Funding Restoration by Selling *Arundo donax* Waste Vegetation as Feedstock for Industry

Proposal for a Thesis

in the field of Sustainability and Environmental Management

in Partial Fulfillment of Requirements for

the Master of Liberal Arts Degree

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Abstract

This thesis examines the potential for improving restoration efforts by selling the biomass of *Arundo donax*, an invasive riparian plant, as a feedstock for the pulp and paper industry. One of the top 100 invasive species in the world, *A. donax* severely threatens biodiversity and ecosystem services in Southern California and eradication involves overcoming significant logistic and economic constraints. It has been identified as a preferable species for the pulp and paper industry due to its rapid growth rate and natural brightness, but plantation-style production risks invasion into local habitats. Removal of *A. donax* biomass for restoration could be integrated into the pulp and paper supply chain, creating new revenue streams and a reduction in the ecological footprint of both industries. I will conduct an economic appraisal that quantifies environmental benefits and cost savings which will inform a cost-to-benefit analysis. A net-benefit model will then be created and several scenarios with adjusted values for harvest techniques, total biomass, stand density, and proximity to point of sale will be run in order to evaluate profitability under different parameter values. Expected results should demonstrate reduced costs compared to *A. donax* removal efforts. Profitability for a private enterprise might be possible in only specific contexts, but in virtually all cases environmental benefits and savings over time will likely outweigh removal costs. This methodology will have potential to be applied to other species in order to reevaluate costs, best practices, and goals associated with invasive species management.

Table of Contents

Introduction

Research Significance & Objectives

Invasive species pose significant threats to biodiversity and ecosystem services. Left unchecked, they typically outcompete endemic species, oftentimes altering disturbance cycles and resource abundance; thus creating a positive feedback loop toward further invasion. Control of invasive species is costly, requiring intensive labor over broad areas and for long periods of time. Many of these species were introduced over a century ago as novel resources and could be once again incorporated into existing industries as raw materials for food, fuel, or fiber products. If proven cost effective, harvesting invasive species has the duel potential of eliminating an ecological pest while lessening the demand on dwindling natural resources.

My objectives are:

- to explore new opportunities for funding restoration by selling waste byproducts as commodities in existing markets.

- to conduct a holistic evaluation of commoditizing invasive species including benefits to ecosystem services and reduced pressure on current feedstocks

- to provide a model for land managers to prioritize, incentivize, and regulate for-profit harvest of invasive species on public lands.

Background

Invasive species control and removal is a vital component to responsible land management. According to the USDA's National Invasive Species Information Center (NISIC), invasive species are non-native plants, animals, or pathogens whose introductions cause harm to ecosystems (USDA 2014). In the United States, environmental damages and losses caused by invasive species are valued at approximately $120 billion per year (Pimentel 2005). These estimates can be considered conservative because they exclude monetary values of losses in biodiversity, ecosystem services, and extinction of native species (Cororaton 2009). Exotic invaders typically lack the biological control agents that restrict populations of endemic species, such as predation or herbivory. Additionally invasive species typically display several weedy characteristics such as rapid growth and reproduction, high dispersal ability, and tolerance of a wide range of environmental conditions. Species with these intrinsic characteristics in an unchecked ecosystem typically spread rampantly, consuming resources and dramatically altering the local habitat. Invasive species typically outcompete native species for resources such as food, water, nutrients, space, or sunlight. In the U.S. introduced species number over 50,000 and roughly 42% of the U.S. Threatened or Endangered species are at risk primarily because of the effects of invasive species (Pimentel 2005). The causes of 256 vertebrate extinctions are currently identifiable, and of them 109 are considered to have been caused directly by biological invaders, compared with 70 that are thought to have been caused by human exploitation (Cox 1993). Biodiversity is threatened when even relatively few exotic species into spread into habitats and at densities that previously were occupied by a much greater number of native species.

In addition to outcompeting native species for resources, the spread of invasive species can impact the abiotic elements of ecosystems. Invasive plant species may alter soil chemistry through the application of allelopathic exudates inhibiting potentially competitive growth of other species. Plants thriving on more frequent or different types of disturbance can further support their spread and dominance over native species. In California, annual oat grass (*Avena fatua*) contributes to an increased fuel load that raises the likelihood of wildfires in chaparral ecosystem (Brooks et al. 2004). This increased fire frequency further encourages the spread of the oat grass, creating a positive feedback loop in which native species end up permanently eradicated due to shortened disturbance intervals (Brooks et al. 2004). Common models used to calculate the invasiveness of non-native species usually don't accurately account for changes to the entire ecosystem, but merely quantify a species' ability to outcompete native species for shared resources (Thiele et al. 2011). When an invasive plant species alters abiotic processes, it has the potential to alter processes that control the entire system.

The United States Department of the Interior spends approximately $100 million annually on invasive species prevention, early detection and rapid response, control and management, research, outreach, international cooperation and habitat restoration (U.S. Fish & Wildlife Service 2010). Invasive species control typically involves complex processes of monitoring, prioritizing, physical removal, revegetation, and clean up. Funding for these projects usually come from publicly funded granting agencies or mitigation funds from development projects. Funding priorities and policy decisions are typically informed by a cost benefit analysis (CBA) that evaluates the net benefit of controlling the establishment and spread of the invasive species.

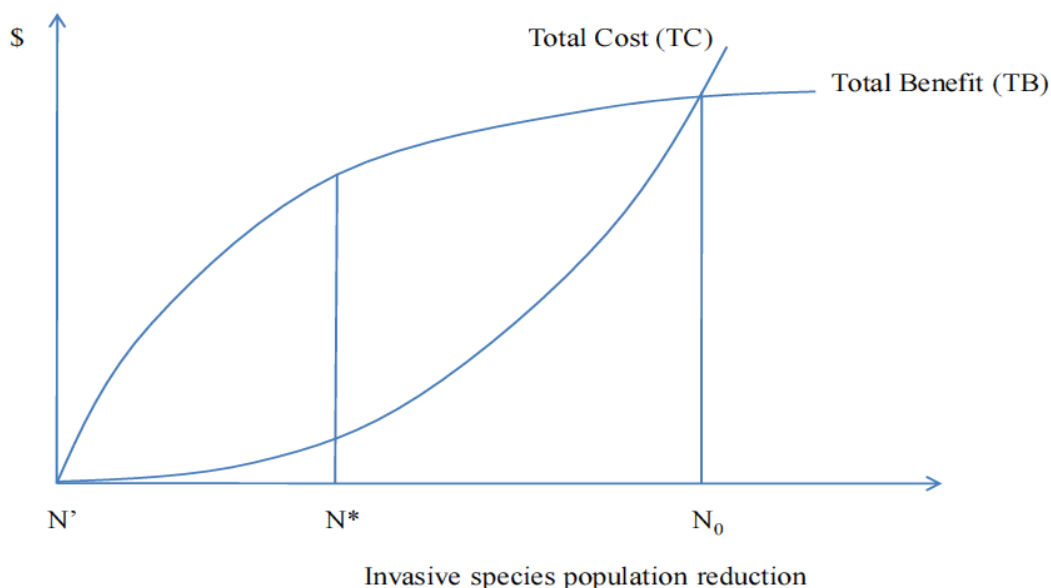Invasive Species Management and Cost Benefit Analysis

Invasive Species Management typically requires significant recourses to ensure success. Under the Guiding Principles of the Convention on Biological Diversity, party countries are instructed to prevent, control or eradicate invasive species that threaten ecosystems, by enacting prevention, eradication, containment, and management practices. Prevention is usually the cheapest and most effective method while management is often the most costly and long-term (Emerton 2008). Policy decisions about management of invasive species are typically based on economic models that are similar to those used for managing renewable resources, except resources such as timber have a positive value, while invasive species are considered with negative value or as having a net cost on the environment (Olson 2006). For renewable resources, policies are set that maximize economic welfare over time, including benefits of human consumption and environmental benefits associated with the resource stock (Olson 2006). For invasive species, models help determine primary management goals that reduce environmental damages by implementing prevention and control measures that minimize the discounted sum of damages and control costs over time (Olson 2006). Rarely are invasive species considered as resources themselves and disposal of the removed species is often prohibitively costly, affecting control methods.

There are four general categories of management of invasive species: mechanical, chemical, biological, and integrated (Emerton 2008). Mechanical removal refers to physical removal by hand, or assisted with controlled burning or the use of machinery. Mechanical methods may be preferable due to their reduced negative impact to the surrounding system, but often are the most labor and time intensive means of control. Chemical control involves the use of pesticides and herbicides to kill the target species, but special precautions must be taken to avoid detrimental

effects on non-target plant or animal life and the release of toxic pollutants into the environment. In 2000 and 2001, pesticide expenditures were over $30 billion globally (Keily, Donaldson, and Grube 2004). Biological control typically refers to introducing parasites or predators of an invader to an area where lack of natural controls allow it to spread rampantly. This is often the most cost effective approach due to relatively low long-term costs once the biocontrols are introduced. Unforeseen ecological consequences and a lack of knowledge or availability of biological control species often limit the biological approach. An integrated approach involves the combination of two or more of the previously mentioned methods. Biological control is commonly used to reduce established populations, while mechanical or chemical methods would be used on outlying populations or along the advancing edges to curb the spread of the invasive population (Emerton 2008). In many cases, cooperation between public agencies and private stakeholders is important if effective control is to be achieved (Olson 2006).

Invasive species removal is typically very costly in terms of time, labor, and energy inputs required to achieve success. A critical issue, then, for invasive species management is directing limited resources towards efforts that will realize the maximum environmental benefit. A key question for the management of an invasive species population is whether or not total eradication is an appropriate goal. Documented eradication attempts indicate that it generally costs as much to control the last 1 to 10 percent of an invasion as it does to control the initial 90 to 99 percent (Myers, Savoie, & van Randen 1998). A simple economic framework has been developed for setting targets for invasive species removal by identifying the point at which a maximized net benefit of removal is reached (Gren 2008). Net benefit is the difference between total benefit and total cost of implementing various invasive species control programs.

Figure 1: Net benefit curve for setting invasive species management goals

Figure 1 diagrams the process for identifying maximized net benefit of invasive species control

programs. The total benefit (TB) curve and the total cost (TC) curve are shown. The horizontal

axis is the reduction of invasive species population, while the vertical axis is in dollars. The TB

curve illustrates diminishing benefits past a certain point of reduction in invasive species

population. The TC curve shows an increasing cost as removal efforts intensify. Along the

horizontal axis, point N' is zero, meaning no reduction in species population is achieved. The

curves TB and TC intersect at point N_0, beyond which total cost exceeds total benefits implying

that invasive species reduction isn't cost effective and should not be implemented. Between

points N' and N_0, reduction measures should be implemented because benefits exceed costs. The

point on the horizontal axis where the most benefit compared to cost of implementing measures

to reduce invasive species population is at N*. This is the point of greatest net benefit. Many

studies attempt to estimate the costs and benefits of various control measures of invasive species, but relatively few of them look at the degree to which net benefit is maximized (Cororoton 2009).

For invasive species management to be successful it is necessary to identify the point of greatest net benefit not just during implementation but over time and accounting for maintenance efforts. If funding for invasive species removal does not include long-term monitoring and maintenance, then reinvasion can often easily occur resulting in a great deal of wasted effort. Long-term funding for preventing reinvasion typically requires less money than repeating full-scale control efforts (Larson 2011). In some cases, if long-term funding is unavailable, it calls into question whether the invasive species removal measures should be undertaken at all.

Riparian Ecosystems and Invasive Plant Species in Southern California

In the American Southwest, and more specifically the state of California, invasive species are of special concern. The California Floristic Province, an area covering 293,804 km² from Southern Oregon to Northern Baja California Mexico, contains over 7,000 plant species, subspecies, and varieties of which over 2,000 are found nowhere else on earth (Hickman 1993). According to the non-governmental organization Conservation International, the California Floristic Province is an internationally designated biodiversity hotspot with roughly 10% of the vegetation remaining in a relatively pristine condition (Conservation International 2011). More than 10% of plant biomass growing spontaneously in the state is exotic, comprising over 3,000 non-native species (Dowell 1992).

Riparian ecosystems are characterized as being the interface zone between rivers and streams and the surrounding banks, floodplain, and upland area. Particularly important in arid Southern California, an estimated 90% of historic riparian habitat has been lost to agriculture,

urban development, flood control, and other human-caused disturbances (Katibah 1984).

Typical native riparian plant species include *Salix* (willows), *Baccharis salicifolia* (mulefat), and *Populus* (cottonwoods) which provide nesting habitat for an array of wildlife including the federally threatened and endangered birds, the least Bell's vireo (*Vireo bellii pusillus*) and the willow flycatcher (*Empidonax traillii eximus*) (Zembal 1990). These riparian ecosystems are adapted to specific flood-dominated disturbance cycles that maintain varying stages of ecological succession and a relatively high level of biodiversity. Riparian systems in Southern California have been degraded due to the introduction of invasive species, particularly tamarisk (*Tamarix* spp.) and giant reed (*Arundo donax*). In 2000, by The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN) listed *Arundo donax*, as one of the top 100 invasive species in the world having successfully invaded most warm regions with a Mediterranean type climate (Lowe 2004).

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Giant Reed (*Arundo donax)*

   Arundo donax is a tall bamboo-like member of the grass family (Poaceae). Its origin is unclear due to longstanding dispersal by humans, although its native distribution appears to have extended from Southeast Asia to the Mediterranean Basin (Perdue 1958). This is in part evidenced by the presence of insect herbivores associated with *A. donax* in the Mediterranean Basin compared to other areas where it grows (Kirk et al. 2003). It is thought that *Arundo* was introduced to other areas primarily for building materials, erosion control, and windbreaks (Perdue 1958). In California, *A. donax* appears to have been introduced for building materials and erosion control in the 1700s, and it was dominant along parts of the Los Angeles River as early as the 1820s (Robbins et al. 1951).

A. donax is one of the fastest growing plants in the world. It has been measured growing as much as 10 cm per day and reaching heights of 10 m tall when mature (Perdue 1958). It is typically grows on bare soil with access to abundant water recourses, such as river beds, banks, islands, and floodplains. Upon introduction, it rapidly invades riparian areas, often dominating native vegetation and forming dense monotypic stands. *Arundo donax* produces a long plume-like flower that has never been observed to contain viable seeds. It is speculated that environmental conditions necessary to stimulate sexual reproduction are highly specific and not frequently encountered (Ahmad 2008). Instead, *A. donax* spreads vegetatively when small pieces of the plant break off, land on bare soils downstream, and begin to grow (Else and Zedler 1996). It expands outward in area, sprouting new shoots via its large rhizome and any stems in contact with the ground. In this manner, *A. donax* forms extensive stands or monocultures along riparian floodplains and terraces. Currently, *A. donax* is present in almost every stream and river system in coastal Southern California (Giessow 2011).

Ecological Impacts of *Arundo donax*

Arundo donax severely threatens both abiotic and biotic elements in riparian ecosystems in which it gets introduced. *A. donax* affects abiotic processes in a number of ways including: altering water flow, water availability, and fire frequency (Giessow 2011). It is estimated that *A. donax* transpires 20 – 40mm of water per day in a climate that typically receives 250 – 400mm of precipitation per year (Giessow 2011, Western Regional Climate Center). Additionally, *A. donax* contributes to increased wildfire disturbance and frequency by increasing fuel loads and fire intensity. Based on annual growth, the productivity of *A. donax* is roughly 400% higher than native riparian vegetation (Giessow 2011). This creates a higher fuel load in riparian areas. The

Arundo stand structure itself, has a tall, well-ventilated structure with dry fuel present throughout its profile. The introduction of this clonal tall grass structure, into an ecosystem naturally dominated by woody trees and shrubs, herbaceous vegetation and open spaces, has altered fuel types and fuel loads (Brooks et al. 2004). After wildfires, *A. donax* largely outcompetes native vegetation. Ambrose & Rundel (2007) found that one year after a wildfire along the Santa Clara River, *A. donax* showed a 24% increase in relative cover resulting in an overall domination of the plant (99% relative cover). The abiotic influences of *A. donax* on ecosystem functioning results in both detrimental conditions for native species as well as improved conditions for the growth of *Arundo* creating a positive feedback loop that leads to eventual conversion to *A. donax* monoculture.

In coastal southern California watersheds, *Arundo* often displaces nearly all vegetation, leaving only mature trees, which have a canopy layer higher than the *Arundo* stand. Within dense *Arundo* stands there is generally little or no understory vegetation. Native vegetation displacement is particularly pronounced in the shrub, perennial herb and annual herb growth form classes.

Arundo donax contributes little to native wildlife; providing virtually no habitat or forage. The stems and leaves contain an array of inorganic noxious chemicals that reduce herbivory by most insects and grazers (Jackson 1964). When invertebrate composition has been compared for aerial and ground dwelling arthropod populations in 100% *Arundo donax*, 100% native vegetation dominated by willow, and mixed stands along a stream in central California, native vegetation supported twice the levels of aerial insects as the *A. donax* stands (Herrera 2003). Aerial insects are the primary food source for many foraging species of birds in riparian habitats.

The change of vegetation structure due to *A. donax* invasion likely reduces the habitat value for those species whose diets are largely composed of riparian arthropod species.

In addition to reducing complexity in the food web, the stand structure of *A. donax* negatively impacts wildlife passage. Riparian systems frequently are the only undeveloped corridors in the highly urbanized southern California landscape. *Arundo*'s dense clumping structure reduces the type and quantity of animals that can access the corridor for travel, forage, nesting and cover.

Invasive Species Management and Control of *Arundo donax*

A variety of methods are used to control *Arundo donax* depending on size and density of the stand, the type of terrain and the distance from other recourses and habitat types. The primary aim for effective treatment of established *A. donax* has been to kill of the root mass (Bell 1997). This almost inevitably requires the application of a systemic herbicide. Currently the only herbicide labeled by the EPA for wetlands use is Rodeo®, a trade formulation of glyphosate, produced by Monsanto Corporation (Bell 1997). Glyphosate has been proven in trials to effectively kill *A. donax* when applied at specific times of the year and at appropriate concentrations (Spencer 2008).

The most effective treatment on *A. donax* has been determined to be the foliar application of a two-to-five percent (2-5%) solution of Rodeo at a rate of 0.5 to 1 L/hectare applied post-flowering and pre-dormancy, when the plant is most actively translocating nutrients to the root, usually between August and November (Bell 1997). Another method, known as cut-stem treatment, involves treating recently cut stems within two minutes of a concentrated herbicide. This method is often more labor intensive and relies on more precise planning but has the potential to use much less chemical and cause less non-target application than aerial spraying.

Pure stands (>80% canopy cover) of *A. donax* or a mix with *T. ramosissima* are recommended for aerial application of an herbicide by helicopter (Bell 1997). This method allows for an application of 50 hectares per day (Bell 1997). In less dense areas, or those prohibitive of helicopter application, herbicide is typically applied by vehicle-based spray tanks or by hand.

A common practice has been to cut the stalks removing the majority of biomass and then wait three to six weeks for the plants to grow to about one meter tall, then apply a foliar spray of herbicide solution (Bell 1997). This has the benefit of using less herbicide This method sometimes requires follow-up treatments causing increased labor costs (Bell 1997). An additional advantage of applying herbicide is that the dead stalks are easier to remove and process and do not have the same potential for rooting in place than freshly-cut living stalks.

Waste vegetation from *A. donax* removal projects is typically removed by biomass burning, heavy machinery, or hand cutting with power tools. Biomass is removed only in those cases where it's density prevents the recovery of native vegetation, or where cut stalks might create a detrimental blockages during flood events (Bell 1997). Prescribed burns, where stacks of *Arundo* stalks are burned, is cost-effective but can easily threaten native vegetation or other urban areas. Chipping involves high chipping and labor costs. Transporting biomass by vehicle is typically prohibitively expensive and only done as a last resort. Additionally, many landfills will not accept *A. donax* biomass (Quinn 2014).

Riparian ecosystems are often considered to be relatively simple systems to restore because once invaders such as *A. donax* and *T. ramosissima* natural flood disturbance patterns lead to the rapid establishment of native species such as *Salix, Populus, Baccharis*. Revegetation is typically easily achieved with imported plant material and supplemental irrigation, but those plantings, once established, might not provide the same habitat value as those naturally

established plant communities (Bell 1997). It has been argued that the best way to address habitat loss, in terms of cost effectiveness, is to implement a comprehensive program of invasive species eradication and allow natural processes to influence the reestablishment of native plant species (Bell 1997). This saves time and energy during the restoration process and is viable because riparian species are not limited by their capacity to regenerate but by their ability to compete with invaders (Bell 1997). Revegetation, therefore, is oftentimes redundant in areas where flood regimes and native species are present and should be implemented only when necessary to introduce missing species or close up strategic corridors (Bell 1997).

Bioeconomics of *A. donax* Management

A Cost Benefit Analysis (CBA) was conducted in 2011 by the California Invasive Plant Council for the State Water Resources Control Board (Giessow et. al. 2011). The costs of removal of *A. donax* have been determined to be $25,000 per acre (Giessow et. al. 2011). This dollar value has been used to evaluate the economics of harvesting wild *A. donax* as a feedstock for the biofuel industry and determined to be prohibitively costly (Quinn 2014).

The CBA analyzed existing data about *A. donax* removal projects in southern California to determine potential benefits of invasive plant removal and known costs of control. The benefits of removal were calculated over a ten year period to in an attempt to account for the duration of *A. donax* control projects (Giessow et. al. 2011). The CBA provided a ratio that justifies the removal of the plant in virtually all instances with a ratio of 2-4:1 benefit to cost (Giessow et. al. 2011). While providing a rudimentary ratio of benefits to costs, this analysis excludes some important components. Discounting and depreciation over time are not present in this CBA. The reason given for this is because the benefits and the costs of removal are "accrued

on a similar timeline" and therefore "not likely to adversely affect the analysis" (Giessow 2011).

Additionally, there are no projections about future ranges of *A. donax* so future CBA ratios are

not considered. The clumsy methodology used to calculate values for benefits and the weakness

of a time function make the Giessow cost benefit analysis useless in estimating actual dollar per

acre estimates for removal projects as well as payback periods accounting for accurate benefits to

A. donax removal. A proper cost benefit analysis that incorporates accepted methodology and

normalizes for the great variability inherent in specific removal projects is needed in order to

better inform decision making about removing *A. donax* from wild ecosystems.

Arundo donax as potential feedstock industry

  Arundo donax has studied extensively as potentially valuable for many industrial

purposes including wastewater treatment, pulp and paper raw material, and ethanol production as

a biofuel (Perdue 1958; Quinn 2014; Jakubowski 2010). Plantation-style agriculture is typically

the most efficient means by which to harvest of *A. donax* plant material. There exists, however,

the potential for the plant to escape cultivation and invade previously pristine riparian systems.

Harvest of invasive *A. donax* biomass has been considered for ethanol production and deemed

economically and technologically unfeasible (Quinn 2014). This is in large part due to the high

costs of tooling ethanol production facilities to be particular plant material and the high transport

cost in getting the material to the relatively few existing facilities. A similar analysis hasn't been

conducted for using *A. donax* biomass obtained from invasive species removal projects for the

pulp and paper industry.

Research Hypothesis and Specific Aims

The primary hypothesis I will examine is that it is both economically and ecologically cost effective to fund the removal of *Arundo donax* by selling the vegetative biomass as a feedstock for the pulp and paper industry.

To test this hypothesis, and explore related issues, my specific aims are:

1. To determine the technical and logistic potential of utilizing wild harvested *A. donax* biomass for the pulp and paper industry

2. To quantify the economic benefits and cost savings, from a land management perspective, from selling discarded *A. donax* biomass

3. To evaluate the net benefit, from an industry perspective, of selling discarded *A. donax* biomass from riparian restoration projects as a pulp and paper commodity

4. To develop a protocol for prioritizing *A. donax* removal projects based on the relative profitability and environmental benefits of removal projects

Research Methods

Research Design

The overall research design will compare the economics of commoditized *A. donax* biomass against business as usual. I will diagram and map the technical aspects of integrating the restoration process into the pulp and paper supply chain. An economic appraisal will quantify total economic value of environmental benefits and cost savings derived from (1) removing the plant from the wild and (2) utilizing it as a resource instead of discarding it as waste. Multiple simulations of profitability (NPV) will be run in a spreadsheet identifying the variables with the greatest impact on profit and environmental impact. Finally, thresholds, or dollar value limits, for specific variables will be determined in order to identify the conditions under which it is profitable to conduct this type of integrated operation.

Methods

The technical and logistic potential of integrating *A. donax* biomass into the pulp and paper supply chain will be determined by diagramming the pulp and paper supply chain with an integrated restoration project workflow in order to assess the proper points of connection, and required levels of processing (represented in a Figure). Transport distances will be determined by mapping the locations of pulp and paper mills in the United States categorized by size, output, or appropriate processing capabilities and overlaying the data with known occurrences of *A. donax*, categorized by estimated biomass density (represented in a Figure). Biomass will be estimated according to established methods (Spencer 2006). This mapping will be used to determine ranked scores for plant biomass per area over distance miles traveled to point of sale.

Next, the operational and environment value of benefits and costs savings associated with selling discarded *A. donax* biomass from riparian restoration will be determined by conducting

an economic appraisal that puts dollar values to outcomes of industry-integrated-restoration. These variables include benefit to the environment such as reduced fire risk, increased water availability, habitat enhancement, and improved hydrologic function obtained from existing CBAs for removing *A. donax* (Giessow 2011, Seawright 2009). Savings related to less intensive removal methods and reduced or eliminated transportation and landfill costs from the restoration industry will be quantified using existing public project data for *A. donax* removal. Figures for reduced cost for raw pulp material and less need for chemical bleaching will be derived from current and projected commodity prices.

Operating costs including subcontractors, disposal fees, equipment rental, data collection, mileage, and consumables will be estimated from published data, existing CBAs (Giessow 2011, Seawright 2009) commodity prices, and personal data to determine removal costs per unit area and stand density as well as shipping costs associated with weight and distance traveled. Multiple simulations will describe net-benefit at varying values for (1) removal technique: one time harvest with herbicide vs. periodic harvest without herbicide, (2) stand biomass, (3) stand density, (4) transportation distance to point of sale. These simulations will allow variables with significant impact on net-benefit to be identified. The values for each variable will be adjusted within real world limits in order to determine profitability ranges as well as optimal values to maximize net-benefit. The optimized values will be used to conduct a simple Cost Benefit Analysis in order to determine return on investment and net-benefit over time, discounted to the present value. The results will be described in accordance with the net-benefit model prescribed in Gren 2008 in order to determine the point at which costs and benefits intersect (N_0) and the point of maximum net-benefit (N^*).

Research Limitations

This research is limited in a number of ways. The quality of data has inherent issues, such as the difficulty in applying financial comparisons among completed projects that differ in scale, methods used, and whether *A. donax* was the sole objective or simply a component of a larger restoration effort. Additionally, there are specific questions not being asked and variables intentionally not manipulated such as projected changes in values due to climate change projections or application of *A. donax* biomass to other industries such as reed instrument manufacture or niche markets such as light construction or ornamental applications. I will likely not significantly address legality of *A. donax* sale and transport or recommended changes to policy so as to incentivize this form of removal. Finally, my analysis will be focused on public lands and will not account for additional costs and benefits to private land owners such as tax incentives or investing schemes.

Tentative Schedule

Proposal accepted by Research Advisor……………………………………………….February 8, 2015

Thesis Director agrees to serve…………………………………………………..June 1, 2015

Thesis Research begins…………………………………………………………..June 1, 2015

Complete and submit first draft………………………………………………….October 15, 2015

Thesis Director returns first draft for revision………………………………...November 15, 2015

Complete revisions and submit second draft……………………………..December 15, 2015

Thesis Director returns second draft for revision………………………….......January 15, 2015

Final draft delivered to Thesis Director and Research Advisor…………………February 1, 2015

Final draft approved…………………………………………………………...March 1, 2016

Bound copy approved …………………………………………………………April 15, 2016

Graduation……………………………………………………………………….May, 2016

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