percent biochar priced at \$4.99, \$6.49, \$7.99, \$9.49, or \$10.99. Prices were based on prices offered for 8-quart bags of potting mix by major home improvement stores at the time of the survey. The sample was randomly divided into five groups, with each group receiving one of the 25 percent biochar potting mix prices. An example choice set is

shown in Figure 2.1. Respondents could choose the conventional bag (*PM0*), the 25 percent biochar bag (*PM25*), or neither.

The third section included questions asking respondents about their potting mix purchase patterns, including frequency and volume of purchases, where they normally purchase potting mix, and their intended uses for potting mix. Respondents were also asked about their gardening habits, expenditures, and gardening practices. This section also included questions soliciting respondent views on various topics related to the environment and gardening. Questions on demographic and household characteristics were also included.

II. Potting Mix and Potting Mix-Biochar Products

Below you are presented with two 8-quart bags of potting mix that serve as potting soil for container plants. Each 8-quart bag fills about two 8 inch pots. The first bag is a conventional potting mix (compost, peat moss, vermiculite, and bone meal) that contains no biochar. The second is 75% conventional potting mix (compost, peat moss, vermiculite, and bone meal) and 25% biochar. Both products are identical in all ways except for the addition of the biochar in the second bag. **Suppose you were shopping for potting mix, please indicate which potting mix you would purchase.**

Please select one			
			
	Price \$4.99 Potting Mix with No Biochar	Price \$6.49 Potting Mix with 25% Biochar	I would not purchase either of the bags
	☐	☐	☐

Figure 2.1. Example Choice Set between a Conventional and 25 Percent Biochar 8 Quart Bag of Potting Mix

Chapter 4: Methods and Procedures

Potting Mix Purchase Choices and WTP Estimates

The contingent valuation (CV) method was used to elicit home gardeners WTP a premium for a potting mix containing 25 percent biochar. The method used follows a Random Utility framework (McFadden 1974). It is assumed that if the 25 percent biochar potting mix product provides greater utility than the product with no biochar, then the biochar product will be purchased. Let U_{i0} represent the i th consumer's utility from choosing the potting mix with zero biochar ($PM0$) and U_{i25} represent the i th consumer's utility from choosing the potting mix with 25 percent biochar ($PM25$). The i th consumer will choose $PM25$ if

$$U_{i25} > U_{i0} \quad (1)$$

If consumer preferences are influenced by demographic and other non-price factors ($\mathbf{X}_i$) as well as price (P), then the decision in (1) for the i th consumer becomes

$$U_{i25}(\mathbf{X}_i, P_{i25}) > U_{i0}(\mathbf{X}_i, P_{i0}) \quad (2)$$

The probability of choosing the potting mix with 25 percent biochar ($PM25 = 1$) for the i th respondent is therefore (Greene 2018)

$$\Pr [PM25_i = 1] = \Lambda (\alpha + \boldsymbol{\beta}'\mathbf{X}_i + \beta_p P_i), \quad (3)$$

where α is a constant, β_p is the price parameter, $\boldsymbol{\beta}$ is a vector of parameters on non-price variables, $\mathbf{X}_i$ is a matrix of demographic and other non-price variables, and Λ is the logistic distribution function. Table 2.1 provides definitions and means of the variables comprising $\mathbf{X}_i$, as well as the dependent and price variables. The variables in $\mathbf{X}_i$ include demographic characteristics, potting mix use patterns, gardening habits, environmental

Table 2.1. Variable Names, Definitions, and Means Used in the Logit Model of WTP for 25 Percent Biochar Potting Mix

Variable Name	Definition	Mean (N=577)
ChooseBiochar	1 if chose the 25 percent biochar potting mix, 0 if chose the conventional potting mix	0.544
Price	Price of the 25 percent biochar potting mix (\$4.99, \$6.49, \$7.99, \$9.49, or \$10.99)	\$8.029
Age	Age of respondent in years	43.808
Female	1 if female, 0 otherwise	0.790
CollGrad	1 if college graduate (4 year), 0 otherwise	0.409
Rural	1 if reside in rural area, 0 otherwise	0.334
HHIncDol	2017 household income (before taxes) in dollars	\$73,535
PctIncGard	Percent of income spent on gardening supplies	0.491
PctIncGardSq	Percent of income spent on gardening supplies squared	0.514
PottingMixAmt	Quarts of potting mix purchased in a year	44.251
Outdoor	1 if primarily outdoor gardener, 0 otherwise	0.716
Organic	1 if use organic gardening practices, 0 otherwise	0.308
InfoMed	1 if obtain gardening information from TV and/or magazines, 0 otherwise	0.393
InfoExt	1 if obtain gardening information from Extension or Master Gardener programs, 0 otherwise	0.293
InfoSocInter	1 if obtain gardening information from social media or internet, 0 otherwise	0.574
GardenCntr	1 if purchase potting mix from garden centers	0.114
BioFuel	Extent to which agree that biofuels are important to meeting the nation's future energy needs ^a	4.054
DecInput	Extent to which agree that it's important that gardening products purchased have decreased need for water or fertilizers ^{a, b}	3.860
RespFutGen	Extent to which agree that we have a responsibility to future generations to protect the environment ^a	4.555
NoUrgentNeed	Extent to which agree that there is no urgent need to take measures to prevent climate change ^a	2.166
Consequentiality	Extent to which agree that responses to this survey could cause potting mix manufacturers to change the characteristics of the mixes they sell ^a	3.799

^a scale with 1=strongly disagree, ..., 5=strongly agree

^b Two variables had a high correlation (0.602), these were preferences for gardening products that decrease water and those that decrease fertilizer use. Hence, Cronbach's Alpha was used to create an index of the two variables (DecInput) (Cronbach 1951).

attitudes, and sources of gardening information. Those with incomplete surveys were omitted from the model, resulting in a smaller respondent size than the total sampled population.

The means estimated from the model, while not representative of the Tennessee population, are representative of the population of consumers that garden. According to the National Gardening Association in 2014, the average U.S. gardener was female, over 45 years old, and had a college degree or some college education. Hence, our sample is similar to these statistics from the national survey of gardeners (White 2014).

Responses are structured as a binary variable, with respondents choosing the base product counted as zeroes, and those who choose the 25 percent biochar product counted as ones. Respondents are also given the option to select neither product. Those that chose neither product were not included in the model. These respondents were not interested in even the conventional product at the base price and thusly, could not be included in the model. In the CV approach used, the prices of the base and biochar-potting mix products are provided to respondents, who may select either or neither product (Hanemann 1984). The probability of the i th respondent choosing the biochar product given the logistic distribution is:

$$\Pr [PM25_i = 1] = \frac{\exp(\alpha + \beta'X_i + \beta_p P_i)}{1 + \exp(\alpha + \beta'X_i + \beta_p P_i)}. \quad (4)$$

The marginal effect of the demographic or attitude variable, X_j is

$$ME(X_j) = \frac{\exp(\alpha + \beta'X_i + \beta_p P_i)}{(1 + \exp(\alpha + \beta'X_i + \beta_p P_i))^2} \beta_j. \quad (5)$$

The WTP by the i th individual for the potting mix with 25 percent biochar is

$$\widehat{WTP}_{PM25} = - \frac{\alpha + \beta'X_i}{\beta_p}. \quad (6)$$

The mean of the WTP and associated standard errors around the WTP are calculated using the Krinsky and Robb method with 5,000 replications (Krinsky and Robb 1986). In addition, the effects of each variable on WTP and their associated standard errors are calculated using the Krinsky and Robb method. The effect of the j th non-price explanatory variable on estimated WTP is calculated as

$$\frac{\partial \widehat{WTP}_{PM25}}{\partial X_j} = - \frac{\beta_j}{\beta_p}. \quad (7)$$

Based on the signs of the estimated coefficients, profiles are developed for consumers with a low probability of willingness to purchase biochar and for those with a high purchase probability. WTP values and their associated standard errors are calculated using the Krinsky and Robb method. These profiles are used to illustrate potential market segments for the 25 percent biochar potting mix.

Chapter 5: Results and Discussion

Results and Outcomes

Means of the variables are shown Table 2.1. About 54 percent of the respondents chose the biochar-supplemented potting mix product. Average respondent age was just under 44 years and about 79 percent of the respondents were female. Just under 41 percent were college graduates and a third resided in rural areas. The average household income was \$73,535. From the National Gardening Association, in 2014, the average U.S. gardener was female, over 45 years old, and had a college degree or at least some college education. Hence, the sample appears to be similar to the population of U.S. gardeners represented by the National Gardening Association's statistics (White 2014).

The results of the estimated logit model for the 8-quart bag of potting mix-biochar blend are shown in Table 2.2. The model log likelihood was -317.84, and the test against an intercept-only model produced a likelihood ratio statistic of 160. With twenty degrees of freedom, the null hypothesis that the covariates were unrelated to the purchasing choice was rejected at the five percent level of significance. The Pseudo R^2 was 0.20, and the model correctly classified 72.79 percent of the observations.

The coefficient on price was negative and significant. Other variables with negative and significant coefficients were respondent age, the square of the percent of respondent income spent on gardening, and the strength of respondent belief that there is no urgent need to take action to prevent climate change. Variables that had significant and positive coefficients were percent of respondent income spent on gardening, amount of potting mix respondent purchases in a year, being an organic gardener, strength of respondent belief that biofuels are important to

Table 2.2. Variable Names, Definitions, and Means Used in the Logit Model of WTP a Premium for 25 Percent Biochar Potting Mix

Variable Name	Estimated Coefficient		Estimated Marginal Effect on Pr(ChooseBiochar=1)	
Intercept	1.764	*		
Price	-0.449	***	-0.083	***
Age	-0.015	**	-0.003	**
Female	0.079		0.015	
CollGrad	-0.275		-0.051	
Rural	0.281		0.052	
HHincDol	0.000		0.000	
PctIncGard	0.926	**	0.172	**
PctIncGardSq	-0.189	*	-0.035	*
PottingMixAmt	0.005	*	0.001	*
Outdoor	-0.185		-0.034	
Organic	0.489	**	0.091	**
GardenCntr	0.749	**	0.139	**
BioFuel	0.339	**	0.063	***
DecInput	0.154		0.029	
RespFutGen	-0.015		-0.003	
NoUrgentNeed	-0.180	**	-0.033	**
Consequentiality	0.068		0.013	
InfoExt	0.243		0.045	
InfoMed	0.415	**	0.077	**
InfoSocInter	-0.225		-0.042	
LL -317.844				
LR(20 df)=159.690***				
Percent Correctly Classified=72.79%				
Pseudo R2=0.2008				
N=577				

^a ***=significant at $\alpha=.01$, **=significant at $\alpha=.05$, and *=significant at $\alpha=.10$.

the nation's energy future, and respondent use of TV and/or magazines as sources of gardening information.

The marginal effects of each of the variables on the probability of selecting the 25 percent biochar bag are shown in the right hand column of Table 2.2. A \$1 per 8-quart bag increase in price decreases the probability the respondent would choose the biochar mix by 8.3 percent. Each additional year of age decreases the probability of purchasing the biochar product by 0.3 percent. The percent of household income spent on gardening supplies had a non-linear effect, first increasing the probability of purchasing the biochar mix, then decreasing it. The turning point in the effect is 2.44 percent of household expenditures spent on gardening supplies. For each quart of potting mix the respondent usually purchases in a year, the probability of choosing the biochar mix increases by 0.1 percent. Hence for each 8-quart bag usually purchased, the probability increases by 0.8 percent. Use of organic gardening practices increases the probability by 9.1 percent. Shopping for potting mix at garden centers increases the probability by 13.9 percent. For each level of increase in agreement that biofuels are important, the probability of purchasing the biochar mix increases by 6.3 percent. Gardeners who use TV and magazines as sources of gardening information are 7.7 percent more likely to choose the 25 percent biochar potting mix bag. For each level of agreement that there is no urgent need to take measures to help decrease climate change, the probability of choosing the biochar mix decreases by 3.3 percent.

The mean WTP a premium for the potting mix with biochar and the associated confidence interval at the 95 percent confidence level are presented in Table 2.3, along with the

Table 2.3. Mean Willingness to Pay and Effects of Variables on Mean Willingness to Pay for the 25 Percent Biochar Potting Mix

	Mean ^a	Lower Confidence Level	Upper Confidence Level
WTP	\$8.52	\$8.08	\$8.98
Premium Over \$4.99 Base Price	\$3.53	\$3.09	\$3.99
Effect of Variable on WTP			
Age	-\$0.03	-\$0.06	\$0.00
Female	\$0.18	-\$0.87	\$1.22
CollGrad	-\$0.61	-\$1.53	\$0.31
Rural	\$0.62	-\$0.32	\$1.57
HHincDol	\$0.00	\$0.00	\$0.00
PctIncGard	\$2.06	\$0.31	\$3.81
PctIncGardSq	-\$0.42	-\$0.86	\$0.02
PottingMixAmt	\$0.01	\$0.00	\$0.03
Outdoor	-\$0.41	-\$1.38	\$0.55
Organic	\$1.09	\$0.10	\$2.07
GardenCntr	\$1.67	\$0.29	\$3.05
BioFuel	\$0.75	\$0.17	\$1.34
DecInput	\$0.34	-\$0.20	\$0.89
RespFutGen	-\$0.03	-\$0.72	\$0.66
NoUrgentNeed	-\$0.40	-\$0.75	-\$0.05
Consequentiality	\$0.15	-\$0.35	\$0.66
InfoExt	\$0.54	-\$0.50	\$1.58
InfoMed	\$0.92	\$0.00	\$1.84
InfoSocInter	-\$0.50	-\$1.37	\$0.37

^a Krinsky and Robb 95% Confidence Interval (5000 reps)

effects of each of the variables on WTP. The variables that have a non-zero effect on WTP at the 95 percent confidence level are boldfaced in Table 2.3. The mean WTP was \$8.52, with lower and upper confidence bounds of \$8.08 and \$8.97, respectively. For each additional year in age, respondents are willing to pay an average of \$.03 less for the 8-quart bag of biochar-supplemented potting mix. For each percentage point of income spent on gardening supplies, mean WTP increases by \$2.06 up to 2.44 percent of income, at which point, it begins decreasing by \$.42 per percentage point of income. For each additional quart of potting mix purchased annually, WTP increases by an average of \$0.01. That is to say, for every 8-quart bag purchased, mean WTP increases by \$0.08. On average, respondents who use organic gardening practices are willing to pay \$1.09 more than those who do not; while those who purchase potting mix at garden centers are willing to pay \$1.67 more. A one-level increase in the extent to which a respondent believes that biofuels are important to meeting the nation's future energy needs is associated with a mean increase in WTP of \$0.75, while a one-level increase in the extent to which a respondent believes that there is no need to take action to help prevent climate change is associated with a \$0.40 decrease. Respondents who use TV and magazines as sources of gardening information are willing to pay \$0.92 more on average for the 25 percent biochar potting mix than those who do not.

The signs of the estimated coefficients are used to construct two profiles of gardeners in Tennessee, one with a low probability of choosing 25 percent biochar potting mix given the option and one with a high probability. The two profiles are shown in Table 2.4. The low probability profile gardener is a 55 year old male, who spends 0.25 percent of a household

Table 2.4. Market Profiles and Willingness to Pay for Low and High Probability of Choosing 25 Percent Biochar Potting Mix

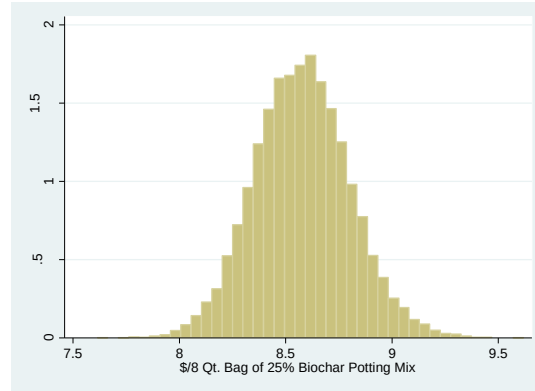
	Low Probability	High Probability
Profile		
Age	55	35
Female	No	Yes
CollGrad	1	0
Rural	0	1
HHincDol	55000	95000
PctIncGard	0.25	0.75
PctIncGardSq	0.0625	0.5625
PottingMixAmt	32	64
Outdoor	1	0
Organic	0	1
GardenCntr	0	1
BioFuel	1	5
DecInput	1	5
RespFutGen	Strongly Agree	Strongly Disagree
NoUrgentNeed	5	1
Consequentiality	1	5
InfoExt	0	1
InfoMed	0	1
InfoSocInter	1	0
Estimated Probability of Choosing Biochar Potting Mix	0.04	0.96
Estimated Mean WTP for Potting Mix with 25 percent Biochar ^a	\$0.76	\$16.03
95% LCL	\$0.73	\$15.99
95% UCL	\$0.73	\$16.07
Premium/Discount Compared with Base of \$4.99	-\$4.23	\$11.04

^a Krinsky and Robb 95% Confidence Interval (5000 reps)

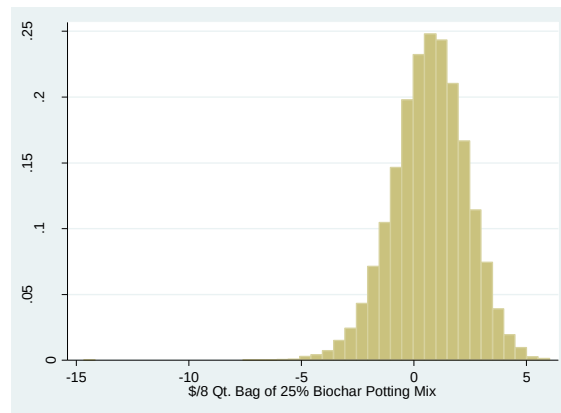
income of \$55,000 on gardening supplies, including about 32 quarts of potting mix in a year at outlets other than gardening centers. The gardeners in this profile do not use organic gardening practices or believe either that biofuels are important to meeting the nation's future energy needs or that there is an urgent need to take measures to prevent climate change. Gardeners in this profile do not obtain gardening information from television or magazines. Conversely, the high probability profile respondent is a 35 year old female who spends 0.75 percent of her household income of \$95,000 on gardening supplies, including about 64 quarts of potting mix per year, which she primarily purchases at garden centers. Gardeners in this profile use organic gardening practices and tend to believe that biofuels are important to meeting our nation's future energy needs and that we do need to take action to combat climate change.

As can be seen in Table 2.4, the low probability profile respondent has about a 4 percent chance of selecting the 25 percent biochar potting mix with a WTP of \$0.76, which is below the conventional price of \$4.99 per bag. The high probability profile respondent has a 96 percent chance of selecting the biochar-supplemented potting mix with a WTP of \$16.03, which is more than a \$10 price premium above the conventional bag price of \$4.99. Histograms of the WTP for the low and high probability profiles are shown in the bottom two panels of Figure 2.2.

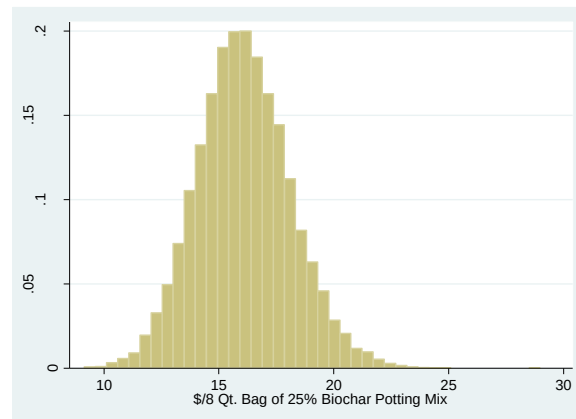
The findings from this research coincide moderately well with the results of the literature review. For those consumers that engage in environmentally friendly practices (like organic gardening), our study finds a greater willingness to pay a premium for a biochar-supplemented potting mix. The demographic profiles made also validate several of the hypotheses made in the literature review, namely that education and environmental practices would positively impact



(a) At Means



(b) Low Probability Profile



(c) High Probability Profile

Figure 2.2. Histograms of WTP for 25 Percent Biochar Potting Mix

consumer WTP. Income, though not significant in this study's model, was found to play a positive role in the probability to purchase the potting mix containing biochar.

Reasons for Not Choosing Biochar

As a follow up to the choice experiment, respondents who were randomly assigned the same price for the biochar-supplement potting mix as the conventional mix (\$4.99) and who indicated they would choose the biochar mix (n=91) were asked if they would pay any amount more for the biochar mix. Of these respondents, 62.64 percent indicated they would pay some amount more and 36.26 percent indicated that they supported the use of biochar as a soil amendment but were not willing to pay any more a biochar mix. Only 1.10 percent did not support the use of biochar as a soil amendment. In addition, respondents who were randomly assigned a price for the biochar mix above the price for the conventional mix and who indicated they would not pay the price offered for the biochar mix (n = 245), were asked if they would pay any amount more for the biochar potting mix blend. Of these, 40 percent stated they would pay some amount more than \$4.99 for the biochar potting mix blend. Another 57.96 percent stated they supported the use of biochar in potting mix but would not pay any more for it. Only 2.04 percent stated they did not support the use of biochar in potting mix. Among those who stated they would not pay any amount more (N=175), the most commonly cited reason was they could not afford to pay more, at 60.57 percent, followed by that they do not pay much attention to labeling on potting mix at 33.33 percent.

Potential Market Size

According to the Census Bureau, Tennessee had 2.59 million households in 2017 (Census Bureau 2018). As a rough estimate of the size of the potential market, if around a third of the households participate in gardening (Garden Center magazine 2016), then there are around 854,700 households that grow flowers or food plants in Tennessee. Assuming that garden centers would be the first to offer biochar-supplemented potting mixes, the extrapolation from the survey sample to the state's population of gardening households could be limited to the approximately 11.44 percent of respondents who usually purchased potting mix at garden centers (about 97,778 households). Overall, the percentage electing to purchase the biochar potting mix was 50.11 percent (accounting for those who chose the conventional product and those who chose neither), suggesting that 48,996 households might try a potting mix that contains 25% biochar. Respondents had a median purchase of 32 quarts of potting mix per year. Multiplying the median annual purchase by the number of households that might try a biochar mix generates potential sales of 1.57 million quarts of biochar-supplemented potting mix. Mean WTP for an 8-quart bag was \$8.52 or \$1.07 per quart. Thus, an extrapolation of the results of this analysis would suggest that Tennessee gardening consumers might purchase as much as 195,986 8-quart bags of biochar potting mix per year, with potential sales of \$1.67 million statewide. Because the potting mix is 25 percent biochar, this results in 391,936 quarts of biochar needed to produce this quantity potting mix-biochar blend.

Chapter 6: Conclusions

Biochar is an important co-product of the production of biofuel through pyrolysis. Development of biochar coproduct markets could enhance the overall profitability of lignocellulosic conversion facilities. One potential use of biochar is as a soil amendment. This study examined consumer preferences and willingness to pay for a potting mix with a 25 percent biochar blend compared to a potting mix with no biochar among gardeners in Tennessee. Estimates suggest that Tennessee's gardeners would be willing to pay, on average, \$8.52 for an eight-quart bag of potting mix containing 25 percent biochar. This amount represents a significant premium over the price of conventional potting mix of around \$4.99 per eight-quart bag. Overall 54.42 percent of the respondents were willing to pay one of the five randomly assigned prices (\$4.99, \$6.49, \$7.99, \$9.49, or \$10.99) offered for the 25 percent biochar potting mix. Furthermore, about 46 percent of those who indicated either they would pay \$4.99 or would not pay the prices offered above \$4.99 indicated that they would be willing to pay some amount more (relative to conventional potting mix prices) for biochar-supplemented potting mix.

The results also suggest that those Tennessee gardeners most likely to purchase the biochar mix are younger, spend a higher percentage of their income (up to 2.44 percent) on gardening supplies, purchase greater amounts of potting mix in a year, and usually purchase this potting mix at garden centers. Thus, garden centers would appear to be a prime retail outlet for biochar-supplement potting mix. Positive correlations exist between willingness to pay for the biochar mix, the use of organic gardening practices, respondent views on the importance of biofuels for meeting our nation's future energy needs and the need to take action to combat

climate change, suggesting that more environmentally concerned gardeners are likely to constitute a target market for a potting mix-biochar blend.

The most commonly proffered reason for not being willing to pay a premium for biochar-supplement potting mix was an inability to afford the biochar mix. However, the second most commonly cited reason was that they did not pay much attention to labels on potting mix bags. Thus, differentiating potting mixes supplemented with biochar from conventional potting mixes may prove a hurdle to marketing biochar mixes at higher prices. Hence, coupling labeling measures with media messaging (such as on gardening-related television shows and in gardening magazines) highlighting the performance and environmental benefits of blending biochar with potting mix might help market biochar potting mix blends.

This study can aid the lawn and gardening industry as they develop products that mirror the preferences of their consumers. This study focused on the aspects of demand for biochar (consumer willingness to pay) and did not analyze aspects of supply (costs associated with production). While this study does not analyze the cost of a potting mix supplemented with biochar, nor the costs associated with biochar itself, it does find that Tennessee gardening consumers are willing to pay a premium for a potting mix-biochar blend. An extension of the study would need to analyze the supply side to note if this premium is enough to make a potting mix-biochar blend product profitable for producers. This research provides a justification for further investigation of a biochar-supplemented potting mix as well as delineates two consumer profiles for use in targeting marketing tactics. The increased knowledge of potential consumers

as well as some barriers to sales (price or labels) can provide insight to industry, overall increasing marketing effectiveness.

CONCLUSIONS

Gardeners have shown growing interest in environmentally friendly gardening products. This interest is evidenced through national surveys findings that indicate that recent top gardening trends include low-maintenance plants and organics (Kellner 2015). With increased interest in environmentally friendly gardening products, it behooves industry to build a better understanding of which environmental friendly gardening products consumers may have the strongest preferences for and any factors that influence these preferences. Results from the analysis contained in the first study of this paper suggest that decreased need for pesticide products would be most widely preferred, while other products such as native species or organically produced might be targeted to more specialized markets. The influences of demographics, expenditure patterns, and attitudes suggest that certain target markets would be more receptive to environmentally friendly gardening products. Older females who are in gardening clubs or environmental organizations, have stronger views on the environment, and garden to grow food might be target markets for these types of products.

The second paper detailed the analysis of potential consumers' willingness to pay for a specific environmentally friendly gardening product, biochar. Biochar is produced as part of the pyrolysis process in making biofuels from biomass and can serve as a soil amendment due to its several environmentally beneficial properties. This study examined consumers' willingness to pay for a 25 percent biochar blend in potting mix. Results show a positive consumer willingness to pay for a biochar blend. Younger gardeners who purchase greater amounts of potting mix,

who use organic gardening methods, and see a greater importance of biofuels development are potential target customers for biofuels. Shopping at garden centers also had a positive influence. This may be because the employees of gardening centers may be more likely to offer expertise to customers than those employed at big box stores. An extrapolation of the study results suggest targeting garden center shoppers in Tennessee might result in a projected purchase of 195,986 8-quart bags of biochar potting mix per year, with potential sales of \$1.67 million statewide.

It is important to note that age was found to have conflicting influences when the studies are analyzed together. This is to say, age had a positive influence on the propensity to prefer gardening products with environmental benefits, however, the likelihood of purchasing the potting mix with biochar was negatively impacted by age. This may suggest that while, overall, the tendency to prefer environmentally friendly gardening products increases with age, certain ecofriendly gardening products may hold greater appeal with younger consumers. Further analysis of the effects of age may be warranted prior to development of certain products or marketing efforts.

An important limitation to both parts of this study is that the survey region was restricted to Tennessee. Further analysis should likely expand the study area to the Southeast region or the nation as a whole. In addition, further analysis might examine consumer willingness to pay for environmentally friendly products beyond biochar-supplemented potting mix. As another method of analysis, a potting mix-biochar blend demonstration product could be developed for an in-store study and may yield a more honest consumer response than those gleaned from a choice experiment of a hypothetical product.

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APPENDIX

SURVEY INSTRUMENT

Biochar Survey

Your Views of Gardening with Potting Mix Containing Biochar

Before You Begin...

Researchers at the University of Tennessee are conducting this survey to learn about the potential markets among Tennessee consumers for potting mix with biochar. We are asking people who garden (for example, outdoor gardening or houseplants) about the purchase and use of potting mix with biochar. Your views are important to us, and we invite you to complete the survey, which should take no more than 20 minutes.



Your participation in this study is voluntary; you may decline to participate or, if you decide to participate, withdraw from the study at any time without penalty. If you withdraw from the study before data collection is complete, your data will be destroyed. There are no foreseeable risks from participating in the study beyond those encountered in everyday life. Checking the box “Accept” on the next page constitutes your consent to participate.

We will not try to sell you anything, and we will protect the confidentiality of your responses and will not provide your name or personal information to anyone else. Data will be stored securely and made available only to the people conducting the study. No reference will be made in oral or written reports linking participants to the study. Thus, your name and other identifying information will not be linked to your responses. The list of those invited to participate in the study will be destroyed after responses are collected. Finally, only summary results from the survey will be publicly reported.

Contact us if you have any questions or concerns. If you have questions about your rights as a participant, you may contact the University of Tennessee IRB Compliance Officer at utkirb@utk.edu or (865)974-7697.

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SURVEY CONSENT

- ☐ ACCEPT: I consent to take the survey
- ☐ REJECT: I do not consent to take the survey

Please indicate the answer that best describes your gardening activities.

- ☐ I participate in either outdoor or indoor gardening
- ☐ I do not participate in gardening

About Biochar

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What is Biochar?



Biochar is a charcoal-like material that can be added to soil to promote plant growth and reduce the amount of water and fertilizer needed. Biochar can also help with carbon sequestration, or the storage of carbon in soils, to help mitigate climate change. Biochar is made by burning biomass, such as crop residues, wood wastes or other organic matter, in an oxygen-starved environment through a process known as pyrolysis.

Have you ever heard of biochar before this survey?

- ☐ Yes
- ☐ No

Have you ever purchased a product containing biochar?

- ☐ Yes

☐ No

☐ Not Sure



The next screen is going to ask you to choose which of two 8-quart bags of potting mix you might purchase if given the opportunity. Responses to questions like this one can sometimes be biased. For example, sometimes people respond how they believe is socially responsible instead of how they would actually behave. So, in answering this question, **we ask that you take a moment to consider your household budget and the fact that paying more for the bag of potting mix would mean you would have less to spend on other items.** *Remember, it is possible to support an issue related to a product without being willing to pay more for the product itself.*

II. Potting Mix and Potting Mix-Biochar Products Below you are presented with two 8-quart bags of potting mix that serve as potting soil for container plants. Each 8-quart bag fills about two 8 inch pots. The first bag is a conventional potting mix (compost, peat moss, vermiculite, and bone meal) that contains no biochar. The second is 75% conventional potting mix (compost, peat moss, vermiculite, and bone meal) and 25% biochar. Both products are identical in all ways except for the addition of the biochar in the second bag. **Suppose you were shopping for potting mix, please indicate which potting mix you would purchase.**



***Please select
one***



Price \$4.99
**Potting Mix with
No Biochar**

☐

Price \$X
**Potting Mix with
25% Biochar**

☐

**I would not
purchase either
of the bags**

☐

(Note: Respondents either saw a biochar mix price \$X of \$4.99, \$6.49, \$7.99, \$9.49, or \$10.99)

Which of the following best describes why you chose *neither* potting mix?

- ☐ They were both too expensive
- ☐ I do not purchase potting mix
- ☐ While I sometimes purchase potting mix, I don't need any at this time
- ☐ Other, please describe: _____

Would you be willing to *pay any more* for a potting mix that contains biochar than for one that does not?

- ☐ Yes, I would pay some amount more for potting mix with biochar
- ☐ No, I support the use of biochar, but would not pay any more for it
- ☐ No, I do not support use of biochar and would not pay more for it

You indicated you would not pay any more for biochar. Please select the reasons that influenced your decision. Check all that apply.

- ☐ I cannot afford to pay more for potting mix with biochar
- ☐ I do not think biochar in potting mix would help my plants
- ☐ I don't think using biochar in potting mix will provide much benefit to the environment
- ☐ I don't purchase potting mix often enough to care about biochar
- ☐ I don't pay much attention to labels on potting mix bags
- ☐ Other, please describe: _____

III. Possible Labels on Potting Mix With Biochar

Biochar can be made in different ways from different processes and, as a result, have different characteristics. Differences in these characteristics could affect whether

consumers would want to purchase products that contain biochar.

We ask that you ***read the following 3 information screens about biochar characteristics***. Then, ***in a series of 8 questions that follow, indicate how attractive these biochar characteristics in potting mix would be to you.***

BIOCHAR CHARACTERISTIC: Percent Biobased Content and USDA Certified Biobased Labeling

Biobased content is how much “new” or recent organic carbon is in an object or substance, compared to the amount of “old” organic carbon it contains. New organic carbon is carbon that comes from plants and other renewable agricultural, marine, and forestry materials, while old organic carbon comes from fossil fuels. USDA certifies biobased products under the USDA Certified Biobased labeling program.



A tree is 100% biobased



Coal is 0% biobased



The **USDA Certified Biobased Product label** indicates *the ratio of new to total organic carbon*. To determine the ratio, the products must undergo testing by a third party using government-approved standards and testing methods. This is a voluntary labeling program.

Prior to this survey, how familiar were you with the USDA Certified Biobased Product label?

- ☐ Not at All Familiar
- ☐ Somewhat Familiar
- ☐ Very Familiar

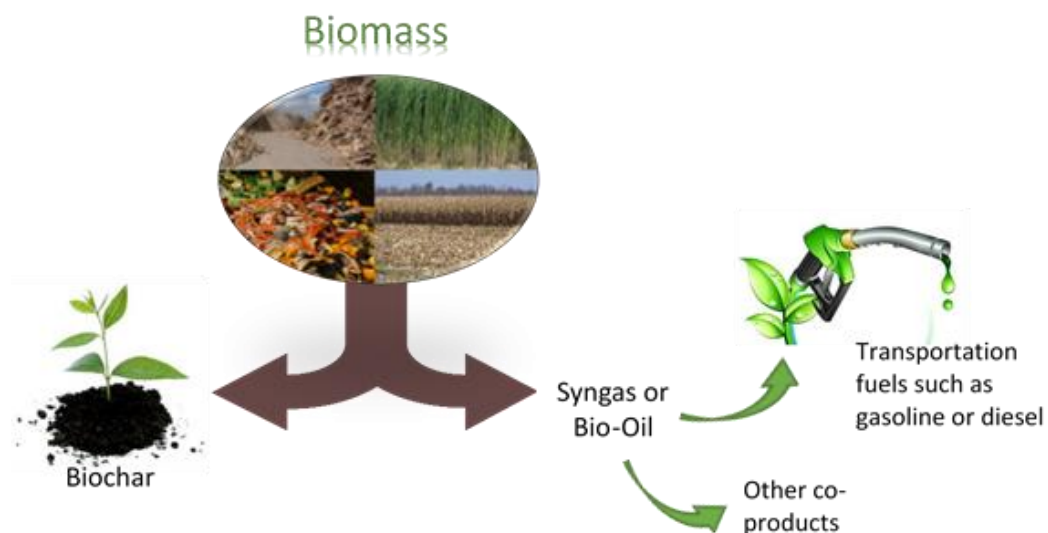
BIOCHAR CHARACTERISTIC: Biochar Source

Biochar can be derived from a variety of sources, including sustainably sourced wood wastes, food wastes, agricultural wastes, and non-food crops grown for energy production.

			
<u>Wood Waste</u> Wood chips, bark, or other material leftover after processing.	<u>Food Waste</u> Leftover food from homes, schools, hospitals, businesses, and restaurants.	<u>Agricultural Waste</u> Leftover parts of crops that are grown to provide food or fiber	<u>Non-Food Energy Crops</u> Plants grown to make energy, not food; for example, switchgrass or other native grasses.

BIOCHAR CHARACTERISTIC: Co-Product of the Production of Advanced Biofuel

One way that biochar can be produced is as a co-product of the production of advanced biofuels. **Advanced biofuels** are those that can be produced from woody crops, wood waste, agricultural waste, and other sources that **do not compete directly with food production**. These biomass sources can be converted to Syngas or bio-oil that can



then be upgraded to replace transportation fuels such as conventional diesel and gasoline. Since **biochar can be produced as a co-product of advanced biofuel production**, a viable **market for biochar can help make biofuel production more cost-effective**.

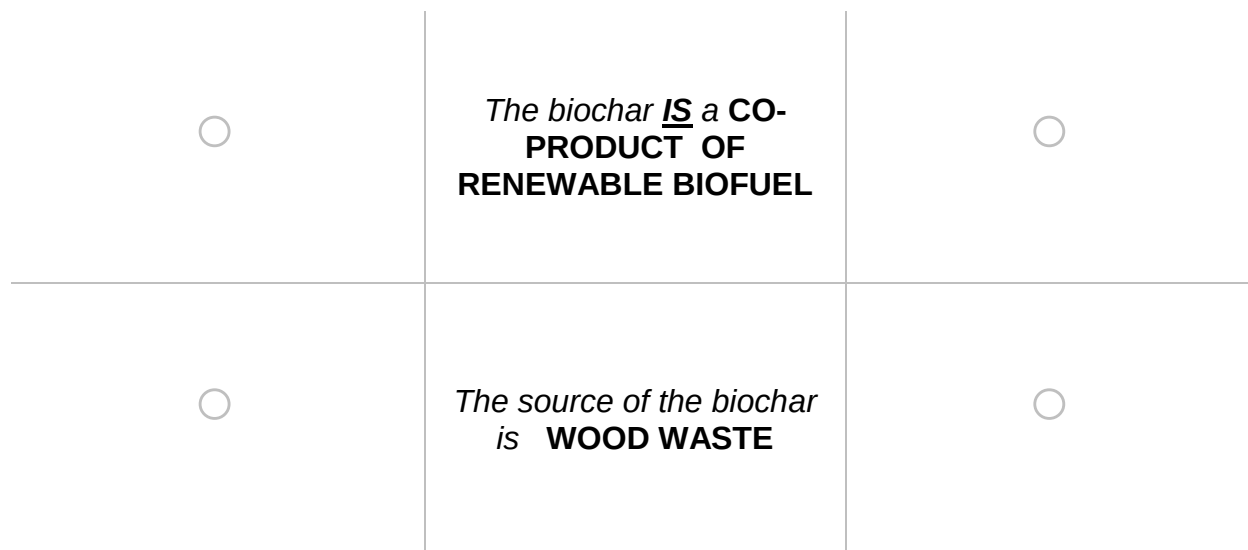
Prior to this survey, how familiar were you with the term "advanced biofuels"?

- ☐ Not at All Familiar
- ☐ Somewhat Familiar
- ☐ Very Familiar

What Biochar Product Characteristics are Most and Least Attractive?

Suppose you could select from potting mix with biochar where the source of the biochar or the way in which the biochar was made differs from one product to another. Please review the following biochar product characteristics and select the characteristic that you believe is most attractive and the one you believe is least attractive. (Note: This question was repeated to each respondent 8 times with the attributes at varying levels in randomized order. There were 4 blocks of 8 repeated most/least attractive choices)

Most Attractive		Least Attractive
☐	<i>The biochar <u>IS NOT</u> 100% USDA CERTIFIED BIOBASED</i>	☐
☐	<i>The biochar <u>IS NOT</u> PRODUCED IN TENNESSEE</i>	☐



Please rate the importance of each biochar attribute to your decision to purchase a potting mix with biochar.

	Not Important at All	Somewhat Unimportant	Neither Important nor Unimportant	Somewhat Important	Extremely Important
Whether the biochar is USDA Certified Biobased	☐	☐	☐	☐	☐
Whether the biochar is produced in Tennessee	☐	☐	☐	☐	☐
Whether the biochar is a co- product of renewable biofuels	☐	☐	☐	☐	☐
What source the biochar came from (wood waste, agricultural waste, food waste, or non- food energy crop)	☐	☐	☐	☐	☐

When choosing between a bag of potting mix without biochar and one with biochar, which biochar source would make you most and least likely to ***buy the bag with biochar?***

Most Likely		Least Likely
☐	Wood Waste	☐
☐	Agricultural Waste	☐
☐	Food Waste	☐
☐	Non-Food Energy Crop	☐

Why did you choose the biochar source that would **make you most likely to buy a bag of potting mix with biochar?**

IV. Your Potting Mix Purchase Patterns

How often do you purchase potting mix? Check one answer.

- ☐ 4 or more times per year
- ☐ About 3 times per year
- ☐ About twice per year
- ☐ About once per year
- ☐ Less than once per year

What size potting mix package do you typically purchase?

- ☐ Less than 4 quarts
- ☐ 4 quarts
- ☐ 8 quarts
- ☐ 16 quarts
- ☐ 25 quarts
- ☐ 32 quarts
- ☐ Greater than 32 quarts
- ☐ Not sure

☐ Other, please describe: _____

Where do you most often purchase potting mix?

☐ Local garden center

☐ Big box stores (for example: WalMart)

☐ Home improvement stores (for example: Home Depot or Lowes)

☐ Hardware stores (for example: Ace Hardware)

☐ Online (for example: Amazon or product website)

☐ Other, please describe: _____

For what purposes do you use potting mix? Check all that apply.

☐ Container grown fruit/vegetables

☐ Container grown herbs

☐ Flowering plants

☐ Indoor non-flowering plants

☐ Use in outdoor beds

☐ Other, please describe: _____

V. Your Gardening Habits and Expenditures

Your household spends

- ☐ More on outdoor than on indoor gardening
- ☐ More on indoor than on outdoor gardening
- ☐ About equally on outdoor and indoor gardening

What do you estimate was the total dollar value of your household's annual spending on gardening supplies (for example: plants, seeds, fertilizer, potting or garden soils, seedlings, etc.) in 2017?

- ☐ Less than \$100
- ☐ \$100-\$299
- ☐ \$300-\$499
- ☐ \$500-\$699
- ☐ \$700-\$899
- ☐ \$900-\$999
- ☐ \$1,000 or greater
- ☐ Don't know

Have you ever had the soil in your garden tested?

- ☐ Yes
- ☐ No, I garden outdoors, but have never had this done
- ☐ No, I am an indoor gardener only

Which of the following do you participate in or donate money to? Check all that apply.

- ☐ A local gardening club/organization
- ☐ Master Gardener program
- ☐ Environmental organizations
- ☐ Community garden or CSA
- ☐ Other, please describe: _____
- ☐ None

Please indicate your level of agreement with each of the following statements.

	Strongly Disagree	Somewhat Disagree	Neither Agree Nor Disagree	Somewhat Agree	Strongly Agree
I enjoy spending time outside.	☐	☐	☐	☐	☐
Gardening is a source of exercise for me.	☐	☐	☐	☐	☐
Gardening is relaxing.	☐	☐	☐	☐	☐
I enjoy residing in a property that is attractive.	☐	☐	☐	☐	☐

I like to grow my
own food.

☐☐☐☐☐

I love growing
flowers.

☐☐☐☐☐

I believe growing
plants helps the
environment.

☐☐☐☐☐

I like learning
about plants.

☐☐☐☐☐

Gardens can
provide wildlife
habitat.

☐☐☐☐☐

How important is it for the gardening products you purchase to

	Not Important at All	Somewhat Unimportant	Neither Important nor Unimportant	Somewhat Important	Extremely Important
Be organic?	☐	☐	☐	☐	☐
Have decreased need for water?	☐	☐	☐	☐	☐
Have decreased need for fertilizers?	☐	☐	☐	☐	☐
Have decreased need for pesticides?	☐	☐	☐	☐	☐
Be native plant species?	☐	☐	☐	☐	☐
Come in recyclable packaging or containers?	☐	☐	☐	☐	☐

**Where do you obtain information for making your home gardening decisions?
Check all that apply.**

☐ Gardening clubs/organizations

☐ Other gardeners

☐ Magazines and/or newspapers

☐ Internet sites

☐ Social media (Facebook, Twitter, YouTube, etc.)

☐ University or Extension Service

☐ Television programs

☐ Master Gardener program

☐ Other, please describe: _____

In which of the following activities do you participate? Check all that apply.

☐ Composting (for example: garden waste, leaves, cuttings, or other household waste)

☐ Organic gardening (for example: using organic plants and organic fertilizers and/or soil amendments)

☐ Recycling gardening packaging (for example: cardboard, plastics, plant containers, kitchen waste, etc.)

☐ Using pollinator plants (for example: plants that attract bees, hummingbirds, or butterflies)

☐ Using a rainwater collector

☐ None of the above

VI. Your Views on the Environment and Gardening

Please indicate your level of agreement with each of the following:

	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Some what Agree	Strongly Agree
Responses to this survey could cause potting mix manufacturers to change the characteristics of the mixes they sell.	☐	☐	☐	☐	☐
Home gardeners can impact the environment with their gardening practices.	☐	☐	☐	☐	☐
My personal actions don't have any significant effect on the environment.	☐	☐	☐	☐	☐
Science and technology will come up with ways to solve environmental damage and pollution.	☐	☐	☐	☐	☐
Most people are not willing to make sacrifices to protect the environment.	☐	☐	☐	☐	☐
We have a responsibility to future generations to protect the environment.	☐	☐	☐	☐	☐

Please indicate your level of agreement with each of the following:

	Strongly Disagree	Somewhat Disagree	Neither Agree nor Disagree	Somewhat Agree	Strongly Agree
Biofuels are important for meeting the nation's future energy needs.	☐	☐	☐	☐	☐
Global climate change is occurring.	☐	☐	☐	☐	☐
Climate change will lead to environmental and health problems in many parts of the world.	☐	☐	☐	☐	☐
There is no urgent need to take measures to prevent climate change.	☐	☐	☐	☐	☐
I don't have enough knowledge to make well-informed decisions on environmental issues.	☐	☐	☐	☐	☐

VII. About You

What is your age in years? _____

What is your gender?

☐ Male

- ☐ Female
- ☐ Prefer Not to Disclose

What is your highest education level attained?

- ☐ Less than high school
- ☐ High school graduate
- ☐ Some college
- ☐ 2 year degree
- ☐ 4 year degree
- ☐ Professional degree
- ☐ Doctorate

Which best describes your housing situation?

- ☐ Own Single Unit Dwelling
- ☐ Rent Single Unit Dwelling
- ☐ Own Condominium
- ☐ Rent Condominium

☐ Apartment or Duplex Rental

☐ Mobile Home

☐ Other, please describe: _____

How would you characterize the area in which you reside?

☐ Rural

☐ Small town

☐ Suburb

☐ Urban

How would you characterize your political views?

☐ Strong Conservative

☐ Lean Conservative

☐ Moderate

☐ Lean Liberal

☐ Strong Liberal

☐ Other _____

In which region of Tennessee do you reside?

- ☐ West
- ☐ Middle
- ☐ East
- ☐ I do not live in Tennessee

What was your household's income before taxes in 2017? (Keep in mind, we will not share your responses. Only summaries across all responses will be used. Your individual responses will be kept confidential.)

- ☐ Less than \$20,000
- ☐ \$20,000 - \$39,999
- ☐ \$40,000 - \$59,999
- ☐ \$60,000 - \$79,999
- ☐ \$80,000 - \$99,999
- ☐ \$100,000 - \$119,999
- ☐ \$120,000 - \$139,999
- ☐ \$140,000 - \$159,999

- ☐ \$160,000 - \$179,999
- ☐ \$180,000 - \$199,999
- ☐ \$200,000 or greater
- ☐ Prefer Not to Disclose

VITA

McKenzie L. Thomas graduated with a Bachelor of Science in Agricultural and Resource Economics from the University of Tennessee at Knoxville in 2016 and graduated with a Master of Science in Agricultural and Resource Economics from the University of Tennessee at Knoxville in 2019.