

Finding the most Cost Efficient Method to Decrease the Number of Invasive Vines in the Nolde

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Abstract

The Nolde Forest is a state park in Pennsylvania which is home to over hundreds of plant species; however, not all the species are native. The Nolde Forest is overruled with invasive vines. Though there are multiple methods to decrease the vegetation they are often expensive and there is no record on how much the Nolde Forest spends on invasive plant management leading to the research question: What is the most cost efficient method to decrease the number of invasive vines in the Nolde Forest? The vines used for the study were english ivy, mile-a-minute, and chinese wisteria all invasive vines in the Nolde Forest hurting native plants. The methods used to decrease the vegetation are chemical, biological, as well as manual and mechanical. The research methods used to find the most cost efficient method to decrease vines were through quantitative and qualitative data. Through interviews and information from other parks lead the information to be found in different hypotheticals finding supplies and the amount of supplies needed. In the end the most cost efficient method to decrease the amount of invasive vines in the Nolde Forest was the chemical spray method.

Keywords: Invasive vines; invasive species; Nolde Forest; Invasive plant management; English Ivy; Mile-a-minute; Chinese Wisteria

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Introduction

The Nolde Forest is a state park in Berks County Pennsylvania with 665 acres of deciduous woodlands. The park serves as an educational center, fishing grounds, hiking grounds, and skiing area. The Nolde Forest is home to hundreds of different species of plants and animals, however; not all the plants are native plants [1,2]. Native plants are plants that are in their country of origin. These plants are natural to their country's ecosystem, meaning therefore they have natural predators and they cannot over run their environment. Invasive plants are the opposite. Invasive plants are plants from other countries that have no natural predators and take resources away from native plants. Introducing invasive plants causes economic and environmental harm, as well as harm to human health [3]. A common example of an invasive plant is bamboo, which is a native plant to Asia eaten by pandas. The United States brought it over for decoration but, now it spreads wildly hurting native plants since there are no natural predators [3]. The Nolde Forest is being overrun with invasive plants which take space and nutrients from native plants which leads to decreasing the species diversity. To solve the

problem, State Park workers and foresters try to decrease the amount of vegetation through various methods.

Research Question

Each year millions of dollars are spent on controlling invasive plant species in the United States. There are various methods which are already researched, however; there is no research on the most cost efficient method to decrease the amount of vegetation. Finding the most cost efficient method of decreasing the amount of species needs to be on a small scale to begin. The Nolde Forest is a perfect research area since it is local and has many park educators who want to participate in the research. Then it one kind of invasive species needs to be choose which would be the invasive vines of the Nolde Forest. This leads to the research question: What is the most cost efficient method to decrease the amount of invasive vines in the Nolde Forest?

Purpose of Research

Finding the most cost efficient method to handle the invasive vines in the Nolde Forest can be beneficial to the government,

environment, and tax paying citizens. Invasive plant treatment and management is expensive. Every year the American government spends \$123 billion dollars to attempt to control invasive species [4]. The National Invasive Species Council's proposed budget for 2017 is \$1,538,716 [5]. If a solution is found to handle the invasive vines taxes can decrease for the tax paying citizens. Decreasing the amount of invasive vines in the Nolde Forest benefits the environment since more native plants can then grow leading to species diversity. Native plants also allow a balanced ecosystem that produces the most oxygen. Native plants are also the primary source of food for native species so if the invasive plants colonize the land of other native plants, native animals can also be affected. Invasive plants also cost the tax payers and landowners money. If something is not done about the invasive plant problem every town America can be this town in Economic Effects on Invasive Weeds on Land Values by Charles Wiser an Agriculture Banker. The article takes a look at Ward County and their problem with an invasive plant called leafy spurge in the 1960s. The invasion of leafy spurge was recognized as a problem, but then the people of the town said it was too expensive to handle and someone else should clean it up. The invasive plant kept spreading to private land and to ditches. The town starting losing money because the land values decreased by 60% and they needed weed control. The North Dakota State University found Ward County lost \$87,972,000 to invasive plants. Finding an cost effective solution to the invasive vine problem in the Nolde Forest can benefit the environment, and tax paying citizens [6].

Invasive Vines

The invasive vines chosen for the research were chosen from a list of invasive plants provided by the Nolde Forest Park educator Rachel Buar. Vines were chosen since they were the plants with the closest similarities so the research could be concise. The invasive vines are also some of the most damaging invasive species in the Nolde Forest since they cover the trees and ground by suffocation.

Wisteria sinensis

Wisteria sinensis is also known as Chinese Wisteria. It is a vine with beautiful purple flowers, it came from China in the 1800s and was used as decoration. The vine is now found growing on houses, gazebos, even in the Nolde Forest. Chinese Wisteria is a invasive vine that grows upwards in a clockwise direction, killing the host tree's bark.

The flowers also make a canopy that blocks other plants from receiving sunlight. The vine can live up to 50 years and is always continuing to spread from the roots. The plant reproduces by seeds and even worse of the roots itself. More vines can reproduces from the original vine if it produces new nodes [7]. *Wisteria sinensis* is also know as Chinese Wisteria. It is a vine with beautiful purple flowers, it came from China in the 1800s and was used as decoration. The vine is now found growing on houses, gazebos, even in the Nolde Forest. Chinese Wisteria is a invasive vine that grows upwards in a clockwise direction, killing the host tree's bark. The flowers also make a canopy that blocks other plants from receiving sunlight. The vine can live up

to 50 years and is always continuing to spread from the roots. The plant reproduces by seeds and even worse of the roots itself. More vines can reproduces from the original vine if it produces new nodes.

Persicaria perfoliata

The next vine is *Persicaria perfoliata* commonly known as mile-a-minute, *Persicaria perfoliata* is one of the common invasive vines of the Nolde Forest [8]. Mile-a-minute originated from Japan and spread to the United States in the 1930s. It spread fast due to it being a self-pollinating plant which, produces seeds through June and October. The seeds can be carried by mammals and downstream causing massive spread of vegetation. Mile-a-minute is an ecological threat to the Nolde Forest it grows rapidly suffocating native plants from sunlight reducing their growth. Mile-a-minute can be recognized by its bright green triangle leaves, dark blue berries, and thorns growing on the stem [9].

Hedera helix

The final vine is *Hedera helix*, *Hedera helix* is commonly known as English ivy. It is found on houses, churches, and gardens for aesthetic appeal. English ivy is recognized by its dark green leaves with three points. What most people do recognize is *hedera helix* is an invasive vine that grows in the Nolde Forest. English ivy was brought

over by European immigrants to use for landscapes because it requires little care and it is fast growing, the reason why landscapers loved English ivy are the same reasons why it spreads so quickly. Birds would facilitate the spread by eating the seeds and moving across the country. English ivy is now found in the Nolde Forest growing up host trees and killing them. The vines would grow rapidly up the host tree weighing them down causing breakage and blocking the host trees' leaves, killing the tree. English ivy can also grow on the ground suffocating natural grasses and other native plants attempting to grow [10].

General Methods to Decrease Invasive Vines

There are three general methods to decrease the vegetation of invasive vines in the Nolde Forest: biological, chemical, and, manual and mechanical [11]. Each methods requires certain materials and skill to accomplish. In order to find the most cost efficient method out of the three there will be a cost analysis [12].

General Background about Biological Methods

Biological control methods are introducing new species into the environment in order to control the amount of vegetation by eating or suffocating the invasive plants [13]. The biological method is usually a predator of the invasive species. The most common animal predator for invasive species is goats. Different species of goats eat different invasive plants. Goats are good in situations where invasive species are covering the territory and there few little native plants. Goats are an effective short term solution for plants that are resistant to most herbicides

with roots deep in the ground. The goats eat the entire plant, off giving native plants room to thrive [14]. Another common species placed on invasive species are insects. Certain insects eat only the invasive plant or animals others, however; will eat native plants. When choosing biological agents foresters should choose carefully and consider all environmental factors.

General Background about Chemical Method

Chemical methods are the next type of general method, chemical methods are herbicides applied to the plants in order to harm them. The herbicide used for the invasive vines is glyphosate [15]. Glyphosate is non-selective so it kills anything it contacts [16]. For small scale applications the herbicide is applied with a spray bottle or backpack sprayer when the plants are flowering. The herbicide mixture should only contain five percent of the active ingredient. For cut stem application the plant stem is cut close to the ground and the herbicide is applied on the open stem. The herbicide mixture should have twenty-five percent of the active ingredient and be applied on the stem with sponge or spray bottle. Cut and spray application is another method of herbicide commonly used for vines that grow on trees [15].

General Background about Manual and Mechanical Method

The last method is manual and mechanical, manual is physically removing the invasive plant using human hands while, mechanical is using tools to physically remove the plant from the environment. Both manual and mechanical go together forming one method. The manual and mechanical method would include: weed pulling, mowing, bush cutting, girdling, mulching, tilling, soil solarization, flooding. Weed pulling is the act of pulling out the plant to remove the plant and the roots. Weed pulling positives are it does not harm neighboring plants and does not cost much unless using mechanical tools called a Root Tallon or Weed Wrench. There are disadvantages to weed pulling if the plant spreads by the roots or leaves being removed [17]. The plant can be furthered spread if not cleared properly. Mowing and bush-cutting are other forms of mechanical and manual methods used jointly with herbicides. After cutting the cut and spray method is applied to the cut vegetation. One has to be careful using the method since some plants grow faster by re-sprouting. Stabbing can kill invasive plants by injuring them at their base by stopping the flow of nutrients. Trees or shrubs with a single trunk can be harmed by girdling. Girdling is the act of cutting parallel lines down the trunk using a knife, ax, or saw. The bark would come off in large pieces removing the vascular cambium, the thin layer of tissue moving sugars through out the tree. Mulching is the act of smothering the ground so no new plants can grow. The method only works for a small patch of land. Tilling is used primarily for agricultural crops and not in the forest. Tilling is the soil being turned over and pulling out shallow rooted plants. Solar solarization is taking the soil and covering it with Polyethylene film and trapping the radiation increasing soil temperatures and killing the vegetation. The last method

is flooding; flooding can only be used if the riverine system can be manipulated. Flooding drowns the plants and kills them [18]. Though there are multiple methods Nolde Forest needs the most effective and cost effective for the three invasive vines.

Effective Methods for Three Invasive Vines

Finding a cost effective method is necessary for solving the problem of high prices for invasive plants. The first step is to find which general methods are effective and used when managing the three invasive vines. Then after finding the specific methods that decrease vegetation of each vine, a cost analysis will be done on them to find the most cost efficient method. Cost analysis is done by making realistic situations to put the materials needed for each method into action.

Biological method for the invasive vines

Since Chinese wisteria and English ivy commonly grow on trees the only vine directly effected by a biological solution is mile-a-minute. Mile-a minute can be chewed by goats and a weevil called *Rhinoncomimus latipes*. The

Weevil *Rhinoncomimus latipes* is from China, Japan, Korea and Russia. It has been in released in the United States since 2004. *R. latipes* is now being sold by the New Jersey Department of Agriculture since 2011. The weevils use the entire plant for their life cycle so not all of the mile-a-minute will be destroyed once the weevils are introduced [19]. Goats can be rented from various companies such as Rent-a-Goat and We Rent Goats as well as local farms. The goats will eat as much as the vegetation as they can by completely chewing off the plant [14].

Chemical method for the invasive vines

All three vines are killed by the same herbicides: glyphosate. Each vine uses the cut and spray method to kill the plant. Chinese wisteria and English ivy both are affected by cut and spray application since both are woody vines that grow up trees. Mile-a-minute can be affected by spray since it is on the ground [20].

Mechanical and manual method for invasive vines

Mechanical and manual methods often are combined together. A manual methods for all three vines is weed pulling. Each plant needs to be disposed of properly in a trash bag and gloves must always been worn. Another manual method is pulling or chipping vines off of the trees using hands or a screw driver. Mechanical methods for mile-a-minute would be repeated mowing and the mechanical method for all three would be using a weed wrench or weed jack. A weed wrench or weed jack is a tool used to remove invasive vines by going under the soil and

pulling it at the root in order to fully remove the plant [21].

Cost Efficient Method Comparison

To find the most cost efficient method, each method would be analyzed for the supplies uses for a day, week, month, year, and

five years. Each method would be examined for even the smallest cost and compared to each for benefits and disadvantages. The supplies are found through various sources such as other state parks and interviews with professionals from the Nolde Forest, Ecological Landscape Alliance, and the New Jersey Department of Agriculture [22].

Chemical cost

For chemical there are two options: spray and, cut and spray. For spray, there would be a team of two people spraying herbicide on the plants. The items needed would be gloves, herbicide and, 32 oz spray bottle. The initial cost to buy the items would be \$30.86 [23]. To perform the spray application every day for a month, the workers would need to find how many bottles it would take for an area. For this hypothetical, the workers each use 2 bottles a day for a total of 4 per day. The spray application requires 1.6 oz per bottle so they would use 6.4 oz of herbicide per day. Over a 30 day period (a month) the pair would use 192 oz of herbicide total leading them to buy another bottle of herbicide. Thus the cost for a month including two spray bottles, two pairs of gloves and two gallons of the herbicide glyphosate would total be \$42.86. For a year it would 6.4 oz. per day over a 365 day period leading to 2336 oz or 18.25 gallons so, for a full 365 day year the total would be 19 gallons of herbicide. The final cost for a year including two spray bottles, two pairs of gloves and nineteen gallons of the herbicide glyphosate would total be \$246.86. For a total of five years it would be 1,825 days leading the workers to use 11,680 oz of herbicide or 91.25 gallons. Over five years the team would use 92 gallons so the final cost for a five year period including two spray bottles, two pairs of gloves and ninety- two gallons of the herbicide glyphosate would total be \$1,122.86 (Table 1).

Now for cut and spray option with a two team person the application requires the initial items of gloves, spray bottle, and hedge trimmers. The cost of two of each item in total is \$64.80 and for the cut and spray option the solution needs 25% of it to be herbicide, 25% of 32 oz is 8 oz. For this hypothetical each worker uses 2 bottles a day for a total of for 4. The pair would use 32 oz a day. For a day the total cost would be \$76.80 including herbicide gloves, spray bottle, and hedge trimmers. Over a 30 day period (a

month) the pair would use 240 oz or about 2 gallons leading to a cost of \$88.80. Over a 365 day period or a year the team would use 2,848 oz or 23 gallons, now making the cost 340.80 dollars a year. For five years it would be \$1,704. Keep in mind gloves, spray bottle, and hedge trimmers are only bought once along with the certain number of gallons per herbicide. Now over a five year period the cost of spray and cut and spray is about five-hundred dollar difference. Yet each have their differences in effects, spray only can be dangerous and kill other plant while cut and spray only kills a certain plant (Table 2).

Biological cost

There is only one biological method for one of the invasive vines in the Nolde Forest. Mile-a-minute can be biologically controlled by weevils. The cost of weevils is a flat rate of \$500 for 500 weevils, they come the New Jersey Department of Agriculture. The first year the weevils get situated in the environment then over the next three years there are noticeable results. The weevils will consistently cost \$500 dollars, however; they only manage one kind of vine and do not fully remove the threat to the forest. In the end the biological method would have to work in coordination with another method raising the cost, since the weevils need the vine to survive in their life cycle. Leading the biological method not be the most cost efficient method to decrease the number of invasive vines in the Nolde Forest.

Manual and mechanical cost

To find the cost of manual and mechanical, there would be the analysis of two volunteer teams known as volunteer group A and, volunteer group B. Volunteer group A is a 20 person volunteer group that only meets once a month for a year. Volunteer group B is a 20 person volunteer group that meets twice a month for a year. Each volunteer group is equipped with the following materials: a vehicle, gas, gloves, trash bags, root talon, cases of water, and hedge clippers. Any of the left over material needs to be properly disposed in a landfill. To find the cost of fuel for the vehicle to get to the landfill the round trip needed to be calculated. The closest landfill is Pioneer Crossing Landfill which is 11 miles away. The trip would be 22 miles, hypothetically the driver only needs to pay for the two gallons of gas for the round

Table 1. Chemical Cost estimation via spray.

Spray	Cost per Item	Amount of each Item	Initial Cost	Cost per Month	Cost per Year	Cost per Five Year
Gloves	\$5.47	2	\$10.49	\$10.49	\$10.49	\$10.49
Herbicide	\$12.00	1	\$12.00	\$24.00	\$228.00	\$1,104.00
32 oz spray bottle	\$1.98	2	\$3.96	\$3.96	\$3.96	\$3.96
Total			\$26.45	\$38.45	\$242.45	\$1,118.45

Table 2. Chemical Cost estimation via Cut and spray.

Cut and Spray	Cost per Item	Amount of each Item	Initial Cost	Cost per Month	Cost per Year	Cost per Five Year
Gloves	\$5.47	2	\$10.49	\$10.49	\$10.49	\$10.49
Herbicide	\$12.00	2	\$24.00	\$24.00	\$276.00	\$1,380.00
32 oz spray bottle	\$1.98	2	\$3.96	\$3.96	\$3.96	\$3.96
Hedge Clippers	\$22.97	2	\$45.94	\$45.94	\$45.94	\$45.94
Trash Bags	\$14.97	1	\$14.97	\$14.97	\$14.97	\$14.97
Total			\$99.36	\$99.36	\$351.36	\$1,455.36

trip. In total the amount of gas would be \$5.10 if gas is at \$2.55 which is the average cost of gas [24] (Table 3).

The next cost is gloves, Home Depot gardening gloves cost \$5.47 a pair. If 20 people need gloves the cost would be \$109.40 [23]. That cost should stay at \$109.40 but wear and tear is possible so the cost may increase. The next cost is trash bags a box of 14 gallon trash bags which are \$14.97 a year of a box of trash bags would be \$179.64, for five years \$898.20 [23]. Another cost would be the root talon, a mechanical device that removes the roots straight from the ground. The cost of two of these devices in total would be \$109.50, this should stay a constant cost over the next five years [25]. The next cost would be cases of water a case of water is \$4.66, for a year it would be \$55.92 and five years \$297.60 [26]. The final cost would be clippers from Home Depot, the group would be using five of them and with their cost of \$53.38 the total would be \$269.40 [25]. The cost should remain constant over five years. In total the cost of maintain Volunteer Group A for a year would be \$785.46 and then five years would be \$1,990.50. These numbers are only if equipment does not break and the price of gas may rise and fall. Volunteer Group B is more expensive then Volunteer Group A since it meets twice a month but, it is about \$2,000 more than the group that meets once a month. That is due to gas, trash bags, and water. Objects may have more wear and tear as well leading to more cost [27] (Table 4).

Limitations

Limitations of the research include no previous knowledge about the cost of invasive plants at the Nolde Forest [28]. Nolde Forest does not currently keep a record about their funds and what they spend them on. Another limitation of my research is the unknown number of acres of invasive plants. According to

professionals contacted such as Bruce Wenning and Lisa Miller invasive plants cannot be totaled in acres, meaning there is no exact measurement for the amount of invasive vines [29]. It is also difficult to know what supplies are needed in all cases. A limitation in finding the cost of the biological method there were local goat companies that needed to be contacted. The major goat companies such as Rent-A-Goat and We Rent Goats were unable to be reached [30]. Another limitation was there is no information about the cost of labor for the chemical method. Technically volunteers can apply herbicides if they are approved from training, however; that is usually not the case [31].

Conclusion

After analyzing the methods the chemical method is the most cost efficient method. The cheapest of the chemical

methods was spray. The spray was the cheapest because it requires the least amount of materials and the least amount of herbicides. Cut and spray is more expensive but, in the end it is softer for the environment since the herbicide is likely to reach in the soil. Cut and spray can also be cleaned up easier to prevent spreading. The next most cost efficient method would be biological. The biological method would be cheaper then a volunteer group even if it is accompanied by chemical method [32]. The chemical method is needed because the biological control can only manage mile-a-minute. The most expensive method was manual and mechanical method due to the amount of tools, gas, and reoccurring costs. Volunteer group A was the cheapest since it meet less. Both volunteer groups ca decrease cost if the members brought their own supplies [33]. Though chemical is the most cost efficient method volunteer groups have benefits of building community and being less harsh on the environment [34] (Figure 1).

Table 3. Manual and Mechanical cost estimation for a Short Term meet once a Month.

20 Person Volunteer Group Short Term Meet Only Once per Month	Cost per each Item	Amount Needed of Item	Cost	Cost per Year	Cost for Five Year
Vehicle	Provided	1	0	0	0
Fuel for Vehicle	\$2.55 per gallon	2 gallons	\$5.10	\$61.20	\$306
Gloves	\$5.47	20	\$109.40	\$109.40	\$109.40
Trash Bags	\$14.97	1	\$14.97	\$179.64	\$898.20
Root Talon	\$54.94	2	\$109.90	\$109.90	\$109.90
Cases of Water	\$4.66	1	\$4.66	\$55.92	\$297.60
Clippers	\$53.88	5	\$269.40	\$269.40	\$269.40
Total			\$513.43	\$785.46	\$1,990.50

Table 4 Manual and Mechanical cost estimation for a Long Term meet Twice a Month.

20 Person Volunteer Group Long Term Meets Twice every Month	Cost per one of each	Amount of Item Needed for Two Times a Month	Cost	Cost For Year	Cost for Five Year
Vehicle	Provided	1	0	0	0
Fuel for Vehicle	\$2.55 per gallon	4 gallons	\$10.20	\$122.40	\$612.00
Gloves	\$5.47	20	\$109.40	\$109.40	\$109.40
Trash Bags	\$14.97	2	\$29.94	\$359.28	\$1,796.40
Root Talon	\$54.95	2	\$109.90	\$109.90	\$109.90
Cases of Water	\$4.66	2	\$9.32	\$111.84	\$559.20
Clippers	\$53.88	5	\$269.40	\$269.40	\$269.40
Total			\$538.16	\$1,082.22	\$3,456.30

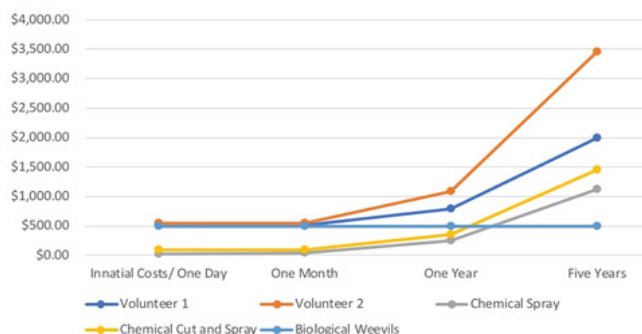


Figure 1 The Most Cost Efficient Method to Decrease the Number of Invasive Vines in the Nolde Forest.

Future of Research

The purpose of my research was to find the most cost efficient

method to decrease the number of vines in the Nolde Forest. In future research I would make an experiment of each method by testing them in the field for a year to find the true cost of each method. I would also set up similar groups to what I made in my research changing the amount needed of each item or different kinds of items to see if the price can be lower. The research can be done with other plants by replicating the groups and changing what is needed. I hope future parks can use the research to find their most cost efficient way to decrease their invasive plants. By doing a cost analysis parks can continuously decrease the amount of invasive vegetation in their parks, leading to better state parks and saving money. The research should also influence national parks to keep track the amount they spend on invasive species and the amount of vegetation they removed. Having records of what was previously spent can help decrease cost since it will help parks know what to buy and how much of it.

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