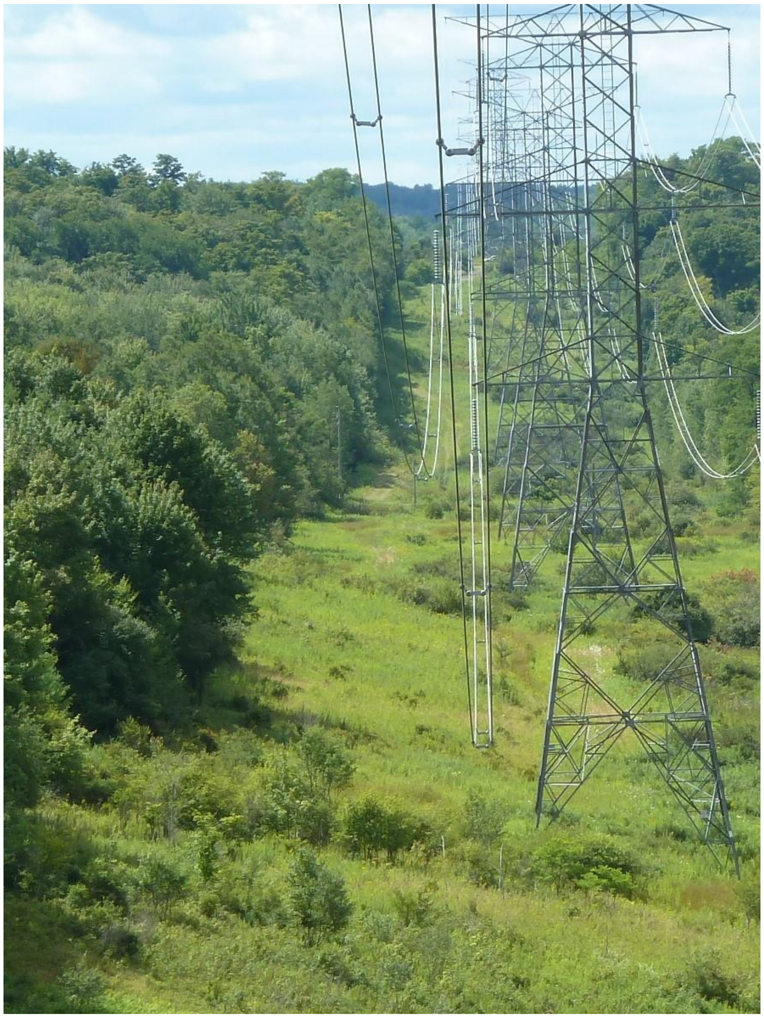

THE COST-EFFICIENCY OF IVM

A Comparison of Vegetation Management Strategies for Utility Rights-of Way

ABSTRACT

This report establishes a business case for the practice of Integrated Vegetation Management (IVM) on electric and gas transmission rights-of-way, both in terms of cost savings and the benefits that are produced.

John Goodfellow

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Abstract

Table of Contents

Acknowledgements

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Cover photo credit – Lew Payne, NYPA

Executive Summary

An earlier project established a preliminary business case for IVM on electric transmission ROW, applying least-cost economic analysis methods that focus exclusively on the direct cost to the utility. Findings from this new project included the development of an enhanced least-cost analysis model and the consideration of the benefits of IVM on electric and gas utility ROW. This project convincingly confirms IVM as the least costly and most beneficial ROW vegetation management (VM) strategy from a longer-term perspective of sustainability.

Significant improvements were made in an application of least cost analysis. Most notable is the inclusion of three different approaches to scheduling preventive vegetation maintenance: a traditional fixed interval cycle, a user-defined prescription, and an on-condition approach in which preventive maintenance is scheduled based on tolerance levels and action thresholds.

Findings from least cost analysis present a compelling case for the economic benefit of an IVM-based ROW maintenance strategy. A vegetation management strategy based on the use of IVM, which includes integration of mechanical and herbicide-based prescriptions, is consistently and convincingly less costly than repeated treatments using only manual and mechanical techniques. This hold true in all situations: when the efficacy of mowing was exaggerated; when the efficacy of herbicides was minimized; when the cycle length was shortened or lengthened; and when action thresholds based on MVCD were used. In addition to lower costs, the IVM strategy demonstrated lower risk (i.e., lower maximum height) between treatments.

The advantage of IVM was demonstrated across a wide array of benefits including public safety, operational risk, recreational use, public nuisance, site disturbance, water quality, compatible vegetation, incompatible vegetation (density & height), and a range of wildlife species. Mechanized mowing was found to have the advantage in terms of safety. Mechanized mowing also provided greater short-term benefits related to public perception and aesthetics. These advantages diminish over time with the development of a stable compatible plant community develops under an IVM based approach to ROW vegation management.

Application of cost efficiency analysis was somewhat limited in some cases due to a lack of quantitative interval data pertaining to several benefits of IVM. Direct comparison of IVM-based and non-IVM vegetation maintenance treatments was also limited due the confounding effect of the influence of land covers adjacent to the ROW corridor. While acknowledging those limitations, it can still be said that the benefits of associated with an IVM-based strategy typically exceeded those associated with simply repeatedly mowing a ROW.

Introduction

There are 450,000 miles of electric transmission line operating at 35-765 kV across North America, with a total land area being managed as electric transmission rights-of-way (ROW) estimated at between 9-11 million acres. There are an additional 306,000 miles of natural gas and liquid petroleum pipeline in North America, representing an estimated 2 million areas of land. Much of the total land areas in ROW are currently being managed under an Integrated Vegetation Management (IVM) regimen. Reluctance by some utility vegetation managers to adopt IVM is often based on a perception that it is a more expensive management system than simply "controlling brush" by repeated mowing.

An earlier project established a preliminary business case for IVM on electric transmission ROW. The scope of that project applied least-cost economic analysis methods that focused exclusively on the direct cost to the utility for vegetation maintenance work practices. That approach limited any consideration of the benefits of IVM to simply avoided cost. However, indirect costs and benefits of IVM are important considerations.

This project included the development of an enhanced least-cost analysis model and broadens the assessment to include consideration of the many benefits of IVM on electric and gas utility ROW. It presents a holistic assessment that includes economic considerations, societal implications, and environmental externalities associated with IVM. In doing so, it established IVM as the least-costly and most beneficial ROW vegetation management strategy.

Defining IVM

IVM-based ROW maintenance programs are intended to create, promote, and conserve stable plant communities. IVM is recognized as an environmentally responsible and sustainable means of managing early successional plant communities on extensive land areas such as ROW and other types of land use. A variety of vegetation maintenance methods and combinations of methods are used to promote sustainable plant communities that are compatible with the intended use of the site, and to control, discourage, or prevent the establishment of incompatible plants that may create a variety of risks.

Industry standard ANSI A300 Part 7 (2019) and ISA BMP *"Integrated Vegetation Management" 2nd Edition* (2014) define IVM on utility ROW. The ROW Stewardship Council's IVM "*Accreditation Requirements"* (2016) define IVM principles and practices for ROW in detail. In short, IVM is well defined.

Comparative study

This project compares a vegetation management (VM)strategy based on the principles and practices of IVM to one that is intended to simply control vegetation within a ROW corridor. The strategies considered are:

- An IVM-based strategy that makes use of a variety of increasingly selective vegetation maintenance actions specifically targeting incompatible vegetation and promoting the development of compatible plant communities. This strategy includes the use of herbicides as well as mechanized mowing of incompatible species of tall growing trees, and assumes proper use of registered products.
- A simple VM strategy that makes use of repeated mechanized mowing to control vegetation within the ROW corridor. This strategy does not include the use of herbicides.

Differences in conditions within the ROW corridor are compared using a variety of measures. This study focuses on maintenance of vegetation following initial establishment of the ROW and does not include consideration of initial clearing of the corridor. Two separate time frames are considered in evaluating the impact of either VM strategy:

- The short-term effect of vegetation maintenance tasks at the time of and within one growing season of the treatment. These effects are directly associated with the work being performed and may vary seasonally.
- The long-term effect of each VM strategy as conditions within the ROW corridor develop over time. Multiple vegetation maintenance tasks would be completed over this 20-year time horizon.

This study focuses on differences between the IVM and non-IVM strategies with the ROW corridor being maintained. The general effects of maintaining a ROW corridor as compared to the general landscape and cover types through which it passes are outside the scope of this study.

Methods

A series of tasks were involved in assessing and comparing the costs and benefits of an IVM-based strategy that makes use of herbicides to a strategy based on repeated mechanical mowing of ROW vegetation without the use of herbicides.

Literature review

A review of the relevant literature included peer-reviewed references as well as the gray literature (e.g., trade publications, industry presentations, unpublished internal studies, and marketing materials). Government databases (OSHA) were also evaluated. These references included limited quantitative data. References that supported a comparison of IVM and non-IVM strategies were more often qualitative in nature or stated outcomes in general terms. Both types of data were used to inform this report.

A wide range of environmental externalities were initially considered. Rather than evaluate each individually, they were grouped into genera with similar characteristics. Seven general categories of benefits identified in the literature review are used in this analysis:

1. Economic benefits stated in terms of avoided cost
2. Safety of VM workers and general public
3. Public perception
4. Public nuisance
5. Environment and site impact
6. Vegetation
7. Wildlife

A review of the available literature demonstrated that in many cases data were limited. That being the case, a three-tier evaluation system was adopted and used in this project to characterize the benefits of each VM strategy.

Table 1 The "Three L's", levels of assessment used to characterize the effects of vegetation management practices.

Level of Assessment	Characteristics	Certainty, Rigor
Literature	Citations in refereed journals and gray literature such as trade publications, newsletters, and presentations.	Highest/best
Logic	Deductive reasoning, defining an issue and using reasoning (and data) to project or estimate benefits.	Reasonably high quality
Lore	Input from practitioners based on practical experience and knowledge.	Medium, needs to be objectively tested.

Economic Analysis

An economic assessment of costs of both the IVM and non-IVM strategies was a first step in assessing the business case for each. Economic analyses of this nature typically include consideration of the costs and benefits associated with an activity. There are two basic approaches to economic analysis that are relevant to this project:

- **Least cost analysis** is defined as minimizing the variable costs to produce a given output or outcome level (Wagner 2012). In this case, the avoided cost of a treatment can be considered a benefit. The costs considered are limited to those that are directly attributable to vegetation maintenance activities.
- **Cost-effectiveness analysis** is defined as producing the greatest output or outcome levels for a given budget (Wagner 2012). In this case, a wider array of benefits are considered, and while they may be stated quantitatively, they do not need to be monetized.

Both these approaches were applied in an assessment of the two different vegetation management strategies.

The overarching purpose of VM on utility ROW is to ensure safety, service reliability and regulatory compliance. VM enhances security, access, and visibility while reducing fire risk and restoration time. When done well, it can provide many environmental benefits. The economic analysis assumes that both IVM and mechanical-only maintenance programs can achieve the operational objectives for the ROW. The goal of the economic analysis was to establish which approach, one that uses versus one that avoids the use of herbicides, has the lowest cost and produces the most benefits.

The economic analysis recognizes that maintenance is not a one-time event. It is a recurring cost because residual vegetation and newly seeded plants will continue to grow. The decision to use or avoid herbicides does not change the recurring nature of VM, but the choice can affect the direct cost of treatment (e.g., density and height of incompatible vegetation) and the frequency of maintenance. The timing and the direct cost of treatment are the two critical elements of the analysis. The general process was as follows:

The Present Value Cost over a 20-year (PVC^{20yr}) maintenance period was determined. The cost of treatment was expressed in terms of present value, which discounts future expenditures to the date of valuation. A 5% discount rate is used throughout unless specifically stated. This combination of factors is generally consistent with industry convention and represents the industry's opportunity cost of capital.

The economic analysis does not attempt to estimate inflation over the 20-year period and therefore the results are described in terms of real rather than nominal costs.

Least Cost Economic Analysis

The cost (PVC^{20yr}) of each vegetation management strategy was calculated using least-cost analysis. As previously noted, an earlier project used least-cost analysis and only considered the direct costs of IVM. That project used Delphi Analysis techniques to identify the cost of contemporary vegetation maintenance treatments across a range of stocking (density and height) classes. This project applied a similar approach to least cost analysis using a refined analytic model.

A stocking matrix for each VM treatment under consideration in this current project was used to codify the cost of each across a range of plant densities and heights. Similar cost matrices were used in the earlier project. The cost and suitability of each maintenance treatment across a range of stocking levels were updated to reflect the current situation.

The stocking matrix reflects the need to consider height as well as density when prescribing VM treatments. The concept of stocking used in this study is adapted from silviculture and describes growing space occupancy relative to complete canopy closure of incompatible tree species within a ROW corridor.

The density classes used in the stocking table reflect ranges reported in the literature and have been proven to be useful in actual practice. The height classes used in the stocking table are reflective of the range of heights of incompatible trees that may occur on an electric transmission line ROW and are intended to harmonize differences in metric and imperial units of measure. The upper limit of the extra tall classification would be practically limited by tree-conductor clearance requirements.

Table 2 Stocking table describing the percent occupancy of a ROW by incompatible species. This design informed the development of cost and suitability information in each cell.

STOCKING, Incompatible vegetation			**HEIGHT**				
			short	medium	tall	very tall	extra tall
			<3 feet	<6 feet	<10 feet	<13 feet	≥13 feet
DENSITY			<1 meter	<2 meter	<3 meter	<4 meter	<4 meter
ultra-light	<50/acre	<125/hectare	5%	5%	10%	15%	20%
very light	<500/acre	<1250/hectare	10%	20%	30%	40%	50%
light	<1000/acre	<2500/hectare	30%	50%	80%	100%	100%
medium	<3000/acre	<7500/hectare	80%	100%	100%	100%	100%
heavy	≥3000/acre	≥7500/hectare	100%	100%	100%	100%	100%

The vegetation maintenance treatments included in each of the two vegetation management strategies considered in the study are presented in Table 3. Treatments that are infrequently used such as aerial applications or used in limited physical areas of ROW such as frilling and cut-stump treatments were not considered in the IVM strategy. Similarly, hand cutting was not included in the non-IVM strategy.

Table 3 Individual vegetation maintenance treatments included in each VM strategy.

VM Strategy	**Vegetation Maintenance Treatments**					
IVM	Mechanized Mowing	Cut Stubble herbicide application	Broadcast Foliar herbicide application	High Volume Foliar herbicide application	Low Volume Foliar herbicide application	Low Volume Basal herbicide application
Non-IVM	Mechanized Mowing					

The cost of individual vegetation maintenance treatments had changed since the earlier cost data were gathered. The general consensus opinion of practitioners is that while herbicide application costs had increased since 2016 (Figure 1), there had been a greater increase in the cost of mechanized mowing (Figure 2).

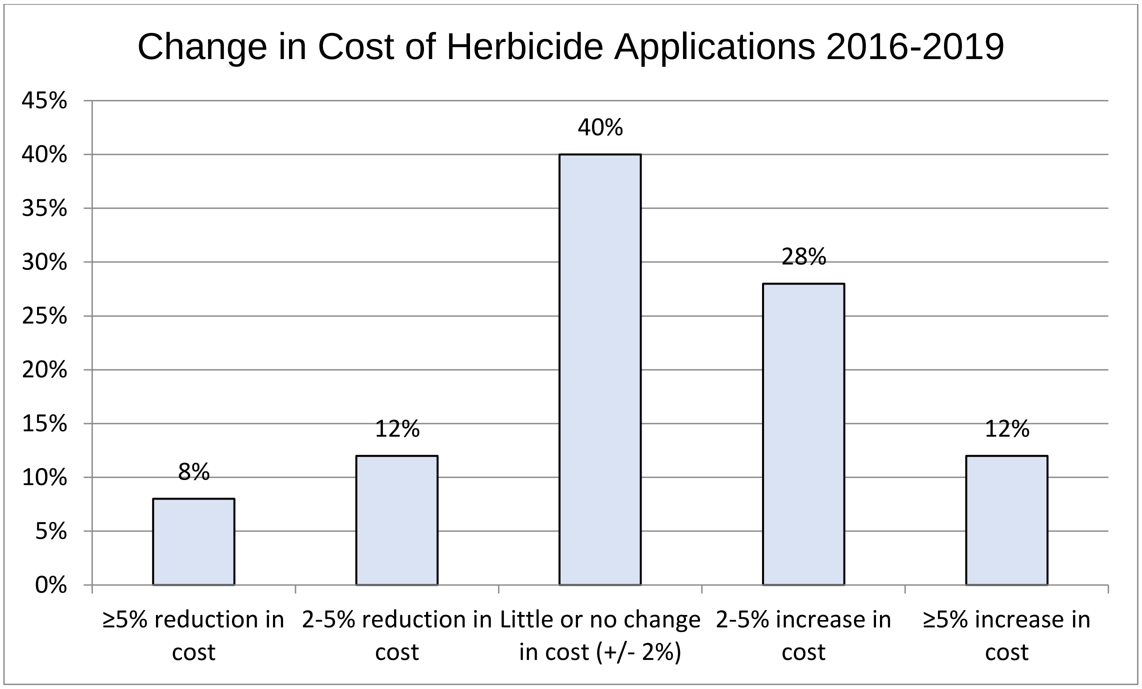

Figure 1 Perception of practitioners regarding change in the cost of herbicide application services over past three years.

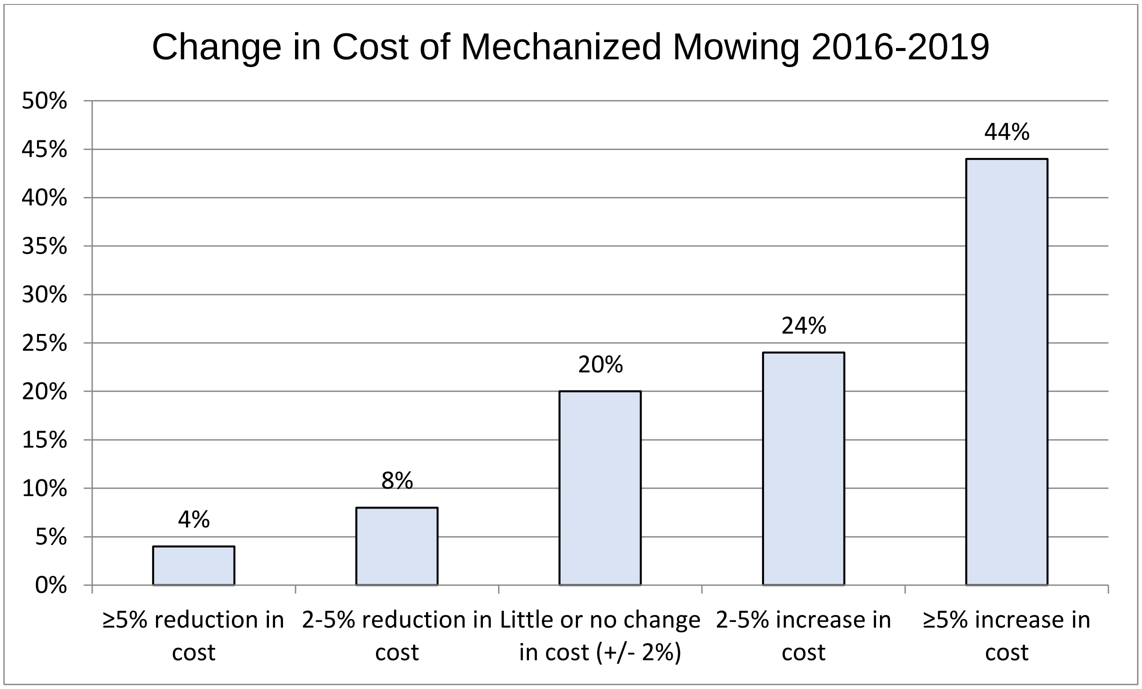

Figure 2 Perception of practitioners regarding change in the cost of mechanized mowing services over past three years.

Appropriate adjustments to the cost structures of the vegetation maintenance treatments relevant to this project were made with the direct input of subject matter experts.

Costs considered in this step of the analysis are limited to direct operational costs of labor, equipment, and materials, and do not include regulatory and administrative costs. Nor does this first step of determining least cost consider any cost-offsetting benefits that may be associated with each treatment.

The basic approach used in conducting least cost analysis was to prescribe an expected sequence of treatments over the 20-year evaluation period. The least cost analysis model used in this project supported assessment of three different approaches to scheduling preventive vegetation maintenance:

Table 4 Approaches used in determining when vegetation maintenance would be performed over the 20-year analysis horizon.

Approach	Determination
Fixed interval	VM is scheduled based on a fixed cycle period.
User defined	VM is scheduled as determined by VM personnel, and the prescription may vary.
On-condition	VM is scheduled base on incompatible tree heights exceeding action threshold.

All three approaches to scheduling preventive vegetation maintenance treatments were used. The fixed interval evaluation considered cycle periods ranging from two to six years. The User defined 20-year preventive vegetation maintenance schedules that were evaluated were based on expert knowledge.

A significant refinement to the least cost analysis applied in this project supported the application of an on-condition approach to scheduling preventive maintenance. This made use of the concepts of "*Tolerance Level"* and "*Action Threshold*" that are included in the current edition of relevant Standard[1].

- Tolerance Level - The maximum allowable incompatible-plant pressure, e.g., species, density, height, location or condition, without unacceptable consequences.
- Action Threshold – The level of incompatible plant pressure (e.g., species, density, height, location or condition) where vegetation maintenance treatments should occur to prevent conditions reaching the tolerance levels.

This concept was used in the economic analysis conducted in this project uses Minimum Vegetation Clearance Distances[2] (MVCD) and minimum over ground clearances[3] for a typical 230kV circuit in determining the need for on-condition vegetation maintenance.

Table 5 Example of setting a Tolerance Level based on MVCD's included in FAC-003.4

Voltage	NESC 232.c.1C	NESC 232	Minimum Clearance (MVDC)		Not-to-Exceed Height	
230 kV	7.7m	25.2ft	1.2m	3.9ft	6.5m	21.3ft

In this simplified case, the tolerance level would be reached when incompatible vegetation grew to a height of 21.3 feet. To avoid this, an action threshold would be set to trigger the need for vegetation

[1] ANSI A300 Part 7 Integrated Vegetation Management (2018)
[2] NERC FAC-003.4
[3]NESC (2017) §232.1 & §232.C.1, vertical clearances for undeveloped sites such as cropland, pastures, forestry.

maintenance well in advance. The model uses an action threshold for IVM-based treatments at the upper limit of the "very tall" height class (12 feet) used in the stocking table (Table 2). The action threshold for mechanical mowing was set at 18 feet.

Cost-effectiveness Economic Analysis

Cost-effectiveness analysis, also known as cost-effectiveness ratio analysis, considers differences in cost between two possible interventions, and the differences in their outcomes (in this case benefits). The costs under consideration (as described above) are stated in monetary terms, while the benefits may be stated in quantitative but non-monetary terms.

The costs associated with the IVM and non-IVM strategies being considered are those calculated using least cost analysis (PVC^{20yr}). The challenge is in quantifying benefits in a form that can be used in the cost-effectiveness calculation. This calculation involves dividing the cost of treatment by the effect and is intended to represent the average incremental cost associated with one additional unit of benefit. The results of the cost-effectiveness analysis are specific to each benefit being considered. In some cases, the benefits being described are qualitative in nature and did not support cost-effectiveness analysis.

Data can be characterized into four classes, as seen in Table 1 below. Ratio data can be used directly in cost benefit analysis. However, data relating to the benefits of each of the topics at hand are difficult to state in monetary terms and as such are generally not available.

Table 6 Characteristics of data used to qualify and quantify outcomes.

Type of Analysis	Values with a 0 Reference	Relative Values Between Ratings	Ranking, Order of Rating	Simple Labels
Ratio	Yes	Yes	Yes	Yes
Interval	No	Yes	Yes	Yes
Ordinal	No	No	Yes	Yes
Nominal	No	No	No	Yes

Interval data, which are quantitatively stated but may not be monetized, can be used in cost-effectiveness analysis. This is what had been proposed. Unfortunately, the literature review found that comparable quantitative interval data for either IVM or non-IVM strategy and for individual treatments were limited, both in terms of quantity and quality/rigor.

The general lack of quantitative interval or ratio data useful in describing the relative benefits of either VM strategy limited the opportunity to apply cost-effectiveness analysis.

Ordinal Analysis of Benefits

A means of scoring ordinal data useful in comparing an IVM-based strategy and a strategy that relies on simply repeated mechanized mowing was developed (Table 7).

Table 7 Ratings used in scoring IVM in comparison to mechanized mowing.

Rating	Definition
++	Significantly better
+	Usually, generally
0	Equal, no apparent difference
-	Usually, generally worse
--	Significantly worse

Practitioner Survey

A survey of senior members of the Utility Arborist Association (UAA) was conducted. The survey population of 142 individuals was based on participation in periodic system forester summits. Twenty-six individual responses were received, yielding a response rate of 18%. This response rate compared favorably with other UAA surveys. The survey asked practitioners to consider each issue from a broad perspective based on their extensive experience.

The survey was designed to focus on the two distinctly different VM strategies that differ in the use of herbicides. Many of the questions were presented in pairs asking participants to consider two time periods: at and soon after treatment, and longer term over several treatments as vegetation within the ROW responded to the two different maintenance strategies. A Likert Scale using semantic differential statements (a.k.a. "bipolar adjectives") was used to develop an ordinal scale of a range of five possible choices as defined in Table 7.

Findings

An IVM-based strategy that includes the use of a variety of vegetation maintenance treatments including herbicides was shown to be significantly less costly as compared to the non-IVM strategy of repeated mowing. In most cases it was also shown to be more cost efficient at producing a variety of benefits.

Findings are presented in a high-level summary table at the beginning of each section that describes the results of analysis for each class of benefit, followed by a more detailed explanation of findings.

Economic benefit (avoided cost)

Differences in the projected maintenance costs between IVM-based and non-IVM vegetation management strategies represent an avoided cost benefit.

Table 8 Summary of observations related to the economic benefit of an IVM-based strategy.

Basis	Observation	IVM rating
Literature	The literature, while somewhat limited, reports significant savings with IVM	++
Logic	Application of least cost analysis method to calculate Present Value Cost	++
Lore	IVM has frequently presented as cost-effective long-term maintenance strategy.	+

Literature

Publicly available references comparing the cost of herbicide-based versus non-chemical-based vegetation management practices is limited. What is available generally compares the cost of using herbicides to non-herbicide-based vegetation maintenance. One publication[4] that describes an application of concepts such as the time-value-of-money (discounting) and cost-effectiveness was identified. There are no publications on the basic system conditions (vegetation density and height), as embodied in production functions, that are requisite for such financial analyses.

Two unpublished references were identified. An industry presentation [5]applied present net value analysis in a comparison of mowing versus herbicide application on transmission ROW over time horizons of 15-21 years, using an 8% discount rate. This presentation included breakeven analysis and reported net present value (NPV) cost savings of 21.2% in favor of an herbicide-based vegetation management strategy, and savings of 47.9% annually once steady-state vegetative conditions are established. The study also projected a 67.4% reduction in scheduled work time.

An internal economic study[6] completed by an engineering consulting firm for an electric cooperative applied present value of cost analysis in comparing the costs of a vegetation management program that incorporated the use of herbicides to one that only utilized mechanical treatments. That study

[4] Nowak, C.A. Cost Effectiveness Analysis for Comparing Vegetation Management Alternatives on Electric Transmission Rights-of-Way: An Illustrative Guide. EPRI, Palo Alto, CA: 2012. 1025379.
[5] Colman, C. Vegetation Management Solutions for a Competitive Advantage. PowerPoint Presentation, BASF Corp., Specially Products Department. Date Unknown.
[6] Finley Engineering. Cost Analysis for Integrated Vegetation Management Plan. Internal report to Carroll Electric Cooperative. 2010

considered treatment intervals of five and six years over a time horizon of 30 years and assumed annual inflation at 2% and a real discount rate of 4.25%. The study projected a 45% reduction in cost when adopting an herbicide-based vegetation management strategy (Finley Engineering 2010). The study projected that a non-herbicide mechanical treatment strategy would be three to four times costlier and could grow to eight to nine times more expensive in the longer term.

Table 9 Reported cost savings from use of herbicides as compared to mechanical mowing

Reference	Time Horizon	Projected Savings
Colman (date unknown)	15-20 years	48%
Finley Engineering (2010)	30 years	45%
CEATI/Goodfellow (2017)	20 years	48%

The most recent and complete reference[7] that specifically compares the cost of an IVM-based strategy to that of simply repeated mowing was completed by the author (Goodfellow 2017). That study is not available in the public domain. Findings from this study are relevant to this project. It made use of least cost analysis and compared the total owned cost of maintenance, the cost of ROW reclamation, and the cost of losing the use of herbicides. The analysis applied Present Cost Analysis using a discount rate of 5% over a 20-year period. The total owned cost case study is comparable to the previously cited studies and found a Present Value Cost savings of 48% in favor of an IVM strategy.

Least Cost Analysis – Base Case

A simple base case was used in a Present Value Cost (PVC^{20yr}) assessment comparing two fixed interval (cycle-based) vegetation management strategies implemented over a 20-year period. The costs presented represent the present value of maintenance costs for the Base Case comparing:

1. An IVM strategy where the site was initially cleared, and herbicides were applied by cut-stubble treatment. Herbicide applications were prescribed every four years after clearing. Two types of herbicide treatments: broadcast high-volume foliar (HVF) and selective low-volume foliar (LVF) were used with the prescription based on density and height.
2. A mechanical-only strategy where the site was initially cleared, and mowing occurs every four years.

This investigation focused on the cost of maintaining vegetation over time. The capital cost of initial clearing would be the same in either case and was not included in this analysis. The added cost of stubble treatment at the time of clearing was included in the analysis of the IVM strategy.

[7] Goodfellow, J.W., C.A. Nowak, and J.E Wagner. Vegetation Management Business Cost Benefit of Herbicide Use. Centre for Energy Advancement through Technological Innovation (CEATI), Montreal. 2017

Table 10. Vegetation maintenance prescriptions used in the Base Case study.

Season	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
IVM	Initial Clearing w/herbicide				*HVF*				*HVF*				*LVF*				*LVF*				*LVF*
Mech. Mow	Initial clearing				*Mow*				*Mow*				*Mow*				*Mow*				*Mow*

The four-year fixed interval cycle used in the Base Case comparison was based on an unpublished Utility Arborist Association (UAA) 2017 benchmark study and reflects the average cycle period reported by 20 utilities for both mowing and IVM treatments.

A more complete discussion of the base case, including incompatible stem density and maintenance costs, is included in Appendix A, Least Cost Analysis. Figure 3 illustrates the cumulative costs of the two approaches over time and Table 11 provides an overall summary.

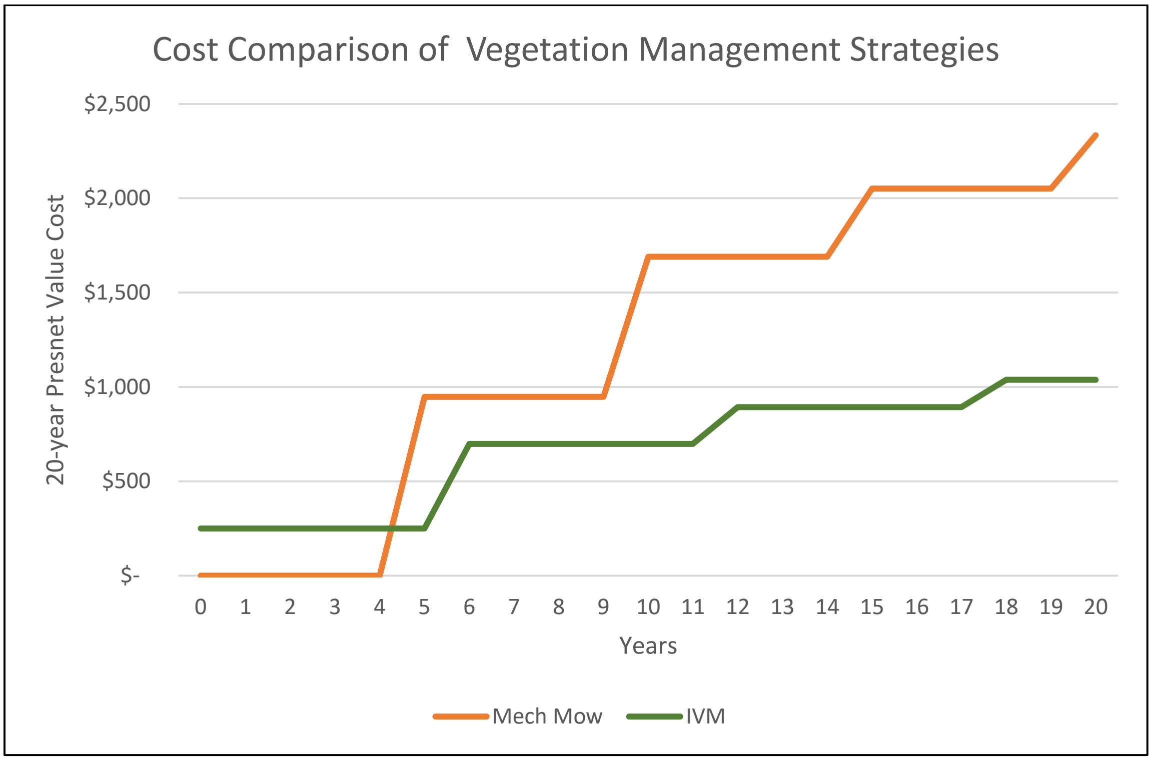

Figure 3. 20-year costs (Present Value) comparing maintenance using mechanical mowing-only treatments v. IVM treatments.

Figure 3 shows that, because of the added cost of herbicide treatment during initial clearing, the IVM strategy is initially the higher cost strategy. At the time of first maintenance event (four years), the cost of mechanical maintenance overtakes that of the IVM.

Table 11 Summary results from Least Cost Analysis performed on the Base Case

Metric	Mechanical Mowing Only	IVM
Maximum average tree height	15 feet	9 feet
Ending stem density	medium	very light
Sum of Present Value Cost	$3,114	$1,412

The total PVC^{20yr} of the IVM-based strategy was 55% less than the mechanical-only treatments. As shown in Table 11, the site that was mowed retained higher stem densities and achieved considerably higher average heights between treatments.

Breakeven Analysis for Base Case

Present value calculations are dependent on the time value of money as reflected in the discount rate. A higher discount rate increases the benefit of deferring costs and disadvantages the IVM scenario, which requires treatment at the time of initial clearing or soon after clearing.

A discount rate of 5% was used In the Base Case PVC^{20yr} analysis. A discount rate of 40.1% would be required to make the 20-year costs of the two scenarios equal.

Findings from least cost analysis present a compelling case for the economic benefit of an IVM-based ROW maintenance strategy.

Safety

The relative safety of vegetation maintenance work associated with an IVM and non-IVM strategy was considered. Safety of the general public frequenting ROW maintained under either strategy was also evaluated.

Safety of VM workers

A comparison of the relative safety of herbicide applications that would be included in an IVM strategy to mechanized mowing work was conducted.

Table 12 High-level summary of observations pertaining to worker safety.

Basis	Observation	IVM rating
Literature	OSHA statistics for industries and bodies of work that may generally pertain to mowing and herbicide applications on ROW are available. Incident rates for mowing surrogate are lower than for IVM. Incident rates for hand cutting are much higher than for either strategy being evaluated.	-
Logic	The difference in OSHA incident rates may relate to protective features associated with mechanized mowing equipment.	-
Lore	A survey of practitioners specifically addresses worker safety issues.	0

The comparison of the relative safety of the two vegetation management strategies is based on data maintained by the US Occupational Safety and Health Administration (OSHA). These data are available by Standard Industrial Classification (SIC) codes. These codes are generally descriptive. Four SIC codes were selected as relevant to this analysis:

0721: Crop Planting, Cultivating, and Protecting
0722: Crop Harvesting, Primarily by Machine
0783: Ornamental Shrub and Tree Services
0851: Forestry Services

There are a broad range of North American Industry Classification System (NAICS) codes within each SIC classification. The descriptions for each NAICS code were reviewed, and the most relevant codes were selected. The following three classifications were identified as best representing three vegetation maintenance activities related to the two vegetation management strategies of interest:

Table 13 Classifications of work approximating vegetation maintenance treatments considered.

NAICS code	Description and assigned vegetation maintenance treatment method
115112	Soil preparation, planting, and cultivating is most closely related to the vegetation management method referred to as 'IVM.'
115310	Support activities for forestry is most closely related to the vegetation management method referred to as 'Mechanical Mowing.'
561730	Logging is most closely related to the vegetation management method referred to as 'Hand Cutting.'

It should be noted that "hand cutting" can be associated with both the IVM and non-IVM vegetation management strategies in that cut surface treatments are commonly used in IVM-based projects. The primary risk is in the act of cutting off a stem. Subsequent treatment of the freshly-cut stump with an herbicide would be unlikely to significantly increase the risk profile over that of simply cutting the stem. Nevertheless, hand cutting of incompatible stems represents an elevated risk over either herbicide application or mechanical mowing operations and is included here as a point of reference.

All safety-related metrics are expressed in terms of incidents per year per 200,000,000 worker hours. This is approximately equivalent[8] to the number of hours 100,000 full-time workers experience over the course of a year. Safety incident data are derived from the OSHA Form 300 (Log of Work-Related Injuries and Illnesses) that is reported to OSHA by employers.

Worker safety data can be grouped into two broad categories: injuries and fatalities. Both are considered in this report.

Work related injuries (ODI)

Data pertaining to non-fatal injuries are found in the OSHA Data Initiative (ODI). Three levels of severity of injury are reported.

DAWFII – Days Away From Work
DART – Days Away, Restricted, and Transfer
TCR – Total Case Rate

[8] 52 weeks x 40 hrs. per week = 2080 hrs./yr.

The availability of ODI data is somewhat inconsistent over the available 10-year time span (2002-2011). The values presented in Table 14 below are averages calculated from the data that are available and include between five and nine years of observations.

Table 14 Average incidence for non-fatal injuries for vegetation maintence work, per OSHA ODI

NAICS code	Treatment Method	DAFWII	DART	TCR
115112	Herbicide Applications	4.24	7.27	9.80
115310	Mechanical Mowing	1.03	3.02	3.81
561730	Hand Cutting	4.02	5.75	9.30

The TCR for injuries related to mechanized mowing is significantly (38%) less than that for the body of work selected as a surrogate for herbicide applications. This may be related to the use of large mowing equipment with enclosures or other safety features to protect the operator from injury, while herbicide applications involve a worker directly exposed to site conditions.

It is also important to consider exposure time. The incident rate metrics presented in Table 14 are expressed in terms of 100 person years (200,000 hrs.). A more relevant assessment considers the amount of time it takes to produce a unit area of vegetation maintenance work. An applicator on foot making a low volume foliar application with backpack sprayer is capable to treating as many as 5-6 acres per day under very low and ultra-low incompatible stem densities. In contrast the production rate for mechanized mowing is much less sensitive to stem density and may be in the range of 3-4 acres per day. The wide range of production rates makes direct comparison very difficult. That said, if an applicator treats twice the area mowed per day the difference between worker exposure rates for the two vegetation maintenance strategies would be smaller than the values presented in Table 14.

A survey of practitioners demonstrated no clear consensus on the relative risk of injury to spray crew workers as compared to mowing operations (Figure 4).

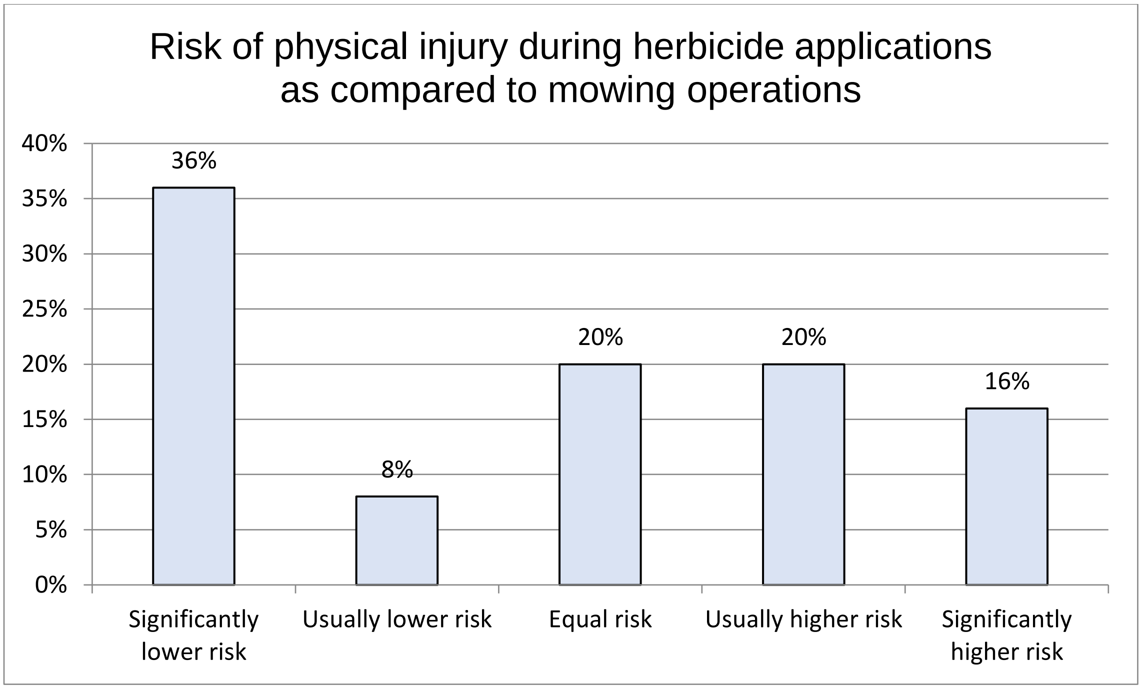

Figure 4 Practitioner rating of risk of injury to workers, herbicide applications vs. mechanized mowing.

Surprisingly, the TCR for hand cutting reported in Table 144 is similar to that of herbicide applications. This observation is inconsistent with the experience of practitioners, while practitioners perceive that herbicide applications represent a lower risk of physical injury.

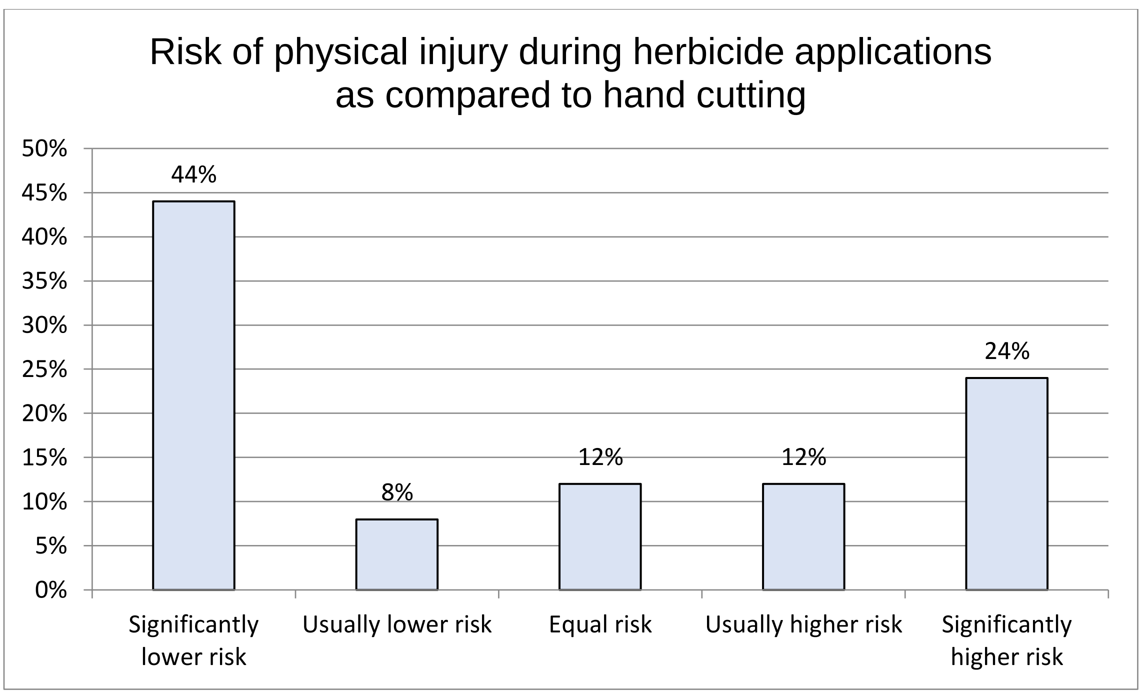

Figure 5 Perception of practitioners regarding the risk of injury to workers, herbicide application vs. hand cutting.

Work-related Fatalities (CFOI)

Data pertaining to fatal injuries are found in the Census of Fatal Occupational Injuries (CFOI). The values presented in Table 1515 below are averages calculated from the complete 15-year record.

Table 15 Average fatal incident rates for causes relevant to vegetation maintenance work, per OSHA CFOI, 2003-2017

NAICS code	Treatment Method	Falls, slips, trips	Exposure to harmful substances or environments	Contact with objects and equipment	Total
115112	Herbicide Applications	0.00	0.27	0.27	0.53
115310	Mechanical Mowing	0.00	0.00	0.21	0.21
561730	Hand Cutting	48.33	25.87	45.13	119.33

Three causes of fatalities were selected as most relevant to vegetation maintenance work. The difference in total incident rates between herbicide applications and mechanized mowing are similar to that reported for non-fatal injuries, with mechanized mowing being 40% lower.   In this case the incident rate for fatalities associated with hand cutting is substantially higher than for mowing or applying herbicides.

Public Safety

No literature was Identified that addresses this issue. Practitioners were asked to rank the risk of physical injury to members of the general public on ROW treated with herbicides as compared to mechanized mowing.

Table 16 High level summary of observations pertaining to public safety

Basis	Observation	IVM rating
Literature	No literature was identified	n.a.
Logic	The cut stubble that remains on a ROW following mowing may create a greater hazard.	+
Lore	A survey of practitioners specifically addresses worker safety issues.	++

Figure 6 demonstrates strong consensus that ROW managed using an IVM strategy presents less risk of injury to the public. This may be due to the cut stubble that results from mowing operations.

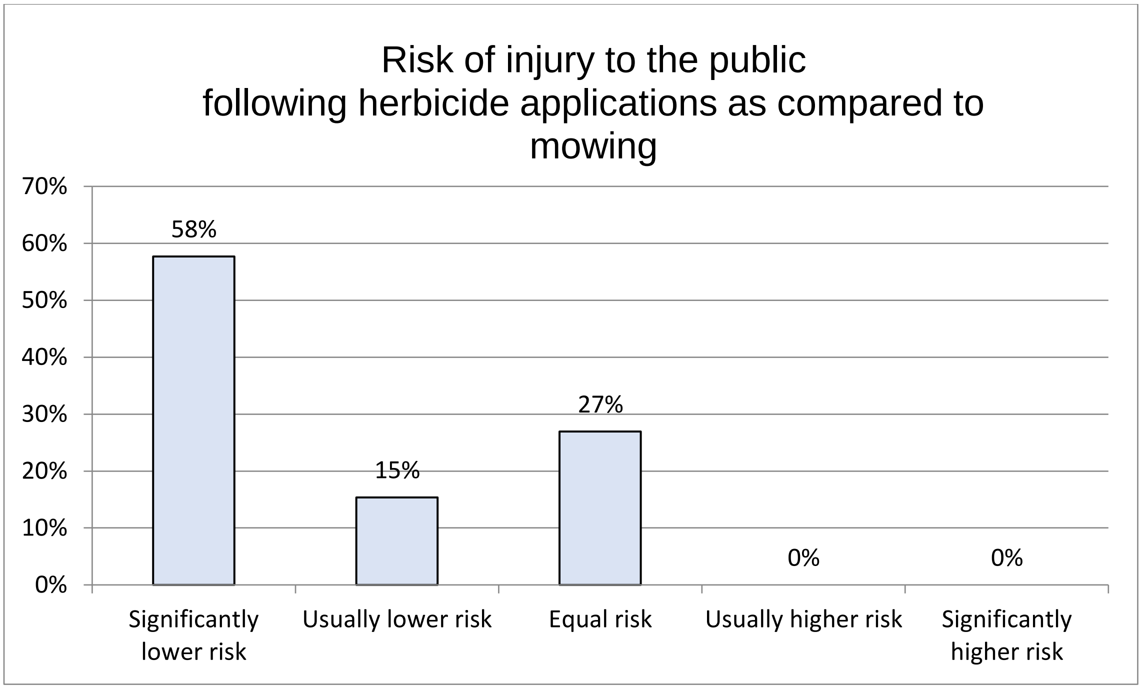

Figure 6 Perception of practitioners regarding risk of injury to the general public using the ROW following completion of vegetation maintenance tasks (herbicide application vs. mechanized mowing)

Operational Risks

Utilities maintain vegetation to reduce risk. Risk is a function of the likelihood of an event occurring and the consequences of said event. In this case, the event occurs when incompatible vegetation (tall growing trees) conflict with the primary use of the site.

Table 17 High-level summary of operational risk

Basis	Observation	IVM rating
Literature	No literature was identified comparing short term operational risk. Literature was identified that demonstrate that IVM reduces stem density and height over time.	Immediate n.a. Long Term +
Logic	The complete elimination of incompatible vegetation follow mowing is an immediate benefit in reducing risk. In the longer term, higher stem densities and heights associated with mowing may increase risk.	Immediate - Long term +
Lore	A survey of practitioners specifically addressed aspects of risk.	++

No literature was identified that made a direct comparison of reduced risk with the relative effectiveness of either an IVM-based vegetation management strategy, or one based on simple repeated cutting of incompatible vegetation.

There are two time frames to consider in applying logic to the question of the effectiveness of either vegetation management strategy:

1. At the time of and immediately after treatment
2. Longer term over the life of the ROW

The first question is whether there is a difference between either strategy in abating the risk of incompatible vegetation. A non-IVM strategy that relies on cutting/mowing all vegetation will immediately eliminate any tree-related risk and facilitate risk assessment following completion of the work. An IVM strategy that relies on the use of herbicides will also control tree-related risk, though the treated stems will remain and can make post-work risk assessment more difficult.

The second question considers risk over time. The literature and experience of practitioners establish that IVM is effective in establishing compatible plant communities that can suppress the re-establishment and growth of incompatible trees. The incompatible height action threshold for IVM treatments is also typically lower than for mowing operations. Both these factors logically establish that IVM would be more effective over the long term. The economic analysis showed that sites maintained by mechanical mowing had higher densities and heights of incompatible stems as well.

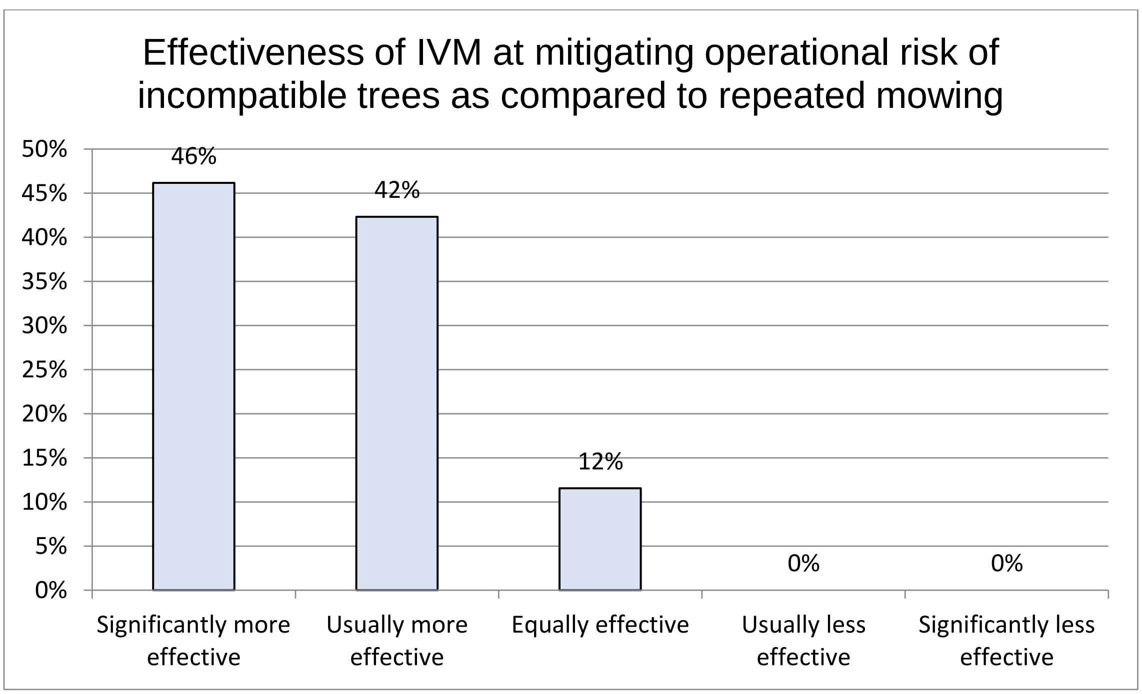

Figure 7 Perception of practitioners regarding the long-term effectiveness of vegetation management strategies in reducing tree-related risk.

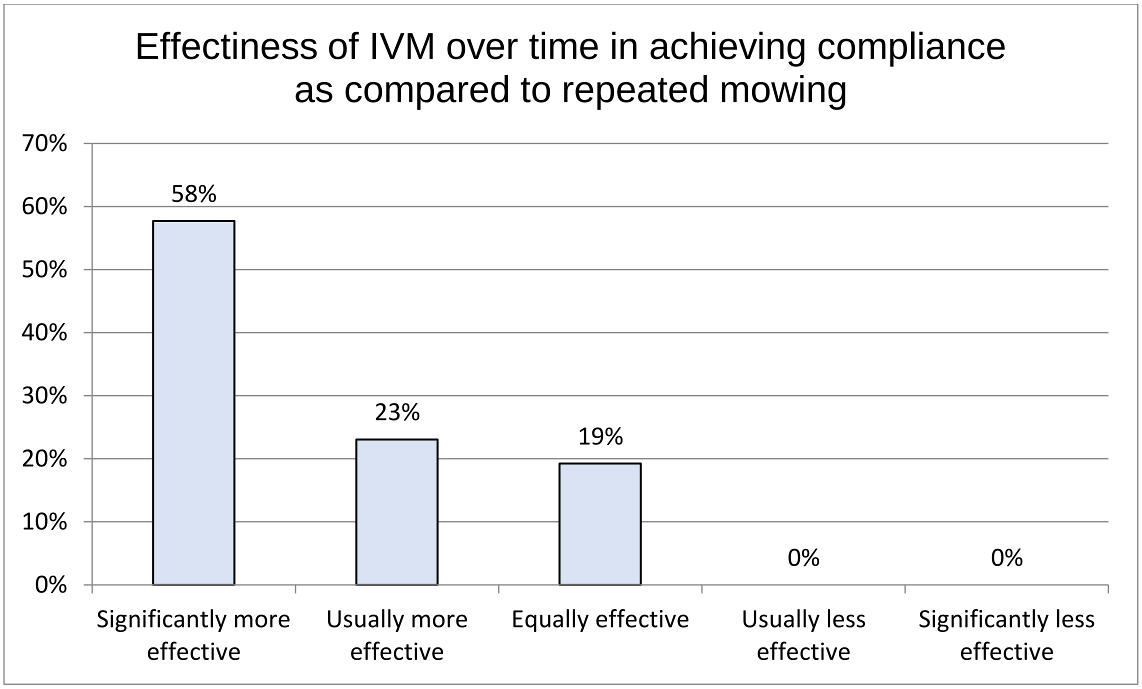

Figure 8 Perception of practitioners regarding the long-term effectiveness of vegetation management strategies in reducing likelihood of violating Minimum Vegetation Clearance Distances.

Perception and Acceptance

The acceptance of the property owners, general public, and regulatory agency staff to vegetation management work are important considerations. Favorable perception by stakeholders is a benefit to vegetation managers.

Table 18 High-level summary related the general perception of stakeholders.

Basis	Observation	IVM rating
Literature	No peer reviewed literature was identified comparing public perception of either vegetation management strategy.	n.a.
Logic	No logical arguments were considered.	n.a.
Lore	There are short-term concerns regarding application of herbicides but a favorable view of the results of IVM over time.	Immediate -- Long term ++

No peer-reviewed literature was identified that directly compared the perception of stakeholders to either an IVM-based vegetation management strategy, or one based on simple repeated cutting of incompatible vegetation in reducing risk. Non-technical articles are available regarding public concern over the use of herbicides.

There are two time frames to consider in applying logic to the question of the effectiveness of either vegetation management strategy:

1. At the time of and immediately after treatment
2. Longer term over the life of the ROW

The first question is whether there is a difference in public perception during and following a vegetation maintenance treatment. The non-IVM strategy relies on cutting/mowing all vegetation within the ROW. The IVM strategy relies on selective application of herbicides to treat and control incompatible trees. Practitioner experience clearly demonstrates (see Figure 9) that herbicide applications are viewed less favorably by landowners and members of the general public.

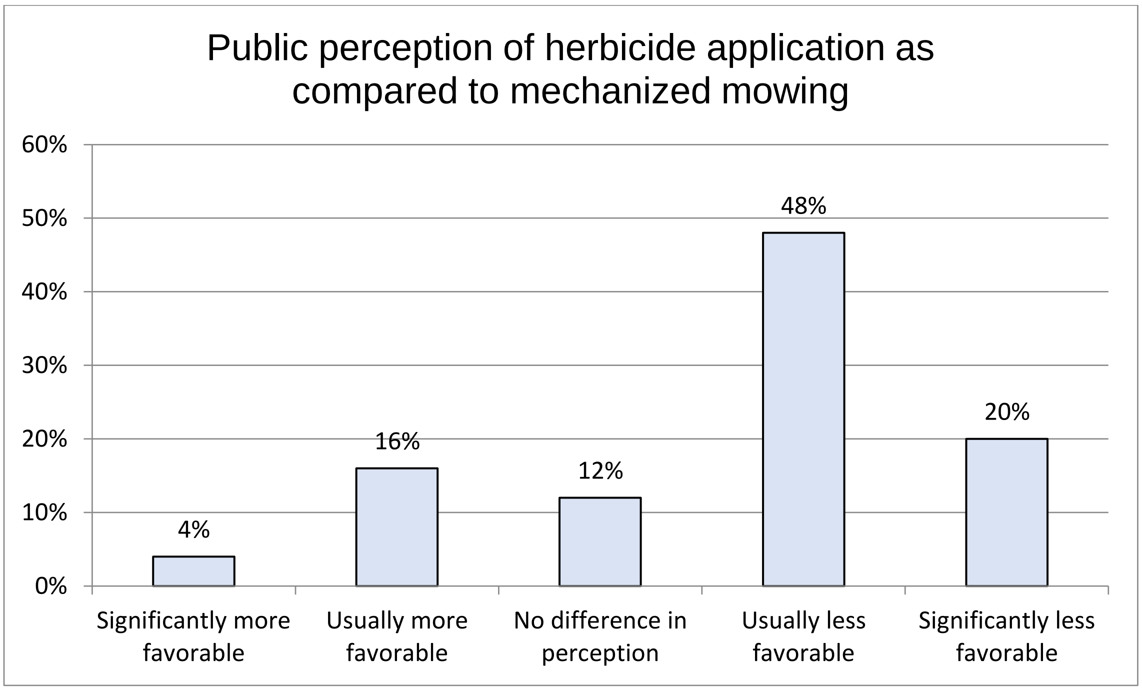

Figure 9 Perception of practitioners regarding public acceptance of a site treated with herbicides as compared to a site where vegetation has been mowed.

The second question considers stakeholder perception over time. As can be seen in Figure 10, there is a significant shift in public perception when a longer term is considered. While there is short term concern over the use of herbicide treatments to control incompatible vegetation, an IVM strategy is favorably perceived over the long term. This is likely due to the establishment and growth of compatible vegetation, which exerts biological control to suppress incompatible species.

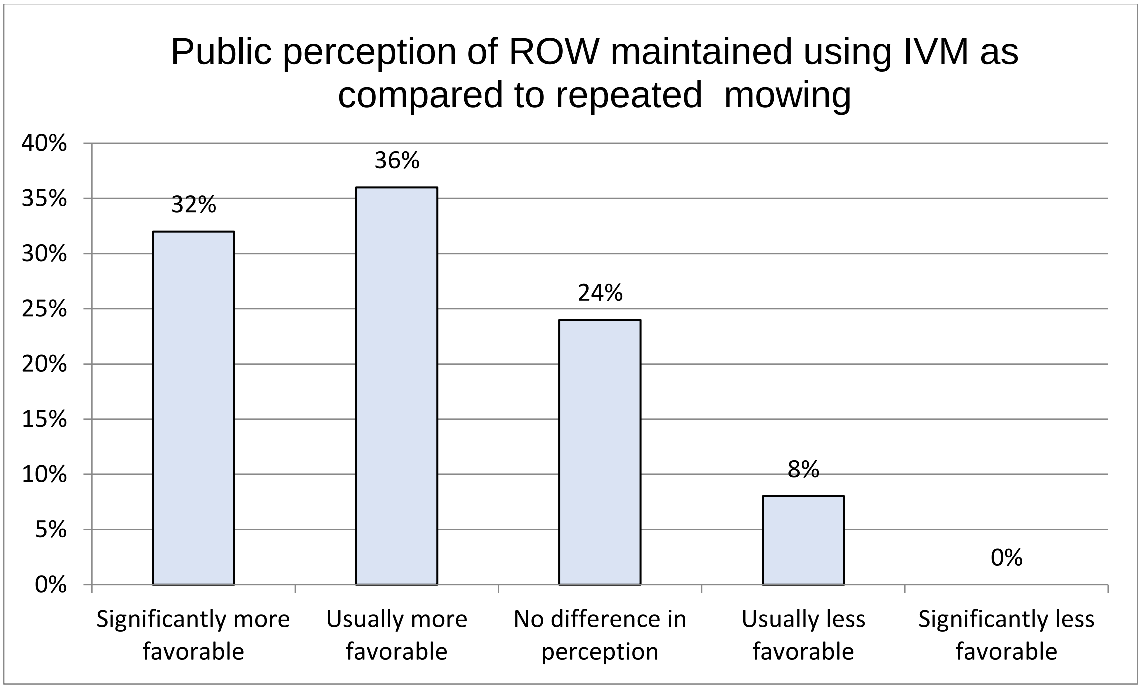

Figure 10 Perception of practitioners regarding public acceptance of vegetation management strategies.

Practitioners reported an even stronger positive perception by utility regulatory staff for an IVM-based vegetation management strategy and program. The support of IVM by regulatory staff is a significant benefit to utility vegetation managers.

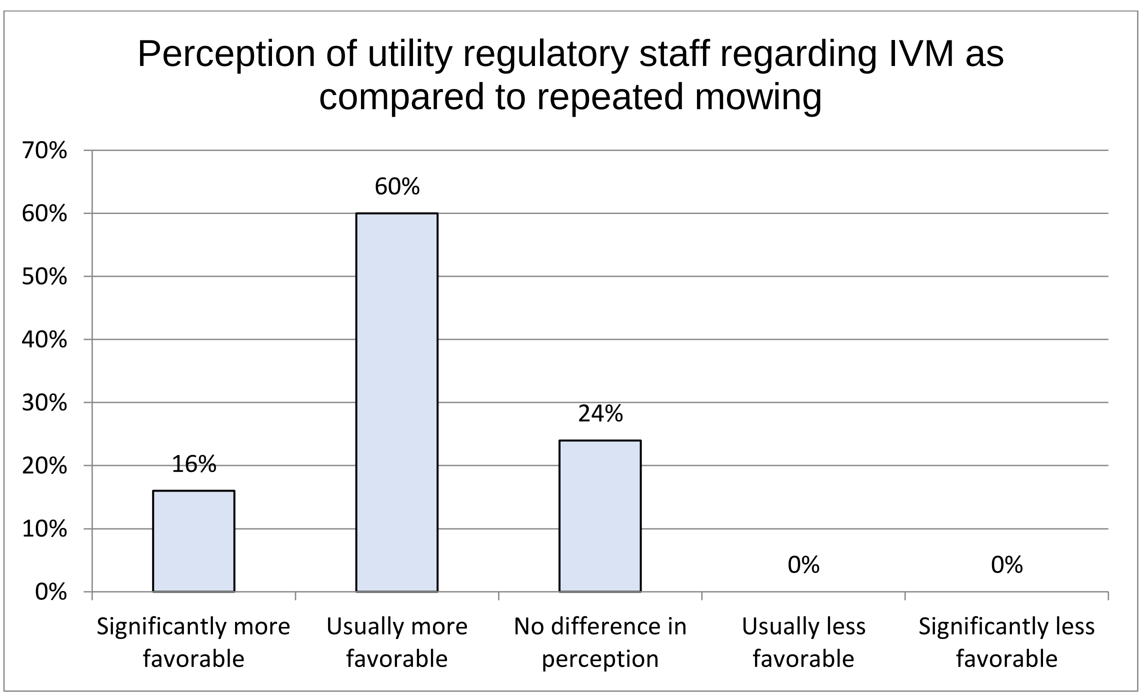

Figure 11 Perception of practitioners regarding the acceptance of regulatory agency staff of vegetation management strategies.

Recreational Use

While the primary use of a utility ROW is to provide for the transmission and distribution of electricity and/or natural gas, these long linear corridors can accommodate multiple uses unrelated to energy delivery.

Table 19 High-level summary of implications of vegetation management related to recreational use of the ROW

Basis	Observation	IVM rating
Literature	No literature comparing either vegetation management strategy affecting recreational use was identified.	n.a.
Logic	Less disturbance/disruption over time associated with IVM should benefit recreational uses longer term.	+
Lore	Fewer limitations were identified for an IVM-based strategy either immediately after or in the longer term	++

No peer-reviewed literature was identified that addressed the use of herbicides or mechanized mowing on common forms of recreation that occur on utility ROW.

Logic would dictate that there would be some limitations to recreational use of ROW while vegetation maintenance treatments were being carried out. The use of heavy mechanical mowing machines and the possibility of portions of stems becoming projectiles logically limits access by the public during mowing operations. The cut stubble and residue that remains on the site following mowing can also create a hazard that may limit some recreational uses. While the herbicides in use in utility IVM programs do not carry labeled regulatory restrictions pertaining to site re-entry, in some cases local requirements include posting a site. While this isn't technically a restriction, it may be perceived as such and self-restrict some users from making recreational use of a ROW following treatment.

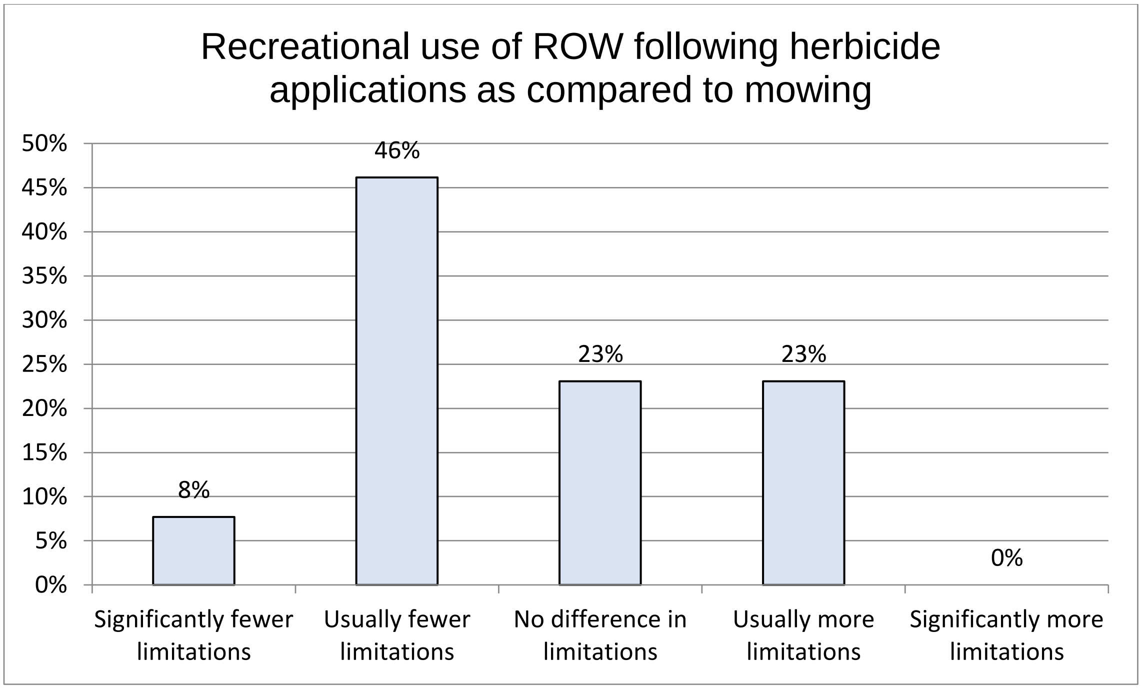

Figure 12 Perception of practitioners regarding the short-term impact of vegetation maintenance tasks on recreational use of the ROW.

In the longer term, a ROW maintained under an IVM would logically have fewer recreational restrictions. This would be due to the development of a stable community of compatible plants. As a result, fewer incompatible stems would require control, reducing the amount of disturbance associated with each subsequent treatment. In contrast, the non-IVM strategy would rely on repeated mowing, creating the same level of disturbance (and limitations to recreational uses) with each treatment.

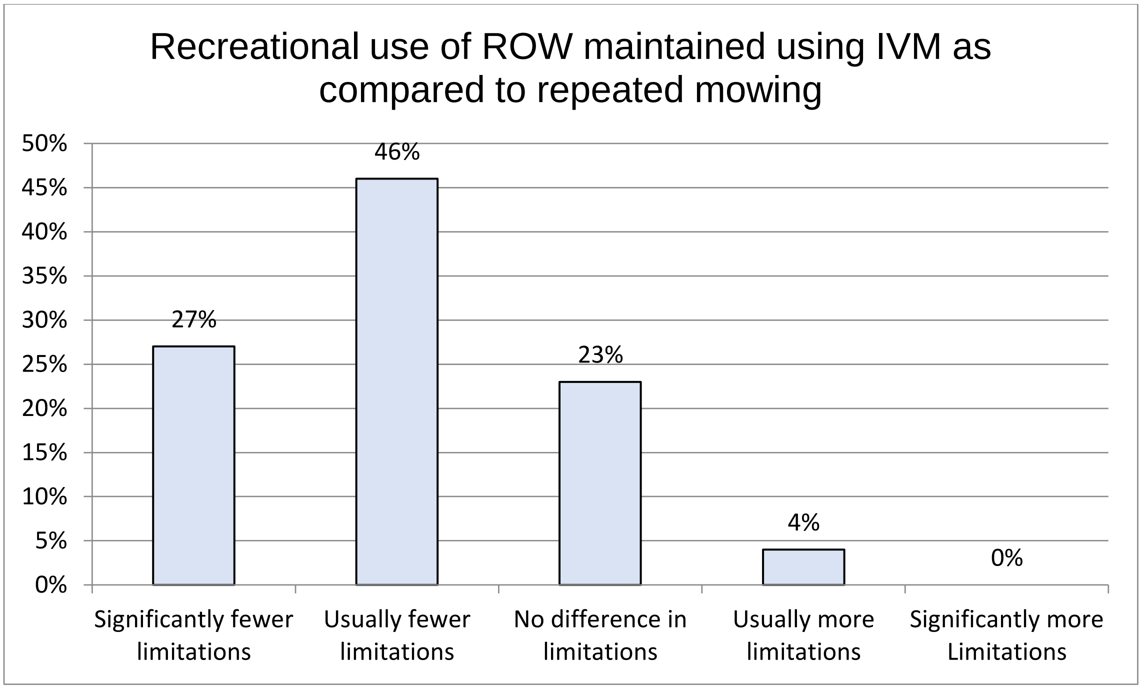

Figure 13 Perception of practitioners regarding the long-term impact of vegetation maintenance tasks on recreational use of the ROW.

Aesthetic impact

Vegetation maintenance work to control incompatible species of tall growing trees can have a dramatic visual impact on a site following treatment, as can changes within the ROW corridor over time.

Table 20 High-level summary of the visual impact of vegetation management activities

Basis	Observation	IVM rating
Literature	No literature comparing either vegetation management strategy in terms of visual impact was identified.	n.a.
Logic	The short-term aesthetic impact of either strategy is potentially significant but different in character. Changes in ROW vegetation and decreasing maintenance task intensity associated with IVM reduce the aesthetic impact.	Immediate 0 Long term ++
Lore	Practitioner survey suggests little short-term difference, and strong advantage of IVM strategy over time.	Immediate 0 Long term ++

No peer reviewed literature was identified that addressed the short- or long-term visual impact of herbicide application or mechanized mowing within a ROW.

There are two time frames to consider in applying logic to the question of the visual impacts associated with either vegetation management strategy:

1. At the time of and immediately after treatment
2. Longer term over the life of the ROW

The first question focuses on the aesthetic impact associated with either treatment by mowing or herbicide treatment. Logic would suggest that the magnitude of the impact of vegetation maintenance work would vary with the height and density of the existing vegetation, and the magnitude of change following treatment. Mechanized mowing would cut all vegetation within a heavily stocked ROW. While an IVM approach would specifically target incompatible stems and preserve compatible vegetation, a ROW stocked with a high density of tall incompatible stems would also appear highly altered. Another point to consider is that a mowed ROW may appear as more aesthetically acceptable when compared to the potential "brown-out" associated with herbicide applications. Yet the visual impact of a herbicide can be mitigated to some degree by seasonal timing.

Practitioners were divided on their rating of the immediate visual impact of either VM strategy.

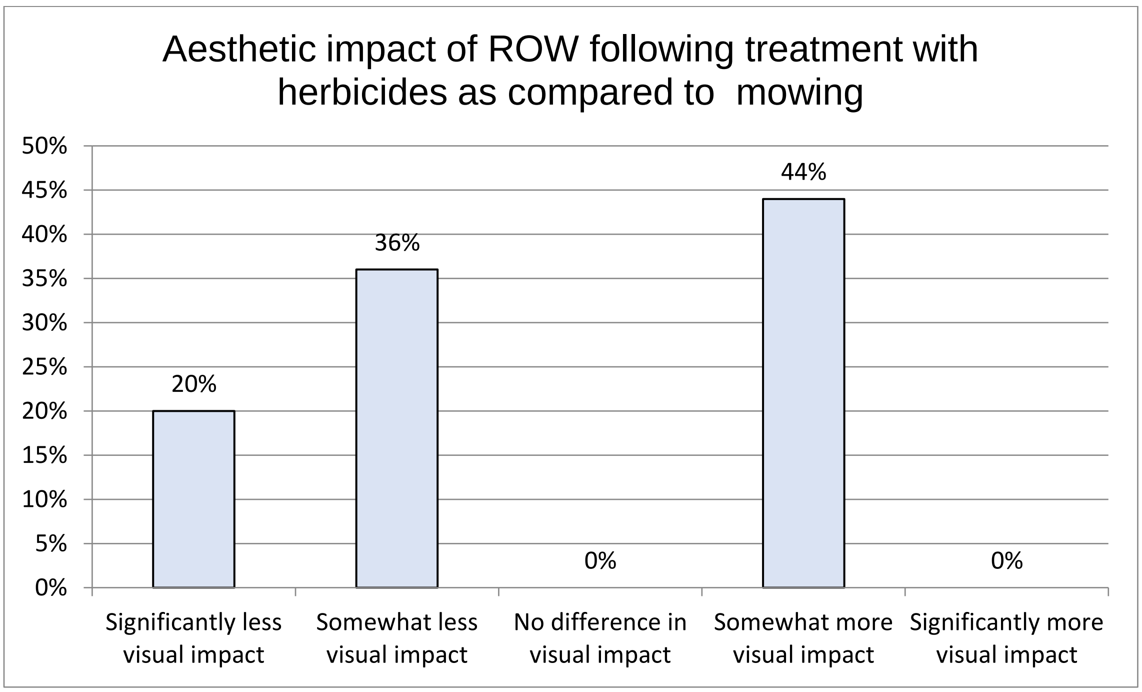

Figure 14 Perception of practitioners regarding the visual impact of vegetation maintenance tasks.

Longer term changes to ROW vegetation under an IVM strategy logically reduce the aesthetic impact of subsequent vegetation maintence work. This is due to the establishment of a compatible plant cover and the corresponding suppression of incompatible tall growing trees. Fewer incompatible stems allows the use of increasingly selective herbicide application methods, including treatments such as low volume basal applications that can be carried out during the dormant season, dramatically reducing their visual impact. This is in contrast to recurrent mowing, which would involve repeatedly mowing heavily stocked ROW vegetation, radically altering the site visually each time mowing occurs.

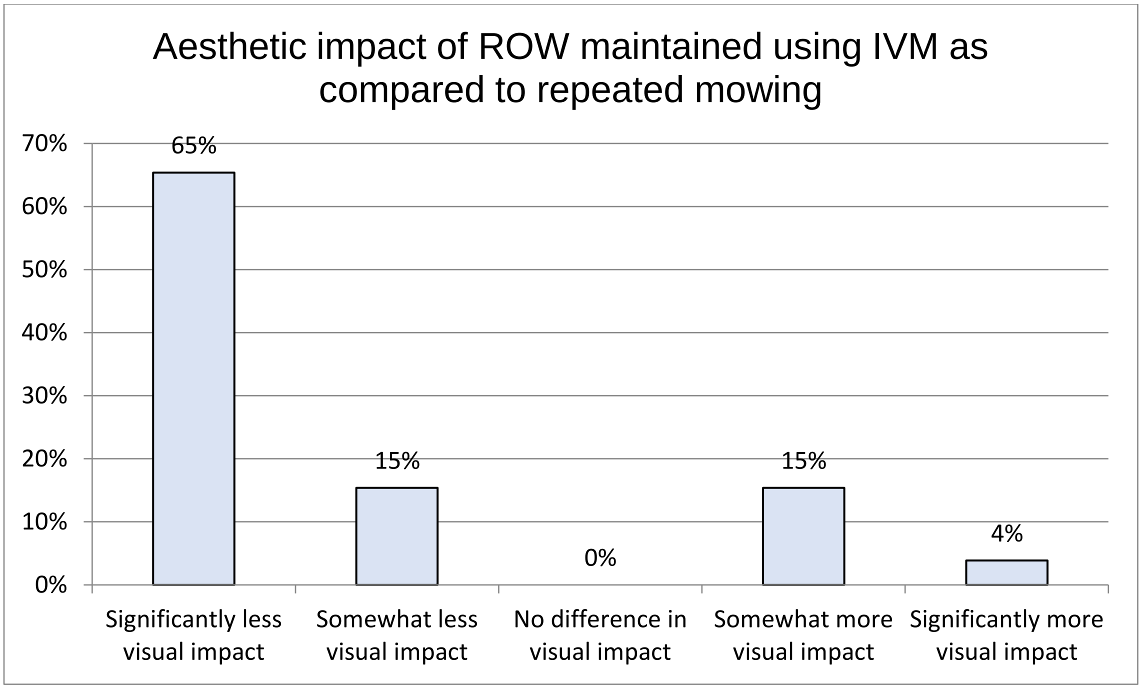

Figure 15 Perception of practitioners regarding the long-term visual impact of vegetation management strategies

Public nuisance

Public nuisance used in this context refers to the potential for adverse impact from factors such as noise and odors associated with ROW vegetation maintenance work.

Table 21 High-level summary of public nuisance-related issues.

Basis	Observation	IVM rating
Literature	No literature pertaining to adverse noise or odor associated with either mechanized mowing or herbicide applications was identified.	n.a.
Logic	Logic suggests vegetation maintenance tasks associated with both vegetation maintenance strategies have only limited potential to create significant public nuisance. IVM treatments at low incompatible stem densities would present little or no nuisance-related concerns.	+
Lore	Practitioners strongly believe IVM treatments are less likely of create any public nuisance concerns.	++

No literature was identified that addressed any noise or odor issues associated with either the use of herbicides or mechanized mowing on utility ROW.

Logic would suggest that the amount of physical disruption and noise created during a heavy mechanized mowing operation could be a nuisance in some cases. However, this is a very short-term effect that can be managed through work-hour restrictions. Odors associated with herbicide applications have the potential to become a concern, however the herbicide formulations currently in use have very little odor, and what little odor is present does not persist.

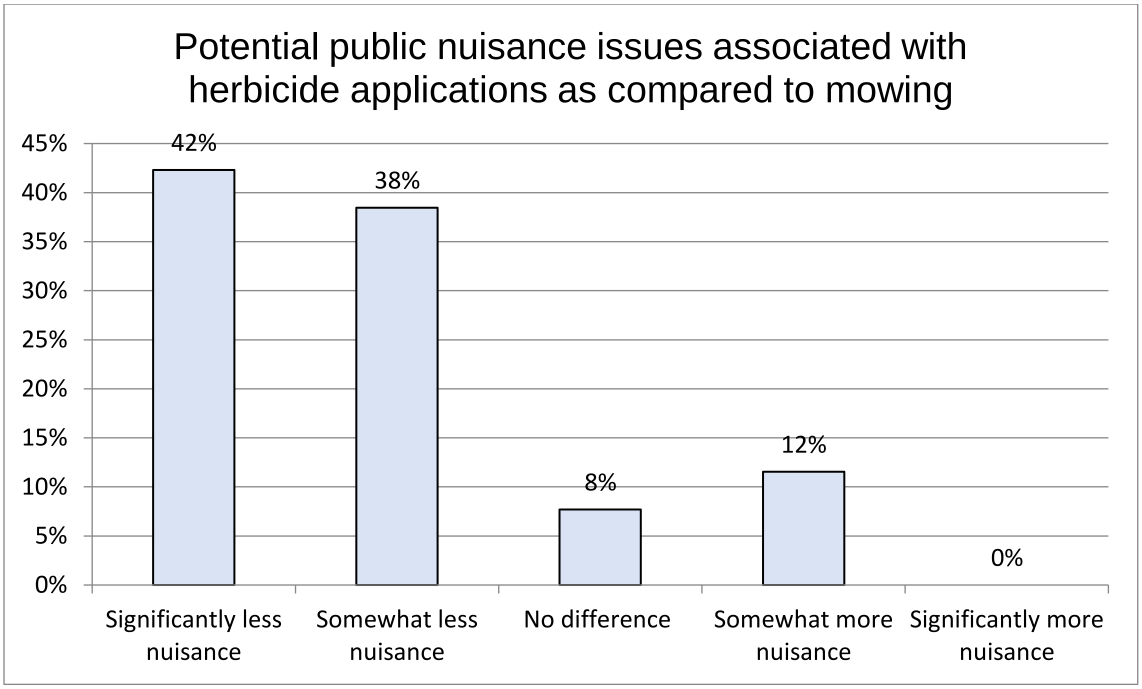

Figure 16 Perception of practitioners regarding the short-term impact of vegetation maintenance tasks in terms of creating a public nuisance (e.g. excess noise, odors, etc.)

While the logical assessment suggested only small differences, experienced practitioners strongly rated herbicide applications as having less potential for an adverse impact in terms of creating public nuisance.

Site Disturbance

Utilities manage ROW vegetation in an effort to assure the safe and reliable operation of the energy delivery system free of interference by incompatible species of trees. This is accomplished through the use of a variety of vegetation maintenance treatment methods, all of which create some level of disturbance on a site. As used here, the term ‘disturbance’ refers to impacts other than changes in vegetative cover.

Table 22 High-level summary of site disturbance associated with vegetation management

Basis	Observation	IVM rating
Literature	Literature address site disturbance in the context of water quality, and is presented in the next section of this report.	+
Logic	Potential disturbance associated with herbicide applications at the time of treatment and over time is significantly less with an IVM strategy.	++
Lore	Practitioners rated herbicide applications as causing considerably less site disturbance.	++

There are two time frames to consider in applying logic to the question of the visual impacts associated with either vegetation management strategy:

1. At the time of and immediately after treatment
2. Longer term over the life of the ROW

The first question focuses on the level of disturbance at the time of treatment. Mechanized mowing creates a very high level of disturbance. All vegetation within a ROW corridor is typically severed above ground level leaving shattered cut stubble and macerated portions of cut stems on the site. The size of mechanized mowing equipment is also a consideration. Smaller diameter and shorter stems may be mown using smaller machines. Heavy density vegetation including bigger and taller stems requires larger machinery which may be on rubber tires or tracked machines. Soil compaction and disturbance can be a concern with larger equipment and when the cutting head comes in contact with the soil surface.

The IVM-based management strategy makes use of a variety of maintenance treatment options including mowing. However, it relies predominantly on the selective application of herbicides. Herbicide application methods generally do not require the use of large machinery, and in many cases rely on an applicator on foot carrying a backpack. Logically speaking, herbicide applications have the potential to create much less site disturbance. The experience of practitioners confirms this logical conclusion.

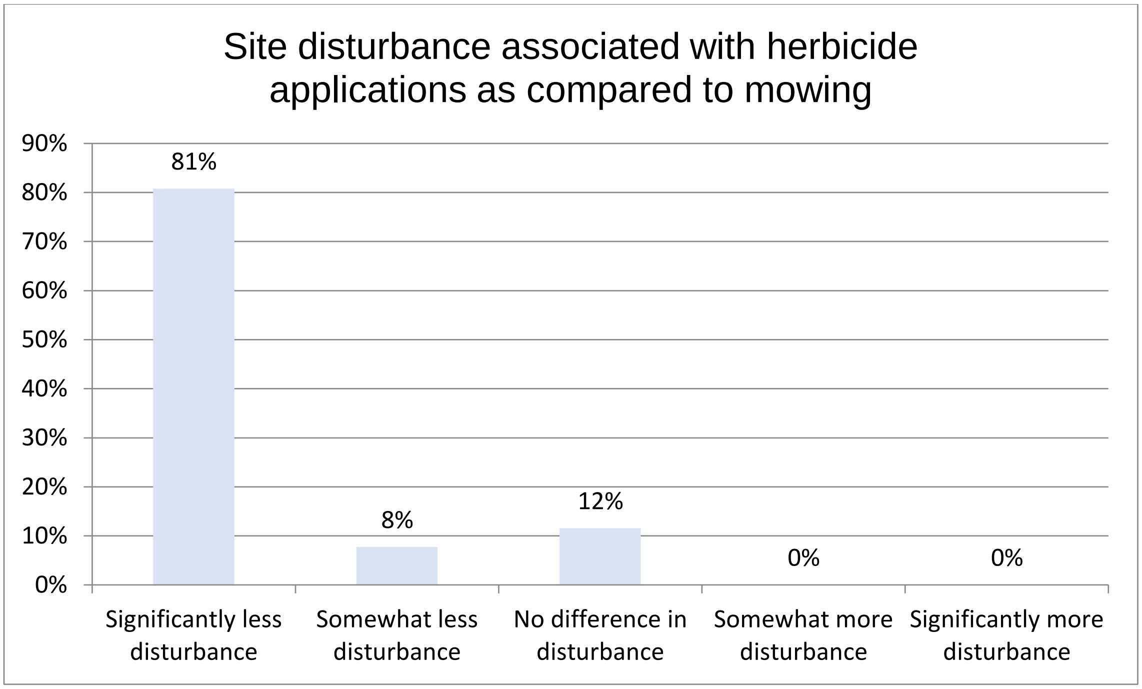

Figure 17 Perception of practitioners regarding the short-term impact of vegetation maintenance tasks on a site.

A similar logic applies to a longer-term assessment of disturbance as conditions on the ROW change. The non-IVM strategy relies on repeated mowing. While repeated mowing has been shown to reduce stem density some degree over time, the non-selective basis of mowing essentially recreates a similar level of severe disturbance with each treatment. This is in contrast to the IVM strategy that relies on the establishment of compatible plant communities that exert biological control through competition, suppressing the re-invasion and growth of incompatible plants. Herbicide application methods become increasingly selective with each subsequent treatment, resulting in further reductions in site disturbance over the longer term.

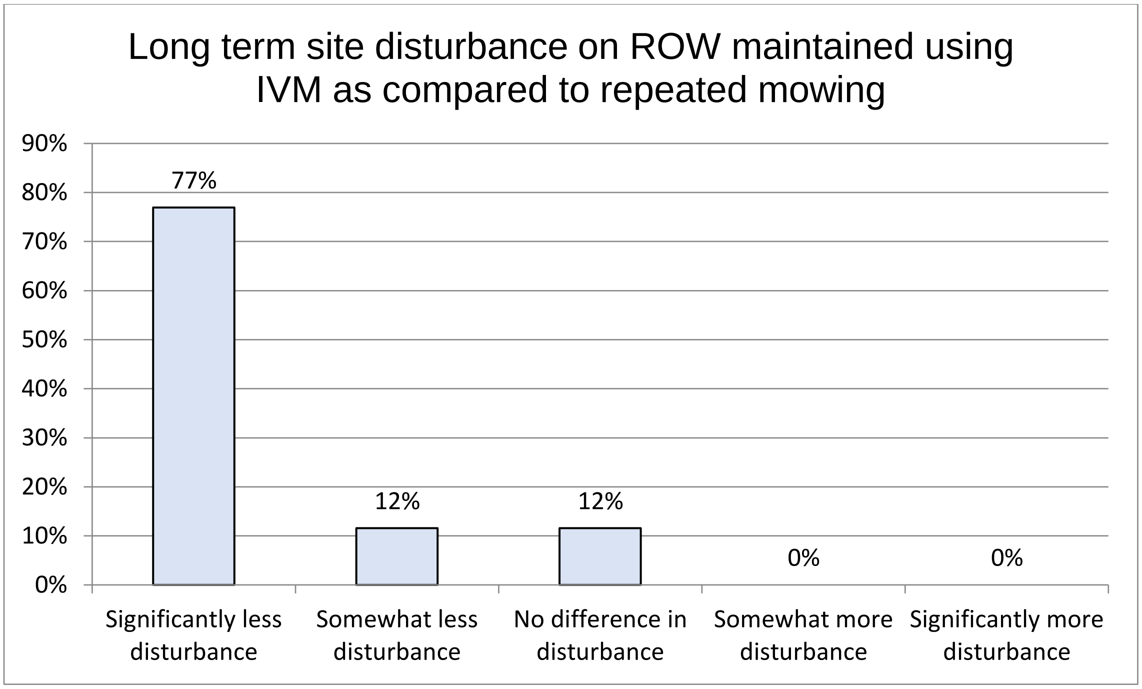

Figure 18 Perception of practitioners regarding the long-term impact of vegetation management strategies on a site.

Water quality

Utility ROW traverse a wide range of land cover types including wetlands, riparian areas associated with water courses and areas of open water. ROW vegetation maintenance work has the potential to impact water quality. The risk of adverse impact is mitigated through the use of appropriate set-backs, buffers, and choice in maintenance methods. This study assumes that appropriate protective measures are in place and meet requirements. It also assumes appropriate labeled use of registered herbicides.

Table 23 High-level summary of potential impact of vegetating management in water quality

Basis	Observation	IVM rating
Literature	Limited reference to risk of soil disturbance and compaction with heavy mowing equipment.	+
Logic	Soil disturbance associated with mechanized mowing is significantly greater as compared to herbicide application. Soil disturbance is a potential source of sedimentation in water courses.	++
Lore	Practitioners rated IVM-related maintenance tasks and longer-term management as having significantly less potential to impact water quality.	++

There are two time frames to consider in applying logic to the question of the visual impacts associated with either vegetation management strategy:

1. At the time of and immediately after treatment
2. Longer term over the life of the ROW

The first question focuses on the potential for a vegetation maintenance treatment to have an adverse impact on water quality. While hand cutting or girdling could be used on the most sensitive sites, the non-IVM strategy basically relies on mechanized mowing. The amount of site disturbance associated with large mechanized equipment has been discussed previously. This has the potential to increase sediment loads and increase water turbidity. The other factor to consider would be the unintentional release of petroleum-based fluids such as fuel, lubricants, and hydraulic fluid.

Mechanical mowing treatments carry the risk of excessive soil disturbance that can facilitate the invasion of non-native plants and soil compaction (Menges 201). This study[9] noted that mechanical treatments should be used in conjunction with herbicides to achieve desired vegetation structural changes where fire cannot be safely applied to the landscape.

The IVM strategy relies on herbicide applications. While herbicides could be excluded from use on the sites that would be the most sensitive, this assessment considers the general use of selective foliar and basal applications. As previously described, most of the herbicide application methods used rely on smaller and in some cases very little equipment, with only minimal potential to create soil disturbance and any sediment that could be contributed to a water course. Provided that proper practices are employed, there is very little chance of direct deposition of an herbicide into a body of water. The possibility of movement of an herbicide into surface or ground water is low.

An assessment of the potential impact of either vegetation management strategy on water quality logically focuses on the potential for soil disturbance resulting in increased sedimentation. The potential for soil disturbance during mechanized mowing associated with the equipment used or directly by the cutting head is significantly greater than that associated with herbicide applications. The potential of petroleum product being a significant concern is very low assuming that equipment is well maintained. Failure of mechanized mowing and herbicide application equipment remains a possibility, but there is no compelling argument to consider there to be a significant difference in failure rates.

The experience of practitioners presented in Figure 19 confirms the conclusion that the vegetation maintenance methods used in an IVM strategy have substantially less potential for an adverse impact on water quality than does mechanized mowing.

[9] Menges ES, Gordon DR. 2010. Should mechanical treatments and herbicides be used as fire surrogates to manage Florida's uplands? A review. Florida Scientist 73(2):147-174.

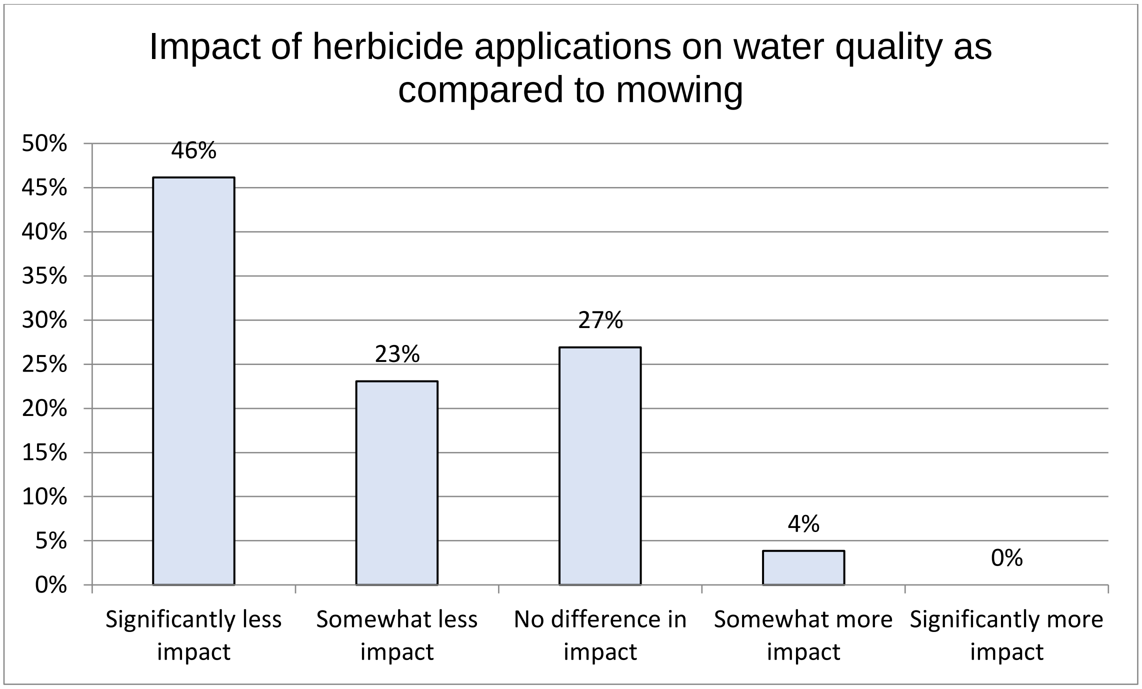

Figure 19 Perception of practitioners regarding the short-term impact of vegetation maintenance tasks on water quality.

An assessment of the longer-term impact on water quality of either VM strategy is similarly based on the amount of site and soil disturbance associated with that strategy. The non-IVM strategy relies on repeated mowing. The same amount of disturbance is repeated every time a site is mowed. In contrast, the potential for site disturbance associated with the IVM strategy decreases over time as herbicide application methods become increasingly selective with each subsequent treatment.

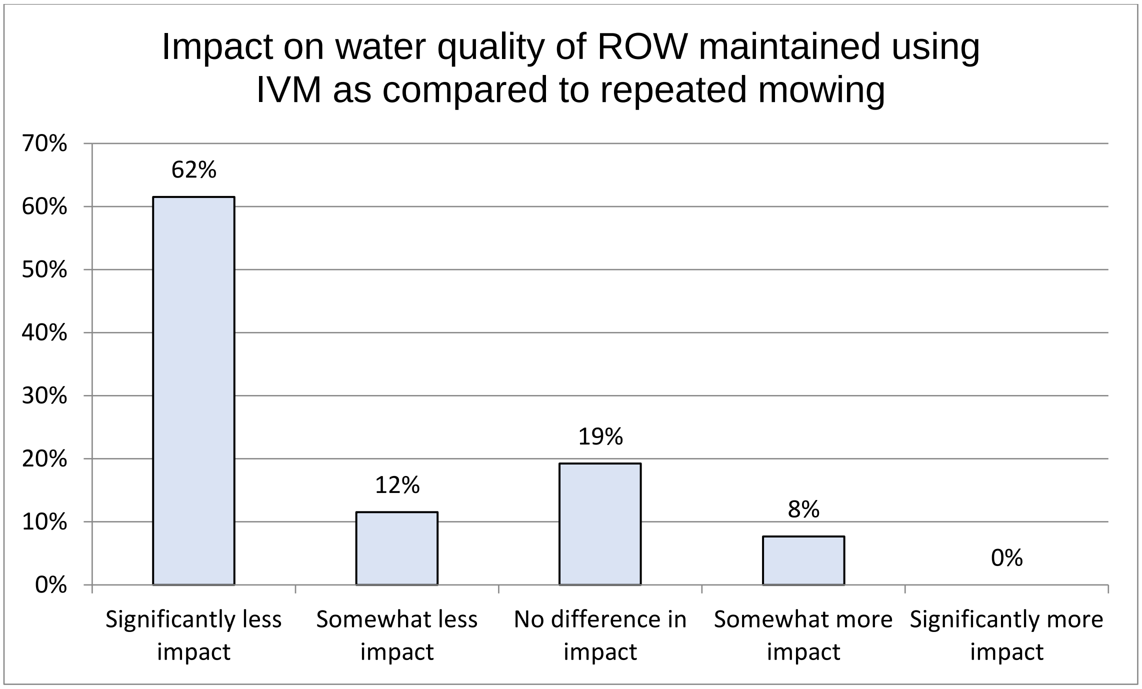

Figure 20 Perception of practitioners regarding the long-term impact of vegetation management strategies on water quality.

Practitioners rated the IVM-based strategy as having significantly less impact on water quality over time.

Vegetation

Differences in the response of incompatible plants under IVM-based and non-IVM vegetation management strategies have previously been described as a benefit in terms of an avoided cost. These differences may be in part be based on the competitive pressure that compatible plant communities exert on incompatible trees. However, in this case the benefit being considered is framed in the context of IVM:

> *"The reason for IVM is to create, promote, and conserve sustainable plant communities that are compatible with the intended use of the site, and manage incompatible plants that may conflict with the intended use of the site[10]".*

The focus of this assessment is the effectiveness of either strategy to creating, promoting, and conserving communities of compatible plants.

Table 24 Summary of observations related to the vegetation-related benefits of IVM-based strategy

Basis	Observation	IVM rating
Literature	Literature directly related to development of compatible plant communities following either VM strategy is largely lacking. However, the literature did support development of density and height re-growth projections that demonstrate IVM is more effective in reducing incompatible stem density and, to a lesser extent, suppressing height growth, which may be related to the competitive success of well-established compatible plant communities in suppressing re-invasion by incompatible trees.	+
Logic	Herbicide applications are more effective at eliminating rather than simply controlling the above ground portions of incompatible plants, which should favor development of compatible plant communities. Mowing operations have the potential create more site disturbance, damaging existing compatible plants and effectively "preparing" a seedbed that increases the likelihood of re-invasion of incompatible tree species.	++
Lore	Practitioners strongly agree that IVM is significantly more effective in promoting compatible plant communities.	++

Intuitively, selective treatment favoring compatible species would logically preserve the favored species. Selective herbicide treatments were found[11] to result in higher compatible, native plant species richness than mowing sites. No significant difference was found in total plant species richness between herbicide or mechanical treatments[12]. Herbicides were shown[13] to have a greater impact on relative species

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[10] ANSI A300 Part 7 (2018), §70.2

[11] Mahan, C.. Floral and Faunal Research on Utility Rights-of-Way at Game Lands 33 and Green Lane Research ad Demonstrations Areas, Penn State University, Altona, PA. 2018

[12] Yahner RH, Yahner RT, Ross BD. 2008. Plant species richness on a transmission line right-of-way in southeastern PA, U.S. using integrated vegetation management. Arboriculture Urban For. 34(4):238-244.

[13] Fortier J, Messier C. 2006. Are chemical or mechanical treatments more sustainable for forest vegetation management in the context of the TRIAD. For. Chron. 82(6):806-818.

dominance than on species composition and diversity. A study of mechanical mulching to reduce crown fire hazard in three pine forest types in Colorado reported[14] an increase in understory biodiversity and coverage in the long term. That study did not include the use of herbicides.

Cutting alone was not a adequate treatment method to control undesirable tree species on power-line corridors in Northern Kentucky. Stump sprouting is too prevalent after cutting/mowing, and sprouts out-compete seedlings of desirable species leading to the increased maintenance of the corridor[15]. Repeated cutting on power-line corridors results in an increased number of stems of undesirable tree species. Power-line corridors in Kentucky need additional treatment methods to efficiently control undesirable tree species.

A study[16] of site preparation in forestry found that mechanical site preparation did not affect competing vegetation. In this case the vegetation that competes with the establishment of crop trees in a forest would be compatible vegetation within a ROW, having the ability to suppress these same species of tall growing forest trees that are incompatible with electric and gas pipeline ROW. A study[17] of simple cutting of a woody shrub (Amur honeysuckle) was shown to lead to an increase in that specie coverage due to re-sprouting, and native plant seedling survival was shown to be significantly higher in herbicide plots than in untreated plots.

Ecological mechanisms can be useful in evaluating the development of compatible plant communities under both IVM and non-IVM maintenance strategies. ROW plant communities, regardless of treatment, do not constantly occupy 100 percent of the available space. Even small openings in these areas create opportunities for re-invasion by incompatible trees. The openings and disturbance created by mowing are typically much larger than those associated with herbicide applications. This is a function of selectivity in that herbicide applications can target individual incompatible stems, whereas mechanized mowing is less so, and manual cutting can be as selective as herbicide applications.

All life forms of compatible plants (e.g., grasses, ferns, herbs, shrubs) can suppress incompatible trees through interference (competition) and by providing habitat for seed and seedling predators. The intensity of competition is similar amongst a wide variety of plant cover types. Compatible plant communities' competitive abilities apparently differ in their influence on trees mainly by the duration of interference effects, rather than intensity, which means that shrubs can be considered better competitors for trees because they are taller than other compatible plant life forms.

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[14] Fornwalt PJ, Rocca ME, Battaglia MA, Rhoades CC, Ryan MG. 2017. Mulching fuels treatments promote understory plant communities in three Colorado, USA, coniferous forest types. For. Ecol. Management 385:214-224.

[15] Luken JO, Hinton AC, Baker DG. 1991. Assessment of frequent cutting as a plant-community management technique in power-line corridors. Environ. Management 15:381-388.

[16] Thiffault N, Roy V. 2011. Living without herbicides in Quebec (Canada): historical context, current strategy, research and challenges in forest vegetation management. Eur. J. For. Res. 130:17-133.

[17] Hartman KM, McCarthy BC. 2004. Restoration of a forest understory after the removal of an invasive shrub, Amur honeysuckle. Restor. Ecol. 12(2):154-165.

- While the amount of disturbance to compatible ROW plant communities does vary significantly among different herbicide treatments, tree invasion patterns are not different amongst many common ROW vegetation management chemical treatments.
- Compatible plant community cover is changed with different herbicide treatment schemes. Broadcast application of growth-regulator herbicides can result in more forbs and graminoids than selective treatments, and selective treatments can result in communities with significantly more woody shrubs than non-selective treatments.
- Absolute reduction in tree density with shrub cover compared to other life forms is expected to be somewhat low, yet ecologically and operationally meaningful with hundreds fewer trees per hectare produced by shrub cover compared to other life forms.
- Mechanical treatments – hand cutting and mowing – consistently result in high abundance vegetative regeneration responses (stump sprouting, root suckering) from treated hardwood tree stems.
- Mechanical treatments on sites dominated by conifers may not produce the high stem density upon re-growth as observed with hardwood species.

Incompatible Tree Density

Data compiled from the literature augmented the available unpublished data. These data were organized into herbicide and non-herbicide mechanical mowing treatments, and further subdivided into a conversion phase following initial clearing and a maintenance phase when a near-steady state phase was achieved. Herbicide treatments include any VM effort that used herbicides to control incompatible trees. Mechanical mowing treatments were defined as any VM effort that used hand cutting or mowing to control incompatible trees. Treatments that combined mechanical with chemical (e.g., cut stump, cut stubble) were included with the IVM data.

Phases of management were based on expected and observed patterns of tree density change over time with treatments. Studies and the experience of practitioners have shown that the number of trees on ROW managed with herbicides decreases after initial clearing in an exponential or geometric manner. Even mechanical treatments, and particularly mowing, can be expected to have a significant decrease in incompatible tree density after initial clearing before producing relatively constant high density of trees over time. A break point of 10 years was chosen as defining when the conversion phase ends (that period when the pre-ROW vegetation is converted to a somewhat stable cover of compatible plants with relatively low densities of trees) and the maintenance phase begins (that period when the ROW vegetation is maintained in a quasi-steady state plant community).

Production function curves used in an earlier investigation[18] were used in this study, and clearly demonstrate a difference between the two vegetation management strategies in terms of their respective ability to reduce the density of incompatible stems.

[18] Goodfellow, J.W., C.A. Nowak, and J.E Wagner. Vegetation Management Business Cost Benefit of Herbicide Use. Centre for Energy Advancement through Technological Innovation (CEATI), Montreal. 2017

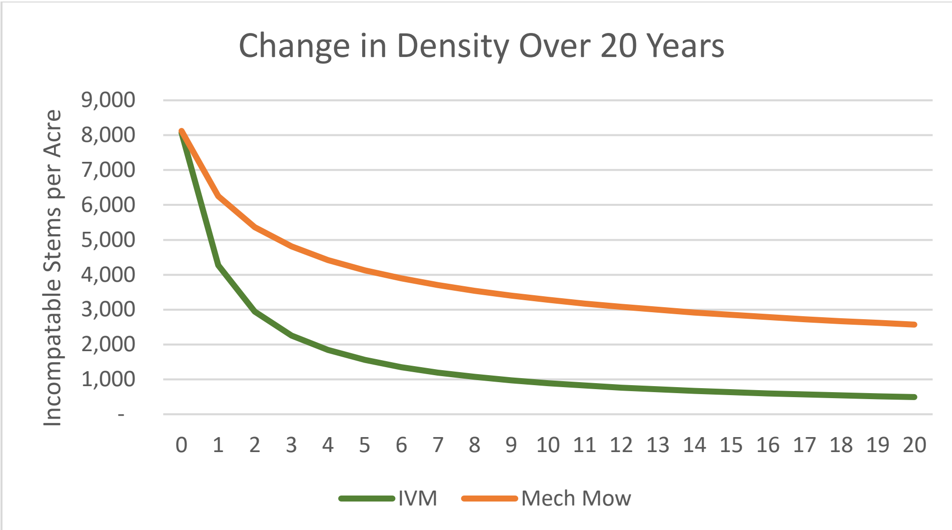

Figure 21 Production function predicting changes in density of incompatible trees over time under IVM-based and non-IVM vegetation management strategies over time.

Incompatible Tree Height

The height growth production function used in the earlier study was limited by a lack of published literature data. Height data from the literature was supplemented with unpublished data. During that project, a request was made of selected ROW industry representatives for unpublished data, resulting in two key data sets that were critical to developing and confirming height growth rates. The height growth response production functions were updated for this project and reflect the differences in initial growth response. The IVM-based curve assumes that incompatible stems present originate at the surface of the soil from seed and develop at a rate typical of seedlings. The non-IVM curve assumes that incompatible stems originate as vegetative reproduction from cut stems above the surface of the soil and initially exhibit an exaggerated re-growth response rate, and then return to the projected average height growth rates for seed- and vegetative-origin trees on managed ROWs at 0.6 and 1.1 meters per year (2.0 and 3.6 feet per year), respectively.

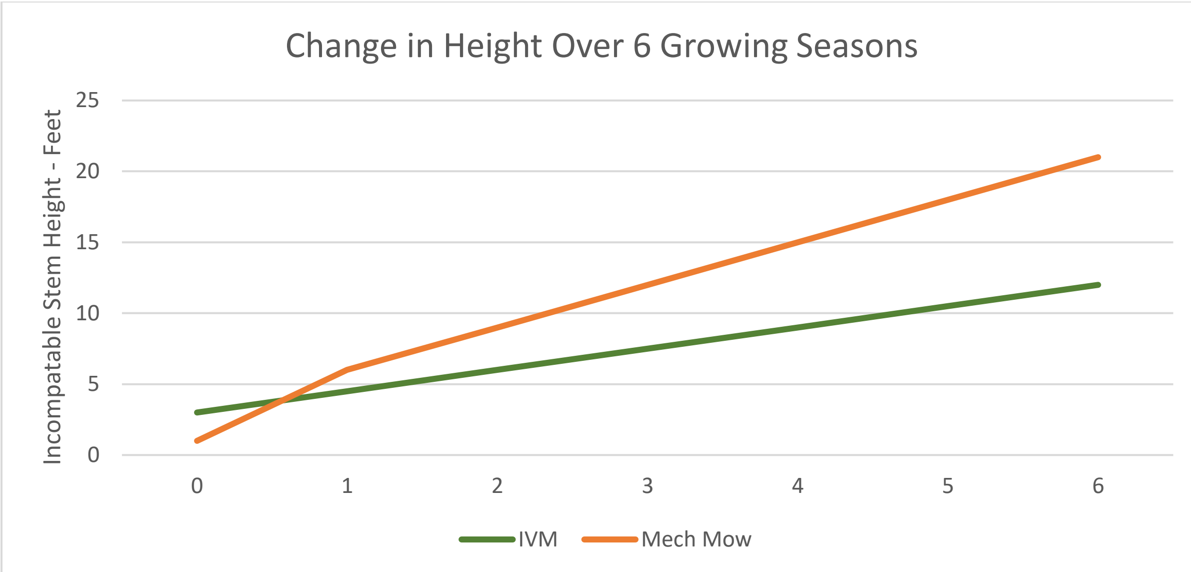

Figure 22 Production function predicting height growth rate of incompatible trees over time under IVM-based and non-IVM vegetation management strategies over time.

The differences in density and height growth prediction over time are consistent with the competitive pressure exerted by well-established compatible plant communities to suppress the re-establishment and re-growth of incompatible tall growing trees. This is a form of biological control that is central to the practice of IVM.

The experience of practitioners presented in Figure 23 below provides anecdotal confirmation of the operational benefits of an IVM-based strategy in reducing the density and height growth of incompatible trees.

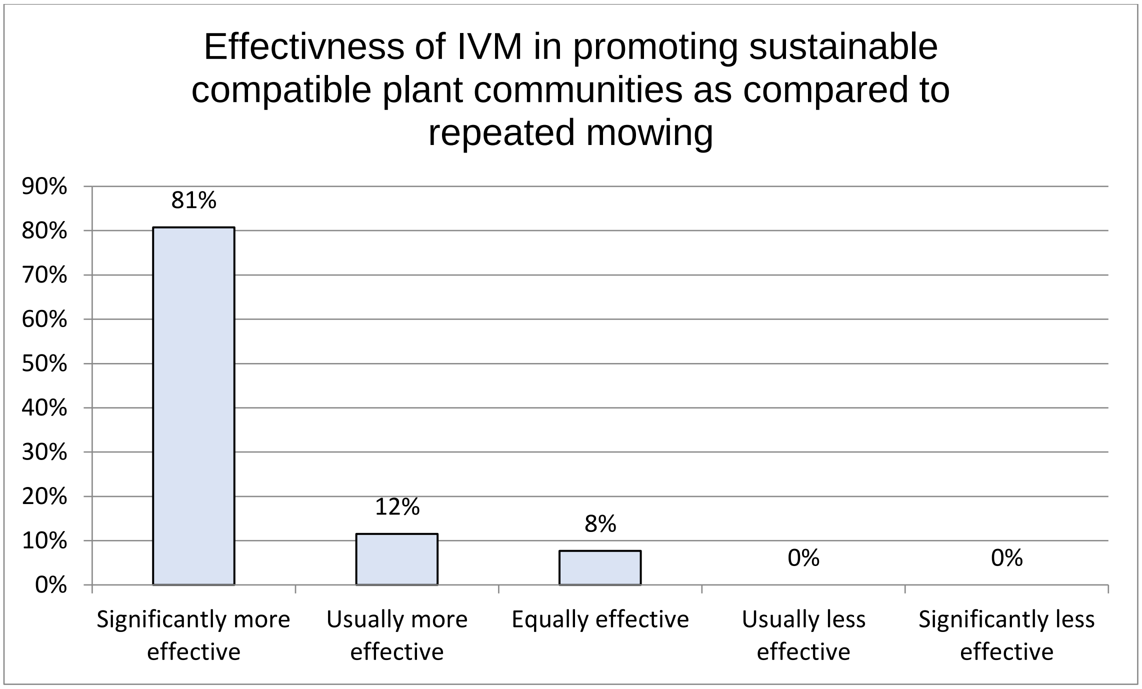

Figure 23 Perception of practitioners regarding the long-term effectiveness of vegetation management strategies in promoting the establishment and growth of compatible plant communities within the ROW.

Wildlife

Information on the effects of individual vegetation maintenance treatments on wildlife is complicated by the reality that, while activities within a ROW occur in a fixed location, wildlife populations frequently are transient in nature, making use of habitat types in a range that may be far larger than the ROW itself. This makes it difficult to determine the influence of an individual treatment in comparison to another, versus the effect of a ROW corridor traversing a variety of land cover types.

A limited amount of quantitative interval data was identified, making it possible to make a partial application of cost efficiency analysis.

Table 25 High-level summary of potential impacts of vegetation management on wildlife populations

Basis	Observation	IVM rating
Literature	The available literature that makes a direct comparison of IVM-based and mechanized mowing treatments is limited. The selected references generally demonstrate the benefit of an IVM-based strategy. The studies that are currently underway, focusing on pollinators, are expected to confirm the advantage of IVM strategies.	+
Logic	Cost efficiency analysis demonstrated a strong advantage for IVM in terms of benefit to wildlife.	++
Lore	There is anecdotal evidence that practitioners believe IVM-based vegetation management programs are beneficial to wildlife.	+

The primary impact of herbicide use on wildlife populations is by temporarily altering plant communities that change the successional trajectory of the vegetation community. The selective use of herbicide may be beneficial for the targeted species, but, by improving their habitat, other species will be reduced or be put at a disadvantage[19]. Herbicide-based vegetation management plans tend to be beneficial for some species of concern, but other species may be put at a disadvantage as the plant community changes due to the herbicide treatment.

A literature survey article summarizing potential impacts of herbicide use on wildlife populations noted limited availability of long-term reporting. In general, populations of songbird and small mammals, including the northern hare, were not observed to have any significant decline as a result of herbicide treatment in support of conifer-release. However, conifer-release treatment with herbicides seemed to decrease the abundance of moose and deer up to four years after initial treatment[20].

Herbicide application has shown to be a very potent tool to change the vegetation structure and improve habitat for many disturbance-dependent species. However, without careful attention to how the herbicide is applied, there is a risk that habitat could be degraded[21].

The potential of herbicide applications having a direct effect on many species of small mammals were reported[22] to be mitigated by the nocturnal habit of most of these species. They would not be active during application. The study also noted that predatory species would not likely be affected because they would have to consume a full day's diet of directly sprayed prey before herbicide levels could reach a harmful point.

No studies were identified that addressed the use of mechanized mowing as a wildlife management tool or more generally the effect of mowing on early successional habitats of wildlife populations. The manner in which mowing immediately alters habitat clearly would have an impact on wildlife populations.

The literature provided quantitative data comparing the quality of whitetail deer habitat, making it possible to apply cost efficiency analysis. In this case, an IVM-based vegetation management strategy was shown to be twice as efficient at producing good deer habitat, though it should be noted that the absolute quality of habitat was slightly better after three growing seasons post-treatment.

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[19] Guynn DC Jr., Guynn ST, Wigley B, Miller DA. 2004. Herbicides and forest biodiversity: What do we know and where do we go from here? Wildl. Society Bull. 32(4):1085-1092.

[20] Lautenschlager RA. 1993. Response of wildlife to forest herbicide applications in northern coniferous ecosystems. Can. J. For. Res 23:2286-2299.

[21] Miller KV, Miller JH. 2004. Forestry herbicide influences on biodiversity and wildlife habitat in southern forests. Wildl. Society Bull. 32(4):1049-1060.

[22] USDA (United States Department of Agriculture) Forest Service. 2015. Malheur national forest site-specific invasive plants treatment project final environmental impact statement.

Table 26 Results of cost efficiency analysis considering the impact of vegetation maintenance treatment on the quality of whitetail deer habitat

Metric	**Treatments**	**PVC^{20yr}/Acre**	**Avg #**	**Cost efficiency**	**IVM benefit**
Quality of deer habitat (1-10 scale) three seasons post-treatment[23]	herbicide use	$1,412	7.1	$198.87	209%
	cutting	$3,114	7.5	$415.20	n.a.

The literature studies generally suggest a negative correlation between non-selective mechanical clearing and bird observations. Mechanical mowing treatments were observed to result in a noticeable decrease in bird observations. This is likely because the mechanical clearing of vegetation reduces both perches and shrubby vegetation favored by many of the bird species for cover and food sources[24]. (Bramble 1992). The decrease in birds in these sections persisted over the entire field season.

Areas treated with mechanical mowing showed a greater decrease in the number of songbird territories than the plots treated with an aerial herbicide treatment. These results suggest that herbicide treatment maintains more of the vegetation structure favorable to early successional habitat-dependent songbirds than mechanical mowing treatments[25].

The literature provided quantitative data comparing the quality habitat for birds, making it possible to apply cost efficiency analysis. In every case, an IVM strategy that makes use of herbicides was shown to be much more efficient in supporting abundance and diversity of bird populations making use of the ROW.

[23] Bramble WC, Byrnes WR, R.J. Hutnik. 1985. Effects of a special treatment forright-of-way maintenance of deer habitat. J. Arboriculture 11(9):278-283.

[24] Bramble WC, Yahner RH, Byrnes WR. 1992. Breeding-bird population changes following right-of-way maintenance treatments. J. Arboriculture 18(1):23-32.

[25] Woodcock J, Lautenschlager RA, Bell FW, Ryder JP. 1997. Indirect effects of conifer release alternatives on songbird populations in northwestern Ontario. For. Chron. 73:107-112.

Table 27 Results of cost efficiency analysis considering the impact of vegetation maintenance treatment on birds.

Metric	Treatments	PVC^{20yr}/Acre	Avg #	Cost efficiency	IVM benefit
Diversity of bird species[26]	herbicide use	$1,412	28.5	$49.54	242%
	cutting	$3,114	26	$119.77	n.a.
Density of birds per acre[27]	herbicide use	$1,412	10.2	$138.43	245%
	cutting	$3,114	9.2	$338.48	n.a.
Abundance of birds per hectare[28]	herbicide use	$1,412	130	$10.86	200%
	cutting	$3,114	143	$21.78	n.a.
Abundance of birds per hectare three seasons following treatment[29]	herbicide use	$1,412	7.8	$181.03	344%
	cutting	$3,114	5	$622.80	n.a.

The literature notes that amphibians tend to favor minimal change. Generally speaking, amphibians tend to be negatively affected by clearcutting, but less affected by less disruptive management methods. Reptiles, although generally thought to benefit from disturbance, also can have species-specific reactions that are not favorable. However, reptiles are more likely to benefit from heavy disturbances[30].

Careful application of herbicides, such as minimizing overspray especially around small static aquatic ecosystems (i.e., small puddles common for amphibian reproduction) is safe and should have no negative impacts on wildlife. When applied at recommended concentrations and during proper environmental conditions, there should be no negative impact to non-vegetative species[31]. Proper

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26 Yahner RH, Hutnik RJ, Liscinsky SA. 2002. Bird populations associated with an electric transmission right-of-way. J. Arboriculture 28(3):123-130.

27 Bramble WC, Yahner RH, Byrnes WR. 1992. Breeding-bird population changes following right-of-way maintenance treatments. J. Arboriculture 18(1):23-32.

28 Bramble WC, Yahner RH, and MD Schuler. 1984. The bird populations of a transmission right-of-way maintained by herbicides. J. Arboriculture 10(1): 13-19.

29 Bramble WC, Yahner RH, and MD Schuler. 1984. Effect of special right-of way maintenance on avian populations. J. Arboriculture 12(9): 219-226

30 Russell KR, Wigley TB, Baughman WM, Hanlin HG, Ford WM. 2004. Responses of southeastern amphibians and reptiles to forest management: A review. In: Gen. Tech. Rep. SRS–75. Asheville (NC): U.S. Department of Agriculture, Forest Service, Southern Research Station. p. 319-334.

31 Tatum VL. 2004. Toxcity, transport, and fate of forest herbicides. Wildl. Society Bull. 32(4):1042-1048.

application practices that minimize herbicide levels in aquatic systems significantly lower the concentrations known to adversely affect fish, amphibians, and other aquatic invertebrates[32]. Areas of the ROW managed by herbicide-based vegetation treatment methods had the greatest reptile and amphibian species richness[33].

The literature provides quantitative data used in comparing vegetation maintenance treatments in terms of effect on amphibian and reptile populations. In every case, the use of herbicides that are a cornerstone of IVM are more economically efficient in increasing abundance and diversity of these groups of animals. It should be noted that in one case, the absolute diversity of species was greater following cutting treatments.

Table 28 Results of cost efficiency analysis considering the impact of vegetation maintenance treatment on amphibians and reptiles.

Metric	Treatments	PVC^{20yr}/Acre	Avg #	Cost efficiency	IVM benefit
Abundance of amphibians and reptiles[34]	herbicide use	$1,412	24	$58.83	529%
	cutting	$3,114	10	$311.40	n.a.
Diversity of amphibian and reptile species[35]	herbicide use	$1,412	5	$282.40	276%
	cutting	$3,114	4	$778.50	n.a.
Abundance of amphibians and reptiles[36]	herbicide use	$1,412	14	$100.86	257%
	cutting	$3,114	12	$259.50	n.a.
Diversity of amphibian and reptile species[37]	herbicide use	$1,412	3	$470.67	132%
	cutting	$3,114	5	$622.80	n.a.

A study of butterflies on ROW found that species diversity between treatments associated with the two vegetation management strategies reported no statistically significant difference between them (Bramble 1999). However, there was a noted difference for species abundance between treatment methods with all units managed with herbicides reporting larger individual butterfly counts than the mechanically managed unit. These finding correlate with the difference in vegetation structure between

[32] USDA (United States Department of Agriculture) Forest Service. 2015. Malheur national forest site-specific invasive plants treatment project final environmental impact statement.

[33] Yahner RH, Bramble WC, Byrnes WR. 2001. Effect of vegetation maintenance of an electric transmission right-of-way on reptile and amphibian populations. J. Arboriculture 27(1):24-29.

[34] Ibid
[35] Ibid
[36] Yahner RH, Bramble WC, Byrnes WR. 2001 Response of amphibian and reptile populations to vegetation maintenance on an electric transmission line right-of-way. J. Arboriculture 27(4):215-221.

[37] Ibid

the cutting and herbicide treatments. Non-herbicide-based treatments had a much greater abundance of tall growing tree species that are not good sources of food for butterflies, whereas the herbicide units consisted mainly of flowering forbs and shrubs, which provide better butterfly habitat.

In another study, insects of pollinator areas that were managed with herbicides reported larger individual butterfly counts than those managed by mechanical mowing (Bramble 1997).

The literature provided quantitative data used in comparing vegetation maintenance treatments in terms of their effect on butterfly populations within the ROW.

Table 29 Results of cost efficiency analysis considering the impact of vegetation maintenance treatment on butterflies.

Metric	**Treatments**	**PVC$^{20\,yr}$/Acre**	**Avg #**	**Cost efficiency**	**IVM benefit**
Diversity of butterfly species (Bramble 1993)	herbicide use	$1,412	28.5	$49.54	242%
	cutting	$3,114	26	$119.77	n.a.
Abundance of butterflies (Bramble 1993)	herbicide use	$1,412	13.5	$104.59	229%
	cutting	$3,114	13	$239.54	n.a.

An IVM-based strategy that makes use of herbicides was found to be twice as economically efficient in terms of supporting butterfly populations.

Conclusions and Recommendations

This project confirms that a ROW vegetation management strategy based on the principles of IVM less costly than a strategy that makes no use of herbicides but relies simply on repeated mechanical and manual treatments. The present value of cost over a 20-year evaluation period were shown to be approximate half as much as simply controlling incompatible trees by cutting without the use of herbicides over the same time period. The cost advantage of the IVM-based strategy considered in the project also was shown to provide significant benefits that would accrue top the vegetation manager, utility and environment. These benefits do not come at an additional cost.

Industry Standards[38] and Best Management Practices [39]for IVM should be adopted and incorporated in management programs used by utilities to preserve the function of electric utility ROW. The ROW Stewardship Council's IVM "*Accreditation Requirements"* (2016) defines IVM principles and practices for ROW in greater detail. These references should guide management of vegetation on electric and gas utility ROW and used be used to develop vegetation maintenance specification that establish requirements and practices used to maintain ROW vegetation in a manner consistent with intended use of the ROW.

[38] ANSI A300 Part 7 (2018) Integrated Vegetation Management

[39] ISA BMP Integrated Vegetation Management, second edition 2014, third edition expected in 2020

Appendix A, Least Cost Analysis

This appendix describes findings of least cost analysis conducted in an effort to develop an economic business case for Integrated Vegetation Management (IVM). The analysis compares a vegetation management strategy based on the principles and practices of IVM to one that is intended to simply control vegetation within a ROW corridor. The two different strategies are:

- An IVM-based strategy that makes use of a variety of increasingly selective vegetation maintenance actions specifically targeting incompatible vegetation and promoting the development of compatible plant communities. This strategy includes the use of herbicides as well as mechanized mowing of incompatible species of tall growing trees and assumes proper use of registered products.
- A simple vegetation management strategy that makes use of repeated mechanized mowing to control vegetation within the ROW corridor. This strategy does not include the use of herbicides.

Three different case scenarios were considered:

1. A Base Case that considered the cost of vegetation maintenance following initial clearing of the ROW as vegetation responded to management and relatively stable "steady state" conditions were achieved.
2. A Reclamation Case that considered the cost of vegetation maintenance as a ROW on which vegetation maintenance that had been deferred was brought under preventive maintenance through development of relatively stable "steady state" conditions.
3. A Loss of Herbicides Case that considered the cost of losing the use of herbicides on a ROW that had been maintained using IVM and in which vegetation had achieved a relatively stable steady-state condition.

Least Cost Analysis – Base Case

A simple base case was used in an assessment of the Present Value Cost (PVC^{20yr}) comparing two fixed interval (cycle-based) vegetation management strategies implemented over a 20-year period. The costs presented represent the present value of maintenance costs for the Base Case comparing:

1. An IVM strategy where the site was initially cleared, and herbicides were applied by cut-stubble treatment. Herbicide applications were prescribed every four years after clearing. Two types of herbicide treatments were used, broadcast high-volume foliar (HVF) and selective low-volume foliar (LVF), with the prescription based on density and height.
2. A mechanical-only strategy where the site was initially cleared, and mowing occurred every four years.

This investigation focused on the cost of maintaining vegetation over time. The capital cost of initial clearing would be the same in either case and is not included in this analysis.

Table 30. Vegetation maintenance prescriptions used in the Base Case study.

Season	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
IVM	Initial Clearing w/herbicide				*HVF*				*HVF*				*LVF*				*LVF*				*LVF*
Mech Mow	Initial clearing				*Mow*				*Mow*				*Mow*				*Mow*				*Mow*

The four-year fixed interval cycle used in the Base Case comparison was based on an unpublished Utility Arborist Association (UAA) 2017 benchmark study and reflects the average cycle period reported by 20 utilities for both mowing and IVM treatments.

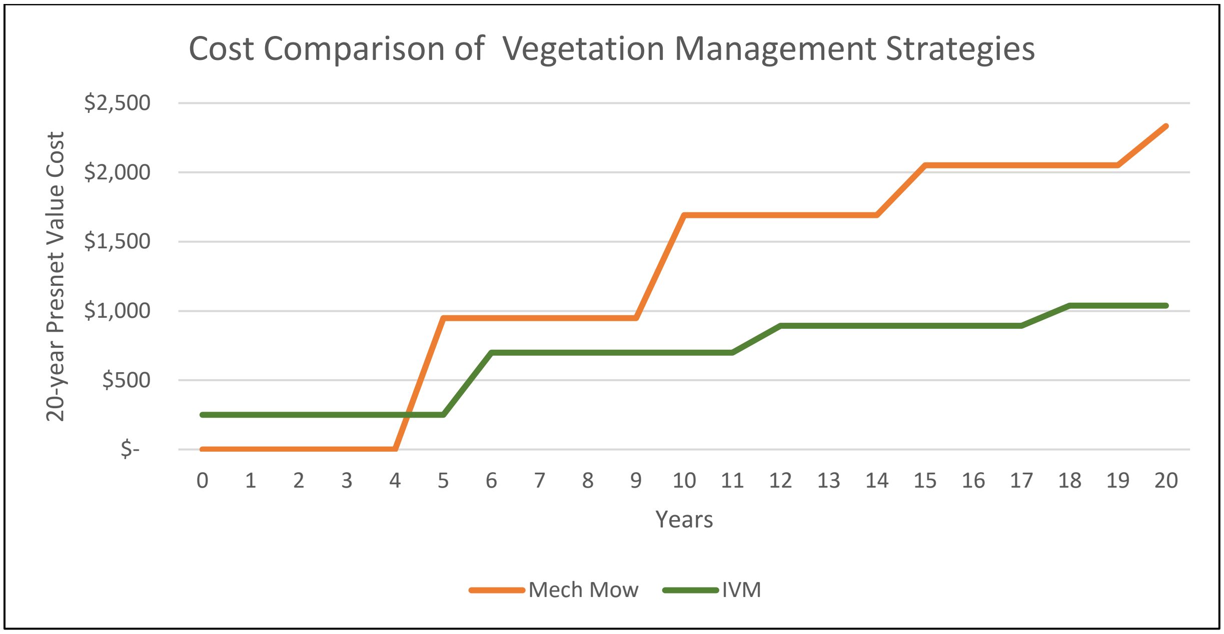

Figure 24. 20-year costs (Present Value) comparing maintenance using mechanical mowing-only treatments and IVM treatments.

Figure 24Figure 3 shows that because of the added cost of herbicide treatment during initial clearing, the IVM strategy is initially the higher cost strategy. At the time of first maintenance (four years), the cost of mechanical maintenance overtakes the IVM costs.

Table 31 Summary results from Least Cost Analysis performed on the Base Case

Metric	Mechanical Mowing Only	IVM
Maximum average tree height	15 feet	9 feet
Ending stem density	medium	very light
Sum of Present Value Cost	$3,114	$1,412

By the end of the 20-year analysis, the total PVC^{20yr} of the IVM treatments was 55% less than the non-IVM strategy that relied on repeated mechanical mowing treatments. As shown in Table 31, the site that was mowed retained higher stem densities and achieved considerably higher average tree heights between treatments.

Breakeven Analysis for Base Case

Present value calculations are dependent on the time value of money as reflected in the discount rate. A higher discount rate increases the benefit of deferring costs and disadvantages the IVM scenario, which requires treatment at the time of initial clearing or soon after clearing.

A discount rate of 5% was used In the Base Case PVC^{20yr} analysis. A discount rate of 40.1% would be required to make the 20-year costs of the two scenarios equal.

Findings from least cost analysis present a compelling case for the economic benefit of an IVM-based ROW maintenance strategy.

Base Case, High/Low-Density Predictions

The selection and cost of ROW treatment are affected by stem density and height. The Base Case analysis above was based on the height and density curves previously discussed. For both strategies, the model assumes heavy stem densities at the time of initial clearing (approx. 8,000 stems per acre).

Two additional scenarios were considered. The first test was intended to approximate and likely exceed the range of conditions that might be encountered in the field. This was accomplished by testing upper and lower projections of changes in stem density over time as predicted by the density production function for both vegetation management strategies. A high-density scenario was created by increasing the predicted densities for both strategies by 75%. Conversely, a low-density scenario was created by decreasing the predicted densities for the two strategies under consideration by 25%.

Results for the high- and low-density scenarios bracketing the Base Case are summarized in Figure 25 below.

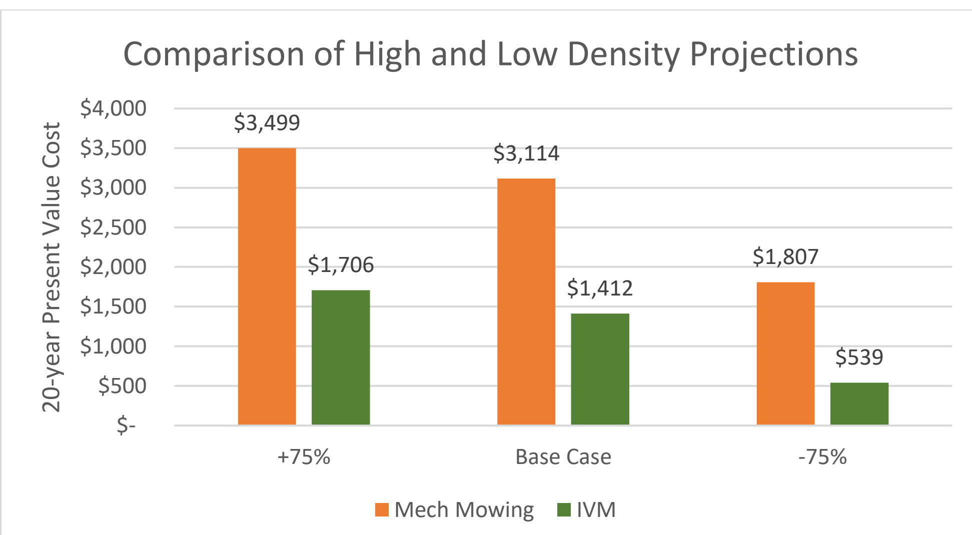

Figure 25. Total Owned Costs in situations where stem density is extremely high (+75%) or low (75%).

In all three cases, the cost of IVM is substantially less that the no-herbicide alternative.

- The Base Case using the production functions for density and height shows IVM costs as 55% lower than maintenance by repetitive mowing.
- Using an assumption that the density of incompatible stems encountered is much higher than expected, the PVC^{20yr} for IVM was 51% lower than for mechanized mowing.
- Using an assumption that the density of incompatible stems encountered is much lower than expected, the PVC^{20yr} for IVM was 70% lower than for mechanized mowing

Base Case, Worst/Best Case Efficacy

A second set of scenarios was created to test the durability of projected costs of both vegetation management strategies, and to gain insight into how the efficacy of the two strategies might impact the outcome. The first creates a bias favoring the mechanical mowing strategy by assuming mowing is 75% more effective in reducing stem density than in the original assessment, while the efficacy of IVM is unchanged. Under this assumption the difference in PVC^{20yr} for the two strategies is not as great as in the base study, yet IVM still yields a savings of 22% as compared to repeated mechanized mowing.

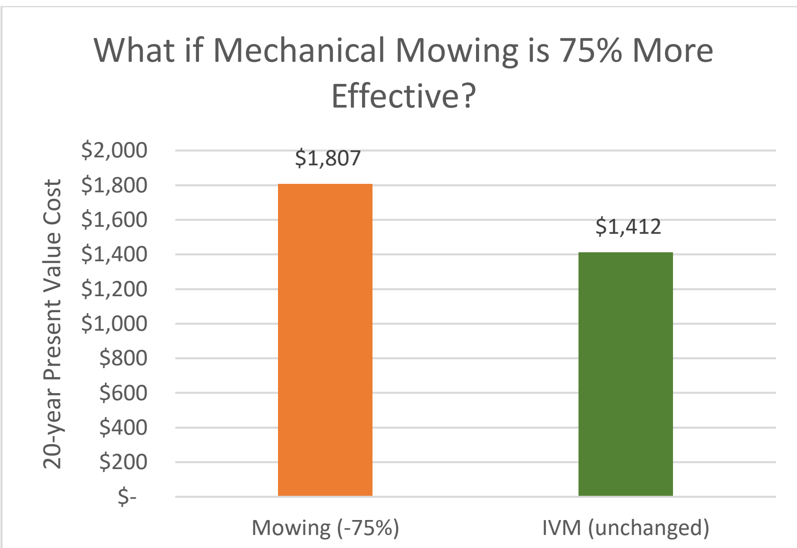

Figure 26. Showing the comparison where mowing is 75% more effective than predicted in the base case

The second variant creates a bias against IVM by assuming herbicide treatments are 75% less effective in reducing the density of incompatible stems, while assuming the predicted efficacy for mechanical mowing is the same as used in the Base Case. In this case, IVM costs are 45% less than mowing (**Error! Reference source not found.**).

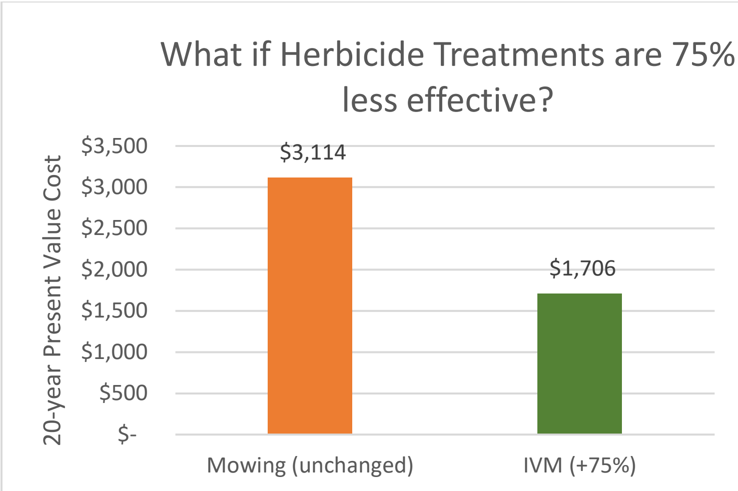

Figure 27 Showing a comparison where herbicide applications are 75% less effective than predicted in the base case.

Effect of Cycle Length

The Base Case utilized fixed four-year treatment cycles for both vegetation management strategies. This is the average cycle period for electric utilities across North America. Although the average was four years for both mechanical and IVM, cycle times did differ among utilities. The majority of electric utilities had cycle periods between three and six years. Table 32 compares mechanical and IVM maintenance programs across this range of cycle periods.

Table 32 Effect of cycle length on 20-year PVC predictions for an IVM-based and mechanical mowing strategy

Cycle	Mechanical	IVM	Cost Savings for IVM	Max. Avg. Height (feet)	
				Mech Mow	IVM
3	$3,116	$1,705	45%	12	8
4	$3,114	$1,352	57%	15	9
5	$2,334	$1,149	51%	18	10.5
6	$1,888	$1,412	25%	21	12

The specific IVM treatments used in the model were selected based on the optimum or lowest cost treatment based on site density and height conditions. In all cases, modeled results favor IVM by significant margins. The margin narrows in the sixn-year cycle scenario, but the height of mowed areas exceeds the action threshold towards the end of the cycle.

On-condition Scheduling

The analyses to this point have been based on fixed cycle lengths, which have been the same for both treatment regimens. Earlier discussion of the tolerance and action thresholds suggests that mechanically maintained sites may have a higher action threshold, 18 feet compared to 12 feet for IVM.

Scheduling preventive vegetation maintenance on an on-condition bias, rather than strictly time-based scheduling, is increasing in popularity and is most consistent with the highest industry standards. The following analysis was based on an optimized schedule using height of the vegetation as the determining factor behind the timing of treatments. The slower growth associated with herbicide-treated sites resulted in longer cycles under the IVM strategy. The results of this analysis are summarized below.

Table 33. A comparison of mechanical and IVM strategies where the timing of treatment is determined by an action threshold: 12 feet for IVM and 18 feet for mowing.

Metric	Mech Mow	IVM
Maximum average tree height	18 feet	12 feet
Ending stem density	medium	very light
Sum of the costs (PV)*	$2,334	$1,038

*A discount rate of 5%; the mechanical portion of initial clearing costs were not included in either strategy; the added cost to treat the stubble during initial clearing is included in the IVM costs.

The 20-year PV cost of IVM was 56% lower than the mechanical mowing vegetation management strategy.

Reclamation

The "Reclamation" case study is intended to describe a situation where a ROW had been previously established but vegetation maintenance has been deferred. Reclamation is defined as follows:

> "Re-establishing IVM on a ROW that is not currently managed to the full extent of its easement or ownership rights and intended purpose. Conditions for a ROW in need of reclaiming include tall, dense amounts of incompatible vegetation, and utility facilities that are inaccessible. Reclamation usually involves initial non-selective methods of mowing/hand cutting or broadcast applications of herbicides."

The mechanical mowing production function was used as the starting point for the Reclamation case study. Conditions at the 10-year point as changes in ROW vegetation shift from establishment to a maintenance phase were selected as a starting point for this case study. At this point, incompatible vegetation is expected to be heavy density and extra tall (>13 feet). This was considered reflective of conditions where ROW management has been deferred and reclamation is required.

To reclamation options were considered:

1. Option 1 was to implement a non-IVM strategy of repetitive mowing without herbicides.
2. Option 2 was to implement an IVM-based strategy that involved mechanically clearing the site with follow-up herbicide treatments.

Figure 28 depicts changes in stem density under these two options. Figure 29 portrays the cost (PVC^{20yr}) of reclamation and maintenance from implementation (year 10) to the end of the 20-year period. Reclamation costs for the IVM option are based on mechanical clearing and cut-stubble as a first treatment, followed by subsequent herbicide applications. The mechanical-only strategy of reclamation and maintenance is 16% higher than the cost of transitioning to IVM by clearing with a cut-stubble treatment. This comparison is based on a five-year cycle after reclamation.

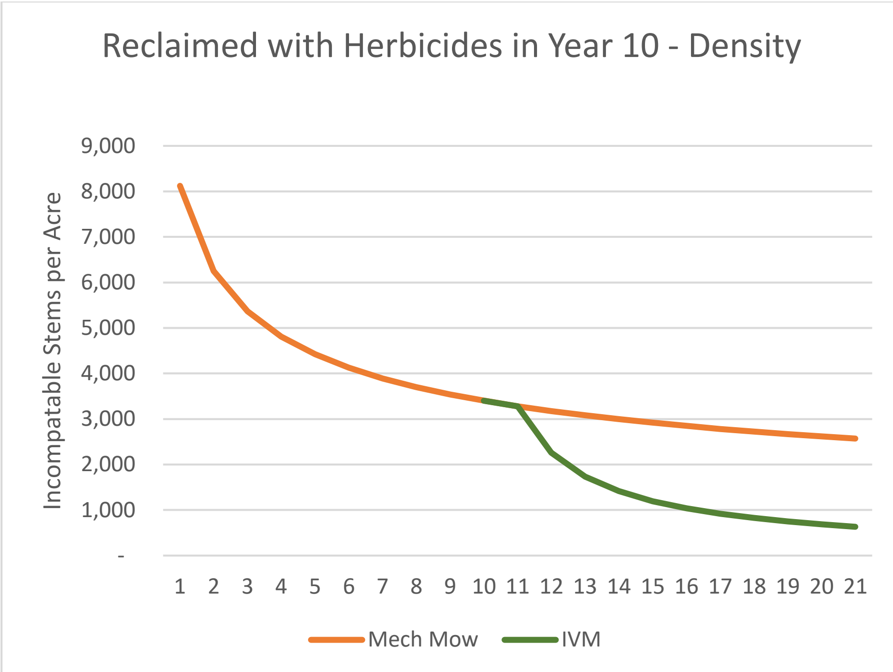

Figure 28. Stem density in the "Reclamation" case simulating conditions that would be anticipated as a result of deferred maintenance and where the site is either maintained by continuous mowing or reclaimed and managed with IVM.

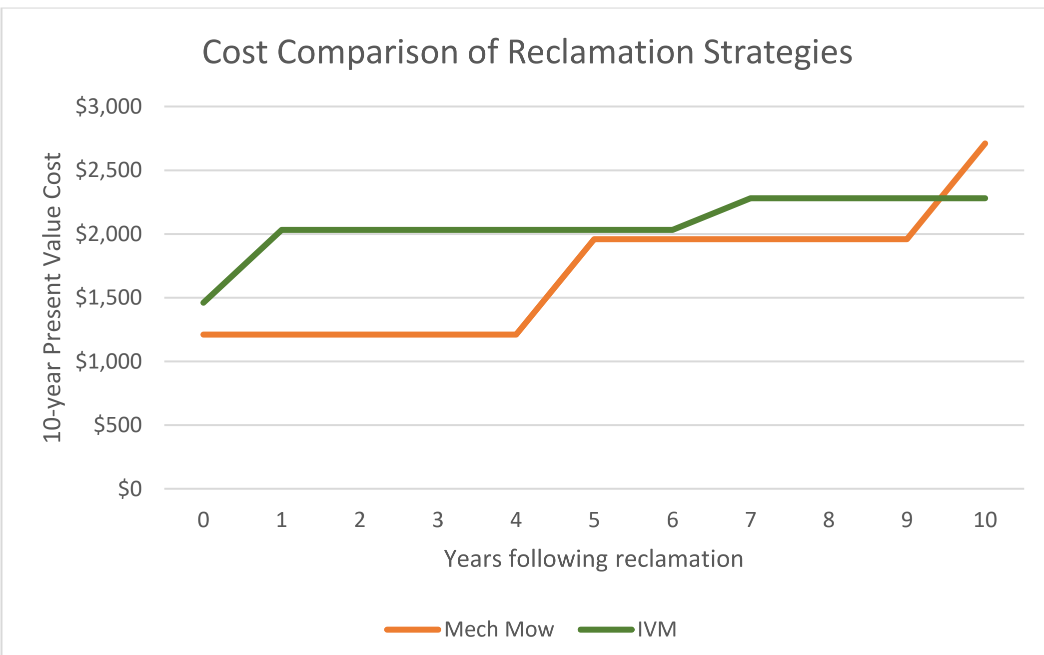

Figure 29. 10-year Cost (PV) to reclaim a site after deferring maintenance for 10 years.

This analysis starts with that same assumption for both vegetation management strategies: the initial treatment is mechanical mowing. In the case of the IVM-based strategy it was further assumed that the site received a cut-stubble treatment associated with the initial mechanical clearing treatment. Some utilities choose to delay treatment for one to two years and then apply a high-volume foliar application.

The data used in this study assume little difference in the direct cost of the stubble and high-volume foliar applications. Delaying the initial herbicide treatment to the second growing season following mowing reduces the present value by $52 or about 3.7%.

Loss of Herbicide

The last situation examined is the “Loss of Herbicide” case study. This considers the situation where the ability to use herbicides is lost at some point in the future, after relatively stable plant communities have been established by the IVM program (approximately 10 years).

Figure 31 illustrates the anticipated change in the stem density on the site. The projection for the density of incompatible stems uses the production function for mechanized mowing and does not predict an increase. No data are available to quantitatively support the notion that a shift to mowing would result in an increase in undesirable stem densities on a well-established ROW where compatible plant communities dominate the site, suppressing the growth of incompatible trees. However, experience suggests that severe site and soil disturbance that could occur during mowing operations would create openings and prepare a seed bed for re-invasion by incompatible species.

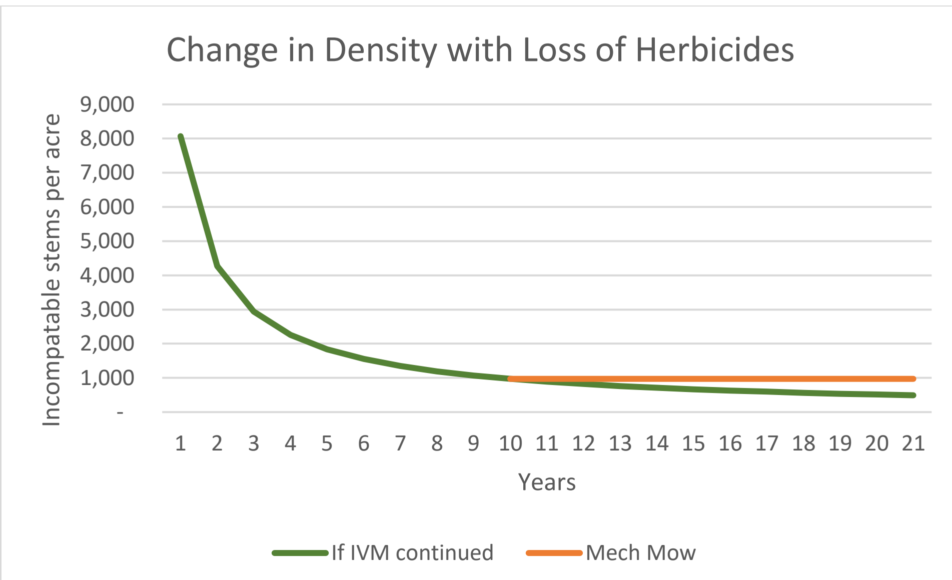

Figure 31 Stem density in the "Loss of Herbicide" case simulating the impact of losing the ability to use herbicides after relative steady state conditions have been achieved with IVM.

Figure 32 compares the cost of mowing the sites over the remaining 10 years against what would have been expected under the planned IVM program. Transition from an IVM-based vegetation management strategy to simple repetitive mowing is estimated to increase the present value of cost over 10 years (PVC^{10yr}) cost in present value by 31%.

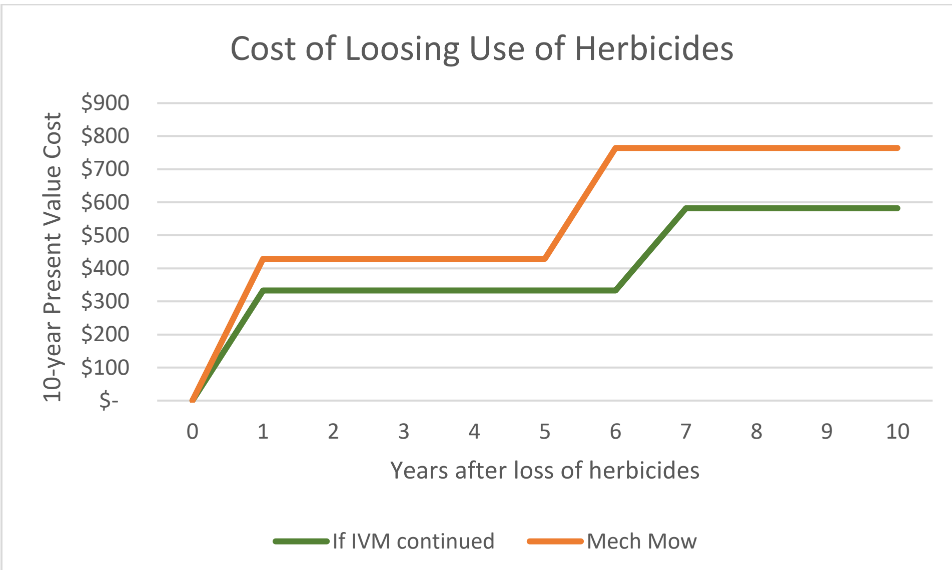

Figure 32. 10-year cost (PV) of maintenance after the loss of herbicide use compared to continued use of IVM.

Conclusions Based on the Economic Analysis

The analysis work completed in this project demonstrates that a vegetation management strategy based on the use of IVM, which includes integration of mechanical and herbicide-based prescriptions, is consistently and convincingly less costly than repeated treatments using only manual and mechanical techniques. This hold true in all situations: when the efficacy of mowing was exaggerated; when the efficacy of herbicides was minimized; when the cycle length was shortened or lengthened; and when action thresholds based on MVCD were used. In addition to lower costs, the IVM strategy demonstrated lower risk (i.e., lower maximum height) between treatments.

Establishing an IVM program does require an early investment in the form of a treatment during or shortly after initial clearing by mechanical means. Although initially more expensive, the higher cost of the mechanical option inverts the relationship by the time of the first scheduled treatment and IVM becomes the low-cost option.