Revista
Bioinvasiones
ISSN - 0719-9287 LATINDEX

www.bioinvasiones.org

Estimating yield and control costs of *Pinus* spp. invasions – a case study in a municipal protected area in Atlantic Forest, Florianópolis, Brazil.

Estimación del rendimiento y los costes de control de las invasiones de *Pinus* spp. - un estudio de caso en un área municipal protegida en la Mata Atlántica, Florianópolis, Brasil.

Silvia R. Ziller[1], Michele de S. Dechoum[1,2], Aracídio F. B. Neto[3], Rafael B. Sühs[2], Alexandre D. Schmidt[4], Guilherme Ritzmann[1], Christopher H. Graves[1] & Guilherme H. Pereira[5]

1) The Horus Institute for Environmental Conservation and Development. Caixa Postal 5047, AC Cidade Universitária, Florianópolis - SC, Brazil 88.040-970
2) Federal University of Santa Catarina (UFSC) Campus Universitário, s/n, Córrego Grande, Florianópolis -SC, Brazil, 88.040-900
3) Municipal Foundation for the Environment (FLORAM), Rua Felipe Schmidt, 1320, Centro, Florianópolis, SC, Brazil, 88.010-002
4) Estrada Rozália Paulina Ferreira, 1568, Costa de Cima, Pântano do Sul, Florianópolis - SC, Brazil, 88.066-600
5) Horizonte Engenharia e Tecnologia Ambiental, Avenida Ministro Victor Konder, 1030, bairro Fazenda, Itajaí – SC, Brazil, 88.301-701
E-mail: sziller@institutohorus.org.br

Received on August 21, 2020 - Accepted on June 20, 2021

Resumo: Pínus invadindo um parque municipal em Florianópolis, Santa Catarina, foram eliminados em 17 dias de trabalho a um custo de R$ 40.000,00. O número por dia variou de acordo com: (1) declividade; (2) vegetação; e (3) densidade da invasão por pínus. Sete classes de rendimento foram definidas para estimar o número de pínus que quatro pessoas podem eliminar por dia. O rendimento variou entre aproximadamente 100 pínus até mais de 700 pínus por dia. Uma fórmula foi desenvolvida para prover estimativas de rendimento a fim de ajudar gestores em trabalhos de controle. A fórmula pode ser ajustada para incluir diferentes fatores que afetam o rendimento. Um desdobramento dos custos é apresentado para referência. O custo por árvore variou de R$ 21,80 para pínus isolados em capoeirinha densa em áreas íngremes e R$ 3,52 para pínus em alta densidade em áreas abertas de declive moderado. Pínus isolados precisam ser eliminados primeiro.

Palavras-chave: : invasão por pínus, controle, rendimento, custos, unidade de conservação.

Resumen: Pinos invadiendo un área protegida en el sur de Brasil fueron eliminados en 17 días a un costo de US$ 10,000. El número por día varió de acuerdo con: (1) declividad; (2) vegetación; y (3) densidad de pinos. El rendimiento fue evaluado en base a la combinación de esos tres factores. Siete clases de rendimiento fueron definidas para estimar el número de pinos que un equipo de cuatro personas logra eliminar por día. El rendimiento varió de 100 hasta más de 700 pinos. Una fórmula fue desarrollada para proveer estimativas de rendimiento con el objetivo de apoyar a la gestión en trabajos de control. La fórmula puede ser ajustada para otros factores en cada situación. Un desglose de los costos es presentado para referencia. El costo varió de US$ 5,45 hasta de US$ 0,88 por árbol. A pesar del elevado costo individual, árboles aislados deben ser controladas primero.

Palabras claves: invasiones por pinos, control, rendimiento, costos, área protegida.

Abstract: Pines invading a municipal protected area in southern Brazil were eliminated over 17 days at a cost of US $ 10,000. The number of pines eliminated per day varied with: (1) slope; (2) vegetation; and (3) pine density. Yield was assessed based on the combination of these three factors. Seven yield classes were defined to estimate the number of pines a team of four workers can eliminate per day. Yield varied between approximately 100 and more than 700 pines per day. A formula was developed to provide yield estimates to support management of control activities. The formula can be adjusted to other limiting factors. A breakdown of costs is presented for reference. Cost varied from US$ 5.45 to US$ 0.88 per tree. Despite the higher individual cost, isolated trees must be controlled first to avoid higher future costs from abundant seed spread.

Keywords: pine invasions, control, yield, costs, protected area.

Versão completa em português disponível, solicite por correio eletrônico à autora.

Introduction

Pine species, especially *Pinus elliottii* and *Pinus taeda*, were introduced in Brazil in the 1950s and 60s with the aim of developing a national forestry industry. Plantations were established in many areas to verify which species from which areas of origin performed best under local conditions. As the forestry industry grew with government incentives, pine trees were seen as income opportunities and celebrated as some sort of miracle trees that adapted to almost any habitat type, grew fast, and outcompeted native species. Therefore, they were widely distributed and also planted for aesthetic reasons or for shade, along roads and highways or to mark property limits. The characteristics that allow pines to thrive are also those of invasive non-native species, i.e., species that are introduced to a new habitat where they manage to adapt, establish, and dominate by displacing native species. A few decades later, pines were recognized as a relevant environmental problem throughout the southern hemisphere (Richardson, Higgins 1997; Simberloff et al. 2009; Machado et al. 2012; Fischer et al. 2013; Pauchard et al. 2015; Bravo-Monasterio et al. 2015).

The Maciço da Costeira Natural Municipal Park was established as a 15.5 km2 protected area in 1995 (Figure 1) on a small mountain range in the centre of the Island of Santa Catarina (424 km2), off the southeast coast of Brazil, in Florianópolis (Barbosa Neto 2012; Prefeitura Municipal de Florianópolis, FLORAM, IPUF 2020). Pines invaded the area from scattered trees planted for shade or small woodlots around 1990 (the oldest pine felled had 28 growth rings), before the protected area was established. These trees were never exploited and became sources of seeds (Dechoum et al. 2019; Caruso, 1990). A municipal law was issued in 2012 requiring the eradication of pines, eucalypts and casuarinas on the island by 2022 (Lei Municipal 9097/2012). In 2019, the Municipal Foundation for the Environment (FLORAM) increased investments in the control of invasive non-native species on the island. Pines in this park were targeted for control, as they prevent forest succession and potentially impact water sources in the mountains. Located in the middle of an urban area, the park has a long history of human disturbance with many patches of deforestation and clearings for cattle farming and agriculture (mainly bananas and sugar cane). Some private areas remain in the park, as not all former owners have been compensated for the land. The vegetation consists of remnants of Atlantic Forest (classified as Dense Ombrophilous Forest in Brazil, IBGE 2012) in different successional stages. Former clearings are mainly vegetated by shrubs, herbs and ferns, while forests predominate along water courses.

Material and methods

The Maciço da Costeira Natural Municipal Park covers a small mountain range in the central part of the Island of Santa Catarina in southern Brazil (Figure 1). Invaded areas in the park were selected for control based on the potential for pine seed dispersal. Therefore, the areas of higher altitude were prioritized. Large numbers of pines in proximal areas that would allow more ground to be covered in a few working days, as well as accessibility, were also used as selection criteria.

As one single trail cuts across the area, leading to the top of the mountain, most of the time the workers had to open their way to reach pines scattered on the slopes. A road in bad condition also leads to the top, but starts from farther away, therefore was not used except in the last days for access to one site. In areas where trees were taller and the understory was scarce, such as natural forests or plots planted with pines, it was easy to move around. However, as the majority of slopes were deforested in the past for use as pasture or agriculture, shrubs, ferns and small trees predominate, forming dense thickets difficult to move through. For this reason, field assistants were essential to open the way for chainsaw operators. Unexpected circumstances arose from the presence of a venomous snake (*Bothrops jararaca*) that required the team to move to a different area on one day; one of the chainsaw operators was stung by a wasp and had to be medicated, then return to the site with a beekeeper outfit to outfit to cut down the two pines that hosted wasp nests; and a light accident with a machete cut on the knee that required one of the field assistants to be taken to a clinic for stitches. Luckily, the accidents were not serious and did not further interfere with the work. Luckily, the accidents were not serious and did not further interfere with the work.

Saplings were pulled out by hand and most trees were cut with a chainsaw. The wood was left to decompose, as removing it for usage was not viable given the terrain and difficult access to the area.

Diameter and height were registered for all pines except saplings smaller than 0.5 m in height and 1 cm in diameter. Geographic coordinates (Garmin GPS) were registered for pines individually or to represent groups in high density. For graphical representation, pines were grouped in four diameter classes: Class 1 < 2 cm; Class 2 > 2 cm < = 12 cm; Class 3 > 12 cm < = 30 cm; Class 4 > 30 cm. Class 1 refers to pines that could be pulled out by hand; Class 2, to saplings and young trees easy to cut down with no significant impact on surrounding vegetation; Class 3, to larger trees that required more skill and care; and Class 4 to the largest trees that had more potential impact and therefore took more calculation and more time to fell. For the same reason of graphical representation, the number of pines eliminated per day was compiled in circular buffers representing pine abundance. Buffers were defined by a 10-meter radius for every occurrence. Occurrences within this area were combined (sum of numbers of individuals for each occurrence) in order to improve the representation of groups of individuals. Then, the centroid of aggregated occurrences was plotted following a classification based on the final number of individuals. These calculations and maps were produced using the QGis platform (QGIS, 2017).

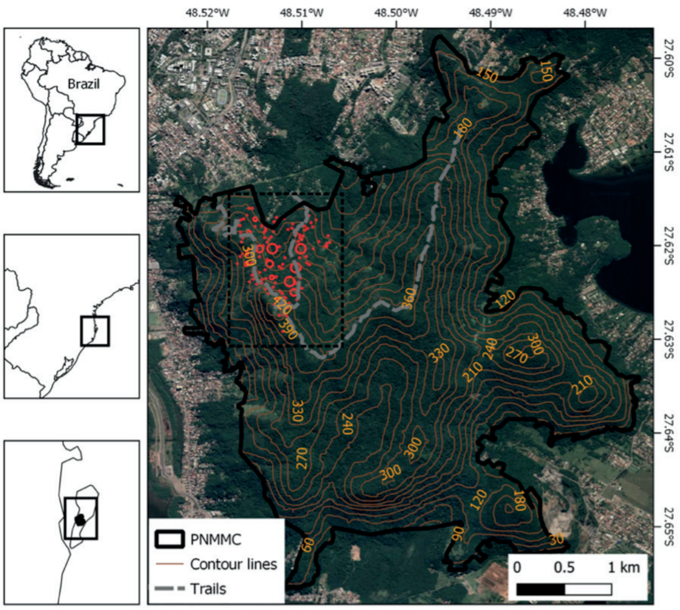

Figure 1: Location map of the Maciço da Costeira Natural Municipal Park, in Florianópolis – SC, Brazil. The black line indicates park limits; the grey dashed lines indicate trails used during control work; orange lines are contour lines (slope); red circles indicate the area where pines were eliminated, with the size of the circle corresponding to pine abundance.

Results

The funds available (approximately US$ 10,000 at an exchange rate of US$ 1.00 to Brazilian Real R$ 4.00) were used to hire a team of four workers (two chainsaw operators and two field assistants), who eliminated pines in the park for a total of 17 working days between 28 November, 2019, and 15 February, 2020. The team worked two days per week and eight hours per day on average, including hiking time to access control areas and transportation from home to the park. Transportation to the site was about one hour per day (both ways), and walking time to access the area of work was estimated at 30 to 60 minutes per day (both ways), so the team actually worked about six hours per day. This rhythm allowed the team to avoid working on rainy days and on excessively hot days (above 30oC), as well as to get enough rest to maximize performance on active days. Other costs included insurance against accidents in the field, gasoline, oil and replacement parts for the chainsaw, chainsaw maintenance, food and transportation, protective gear, depreciation of field equipment (GPS, machetes, chainsaws), production of two reports including all data and maps, registry of the project in the Regional Council of Engineering, Architecture and Agronomy, and taxes and administrative costs (Figure 2). Considering all the expenses, the cost per day was US$ 588.23.

A total of 5,340 pines were eliminated in 17 working days (Table 1, Figure 3). Considering all pines from 1 cm in diameter at ground level and 0.5 m in height, the average diameter was 16 cm, minimum 1cm and maximum, 70 cm. The average height was 6.7 m, minimum 0.5 m and maximum, 27 m. A total of 2,887 GPS coordinates were registered for 4,490 pines measured individually or in dense stands, plus 850 saplings smaller than 1cm in diameter or less than 0.5 m in height not recorded individually, only counted.

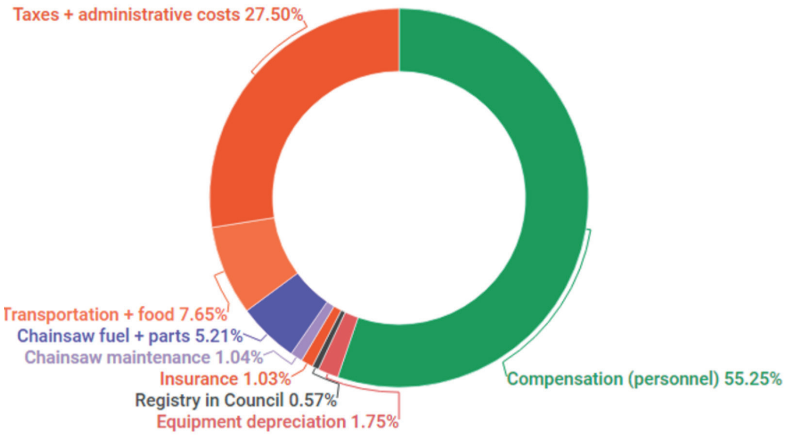

Figure 2: Distribution of pine control costs in a municipal protected area in Florianópolis – SC, Brazil. Chainsaw fuel + parts include gasoline, oil and, spare guide bar and chain.

Table 1: Number of pines eliminated per working day, dates, numbers of pines bearing cones, area covered (hectares) and pine density per working day (number of pines/ha) at the Maciço da Costeira Natural Municipal Park, Florianópolis, Santa Catarina, Brazil.

Working day	Date (dd/mm/yy)	Number of pines eliminated	Pines bearing cones	Area covered (ha)	Pine density (pines/ha)
1	28/11/2019	134	31	7,64	**17,5**
2	29/11/2019	498	49	4,16	119,7
3	06/12/2019	401	70	3,66	109,6
4	07/12/2019	609	52	5,40	112,8
5	12/12/2019	339	109	2,17	156,2
6	13/12/2019	233	117	0,81	**287,7**
7	19/12/2019	326	109	3,31	98,5
8	20/12/2019	245	60	2,31	106,1
9	09/01/2020	214	48	4,47	47,9
10	10/01/2020	246	43	3,08	79,9
11	25/01/2020	233	64	10,15	23,0
12	26/01/2020	108	55	5,74	18,8
13	27/01/2020	441	46	5,25	84,0
14	10/02/2020	667	19	3,31	201,5
15	11/02/2020	230	36	5,84	39,4
16	14/02/2020	246	81	2,29	107,4
17	15/02/2020	170	49	4,09	41,6
Totals		5340	1038	73,68	72,5

Number of pines eliminated

An approximate number of 931 saplings were small enough to be pulled out by hand (Class 1 - diameters smaller than 2 cm), but were partly cut off with a chainsaw to optimize working time. Saplings and small pines (Classes 1 and 2) were carefully searched for and eliminated before larger trees were felled to ensure none would be left behind. All trees were cut as close as possible to ground level. This is especially important for young pines up to approximately 1m in height, as they can resprout when part of the stem or branches remain. As larger pines do not resprout when cut at ground level, or below the lowest branches in older trees, no herbicides were used. Trees were felled in directions that minimized impact on native species, preferably onto clearings or openings in vegetation, as much as possible. The trees were left where they fell except when interfering with the trail or road. In these cases, trunks and stems were cut in smaller parts and left on the side of the passage. One tree was ringbarked to avert the risk of falling onto a power line. No trees were taken out of the area for utilization due to the impossibility of access by vehicle and low value of the wood.

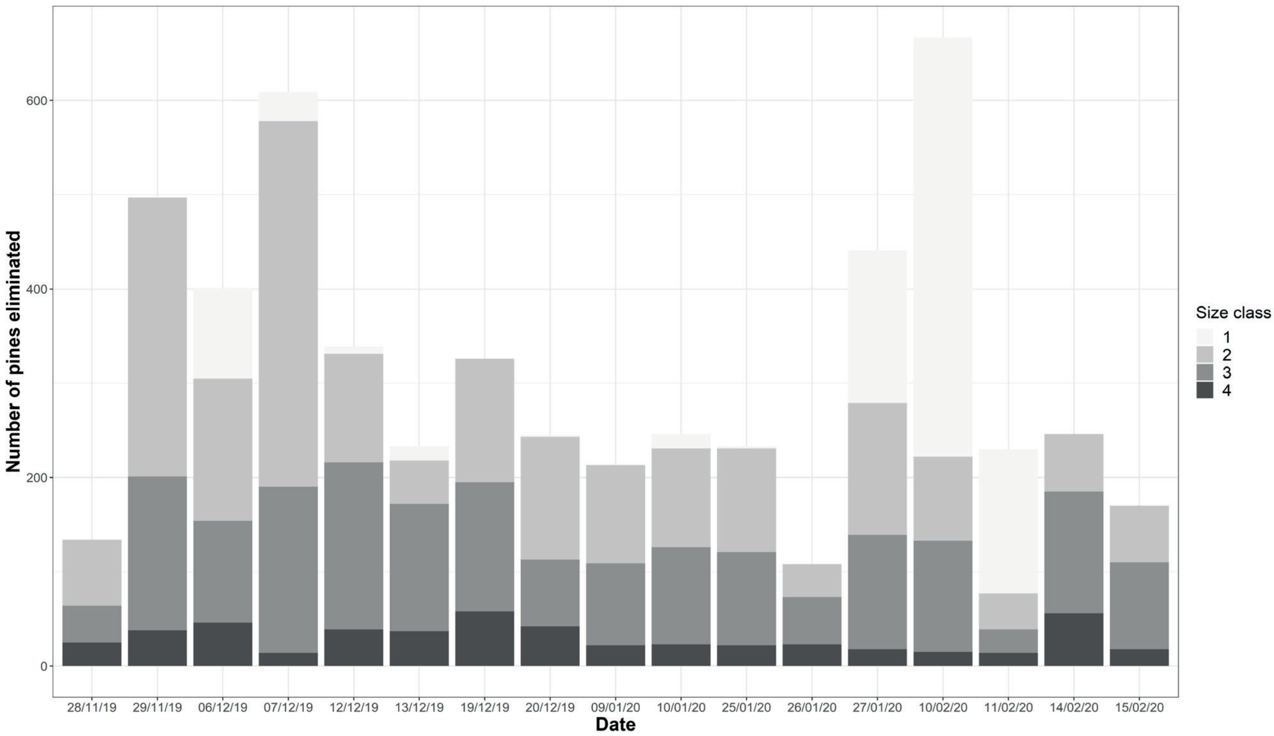

Figure 3: Number of pines eliminated per working day according to size class in a municipal protected area in Florianópolis – SC, Brazil. Class 1 < 2 cm; Class 2 > 2 cm and < = 12 cm; Class 3 > 12 cm and < = 30 cm; Class 4 > 30 cm.

Yield

The number of pines with diameters smaller than 12 cm at the base was 2,069 or 38.7% (Class 2). Only 509 trees (9.5%) were larger than 30 cm in diameter (Class 4). The average number or pines eliminated per working day was 314 at an average cost of US$ 2.14 per tree, regardless of size. The day when less pines were eliminated (108) indicates that pines were very scattered (Figure 4), amidst dense scrub (shrubs and ferns, Figure 5) and/or on steep slopes. On the other hand, when the team worked in an area where pines were highly grouped and included many saplings (Figure 6), 667 pines were eliminated in one day.

Figure 4: Dense pine cover, small trees, high yield.

Figure 5: Scattered pines on steep slope and dense shrub cover, low yield.

Figure 6: Dense fern (*Gleichenia* sp.) cover, difficult access, low yield.

Pine abundance (Figure 7) and the number of pines eliminated per day (Figure 8) varied according to three main factors: (1) slope (how steep the terrain was); (2) vegetation (varying from sparse open grassy areas to dense shrubs and ferns to forests); and (3) density of invasion by pines. The steeper the slope, the denser the vegetation, and the more isolated the pines, the lower the yield. Higher areas close to the main trail were moderately steep, covered with low vegetation and easy to move across, while invasions were moderately to very dense. Felling very large pines also reduced yield, but as most trees were of medium or small size this was not con sidered as relevant as the other factors. Access to open areas was easy, but full exposure the sun took its toll on the team as the work was carried out in the summer. In February, 2020, the temperature was rather high, sometimes over 35 degrees Celsius at noon with extremely high humidity. Again, because these represented very few of the 17 days and such days were avoided as much as possible, and the team started work early to finish around noon, this factor was not considered very relevant. In the valleys, on both sides of streams, the terrain was moderately to very steep, covered with forests, with pines moderately to very dense in some areas, and scattered in others, with younger plants difficult to find as they were camouflaged in the understory.

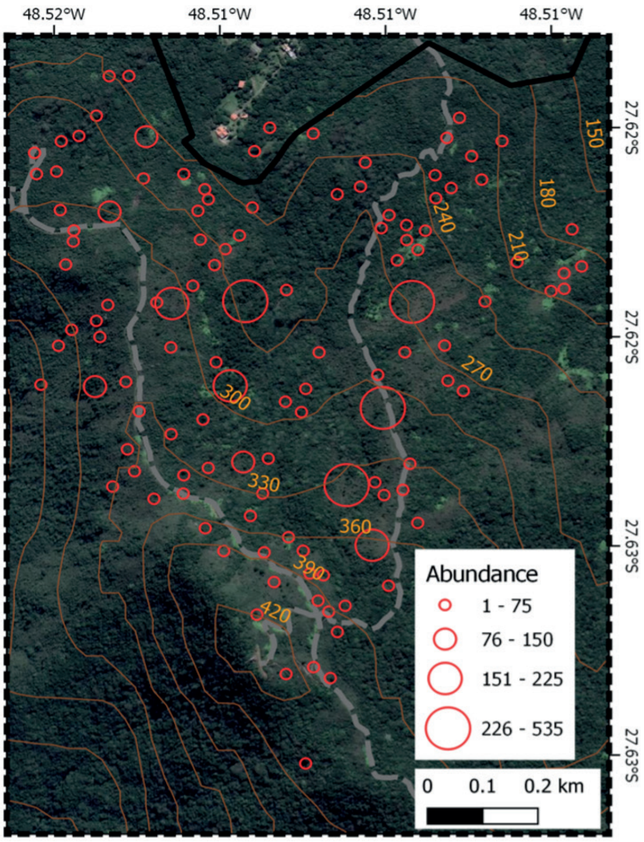

Figure 7: Detail of the municipal protected area in Florianópolis – SC, Brazil, where pine control was undertaken, with abundance represented by red circles. Image: 21 May, 2018. The black line represents the park limits; dotted lines indicate trails used during control work; light green vegetation indicates grasses, ferns, and shrubs, dark green vegetation indicates forest.

The combination of the three factors considered as the main influences on yield generated seven yield classes. The difference between the lowest (108) and the highest (667 pines per day) yields achieved was calculated (559) and divided by the number of yield classes excluding the extremes (therefore divided by 5, not 7) to derive the interval between classes, 112 pines. This means that, beginning from the lowest yield (108, Class 7), the next yield class considers an estimate of 108 + 112 pines = 220 pines eliminated per day in combinations defined as yield class 6; and so on. The realistic numbers in this sequence, derived from our field work, are the base for the calculations shown as yield classes 2 and 7 (maximum yield in field work being 667 pines per day, and minimum yield 108 pines per day). The combinations are presented in Table 2 with respective estimated average number of pines eliminated per day. The complete data set is available as supplementary material.

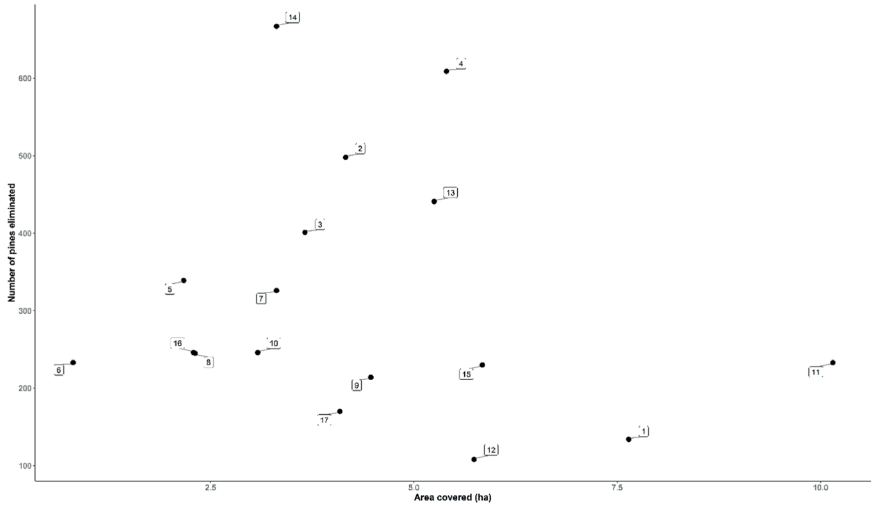

Figure 8: Pine density per working day in a municipal park in Florianópolis – SC, Brazil. Density is shown by black dots in the graph; each dot corresponds to a working day represented by respective numbers in a square linked to each dot.

The data collected in the field was used to generate estimates of the number of pines eliminated per day considering different combinations of factors that affect yield, as explained before. These estimates and respective costs in US dollars and in Brazilian Real are presented in Table 2. Once the work is resumed in the park, better estimates of cost and yield will be available for reference, contributing to managers expectations and supervision of control work.

The highest density of pines was observed in open vegetation, where germination and establishment are facilitated for pines (three out of four of the largest circles in Figure 7, 226-525 pines), and one in forest, which represented an old pine plantation. The same pattern is observed in the next buffer, with two of three circles representing pine density between 151 and 225 in open vegetation. All four circles representing buffers of 76-150 pines are in open vegetation mixed with shrubs. The majority of circular buffers (density between 1 and 75) show that pines were scattered over the area.

Table 2: Estimates of yield and respective cost per pine based on the data collected from control work at the Maciço da Costeira Natural Municipal Park, Florianópolis, Santa Catarina, Brazil. Slope: 3 – steep; 2 – medium; 1 – flat; vegetation: 3 – scrub; 2 – forest; 1 – open; invasion density: 3 – scattered; 2 – medium; 1 – dense.

Yield	Slope	Vegetation	Invasion density	Yield	Trees/day	Cost/tree (US$)	Cost/tree (R$)
Very high	1	1	1	**1**	**779**	0,76	3,02
Very high	1	2	1	2	667	0,88	3,53
Very high	1	1	2	2	667	0,88	3,53
Very high	2	1	1	2	667	0,88	3,53
High	2	2	1	3	555	1,06	4,24
High	2	1	2	3	555	1,06	4,24
High	1	2	2	3	555	1,06	4,24
High	2	2	2	**4**	**443**	1,33	5,31
Medium	2	2	3	5	332	1,77	7,10
Medium	2	3	2	5	332	1,77	7,10
Medium	3	2	2	5	332	1,77	7,10
Medium	2	3	3	6	220	2,68	10,70
Medium	3	2	3	6	220	2,68	10,70
Medium	3	3	2	6	220	2,68	10,70
Low	3	3	3	7	**108**	5,45	21,79

Discussion

Considering the yield factors mentioned earlier (slope, vegetation, and invasion density) in combination with the numbers of pines cut per day, a team of four workers in areas of high yield can eliminate more than 700 pines per day, while in areas of low yield (steep terrain, dense vegetation and scattered pines) it may be about or even lower than 100 pines per day. These numbers would be slightly lower for species that require chemical control and other combined methods that increase the time per tree. In this case study, the terrain was never flat, varying between steep and medium (minimum about 20 degrees, maximum 60 degrees, but most of the area between 30 and 45 degrees), so the number of pines eliminated per day can be higher than the 667 achieved. In best conditions of flat land, open vegetation, and dense invasion, the yield can be at least 779 pines per day (Table 2).

We derived the following formula to provide estimates of yield:

Y = s + v + i – 2, where:

Y = yield (number of pines eliminated per day)

s = slope (steep = 3; medium = 2; flat = 1)

v = vegetation (dense scrub = 3; forest = 2; open = 1)

i = invasion density (scattered = 3; medium = 2; dense = 1).

The more data are collected on different invasive species in different areas, the better these estimates will become. Far from seeking exactness, the purpose of this formula is to help field practitioners and managers estimate control costs and supervise control work in the field by checking the yield of control teams within a reasonable range of error. Other factors that may be specific to each situation must be considered, although not necessarily factored in to the equation, to explain very low or very high yields. These may be very high temperatures, very large trees, labour-intensive control techniques such as ring-barking, need to remove plants from the site or to cut trees into small parts to clear access ways, high altitudes, incidents with dangerous animals, exceptionally difficult or dangerous terrain e.g. very steep, loose rocks, and others. In this case study, the best yields were characterized by:

Y = 2 + 1 + 1 -2 = 2 (medium slope, open vegetation, dense pine invasion). Considering the cost per day at US$ 588.23 and a total of 667 pines eliminated, the cost per pine was US$ 0.88 (Brazilian R$ 3.53). The lowest yield was characterized by:

Y = 3 + 3 + 3 – 2 = 7 (steep slope, dense scrub, and scattered pines). Once more considering the cost per day at US$ 588.23 and a total of 108 pines eliminated, the cost per pine is US$ 5.45 (Brazilian R$ 21.79) per pine.

Now, considering the total number of pines eliminated (5,340) for a total cost of US$ 10,000 (Brazilian R$ 40.000,00), the average cost per pine was US$ 1.87 (Brazilian R$ 7.49). Of the 17 working days, yield was higher than 600 pines per day only on two days, but yield was also lower than 200 pines only on three days. Most of the time, the average yield was satisfactory considering the local conditions. Trimming off the extremes of highest and lowest yields, the average number of pines eliminated per day was 304, at an average cost of US$ 2.09 per pine (Brazilian R$ 8.36).

The number of pines eliminated per hectare and per day were rather variable (Figure 8). The area of lowest pine density was covered on the first day (17.5 pines per hectare), beginning from the hill top, where pines were scattered on steep slopes in dense scrub. On the day of highest pine density (day 6, 287.7 pines per hectare) the team felled pines along a valley in a shaded area, where movement was facilitated by an open understory and pines were densely grouped; on this day the yield was lower than expected because one of the field assistants cut his knee with a machete and the other assistant left with him for help, so the chainsaw operators worked on their own half the time. On the day when more area was covered (day 11), pines were scattered on grasslands in low, open vegetation. On day 14, the highest number of pines was eliminated, but 445 of these were saplings, again mostly in open areas. The last two days of work (16 and 17) required increased walking time to reach the other side of one slope. Scattered pines were taken down along the way to a group of larger trees, and on the last day the team had to find a way around a swamp to cut the last trees in the area, which increased walking time even more.

Estimates produced over the years by the Working for Water Programme in South Africa use a similar logic and were used as an inspiration. Person days per hectare are estimated based on species, species size/age, stage of clearing (initial or follow-up), cover, size of area to be cleared (ha), control method, drive time to site and walking time to site. Walking time and transportation time are factored in afterwards, along with slope, and used to adjust contracts with control teams as well as for surveillance in the field (Ahmed Khan, Working for Water Programme, personal communication, 28 May, 2020; Loftus 2013).

Although the cost per pine increases significantly as yield decreases, it is important to note that isolated trees tend to develop larger crowns, especially in low vegetation, and therefore produce higher abundance of seed than trees in groups or in forest cover, when crowns are thinner and partly shaded by other trees. This means that priority must often be given to isolated trees despite the higher individual cost to avoid higher future costs from more intensive spread.

Although the funds available were not enough to clear pines from the entire park, two slopes were partially cleared, totalling approximately 74 hectares of invaded areas, and 93 hectares covered. Although this represents only 6% of the park and control has to be continued, pine invasions are not homogeneously distributed, and work begun in one of the areas of higher spread potential and some dense pine stands. Of the 5,340 pines eliminated, 1,038 bore cones. This indicates that a seedbank is probably established and that the area needs to be reviewed in 2-3 years, when new pines have grown enough to be visible amongst the native vegetation and before reaching maturity at 4-5 years old (Dechoum et al. 2019). Because plant cover is already dense in most areas, especially when dominated by shrubs and ferns or shaded by forests, the probability of seeds germinating may be low. Besides, as pine trees shed seeds in winter, the season of lowest rainfall in this region, there will not be new seeds to replenish the seed bank in 2020, while seeds shed in the 2019 winter most likely germinated shortly afterwards and plants were removed in the control effort. Although few pines are expected to grow back in the area for these reasons, seeds can come from surrounding areas, carried by winds, and part of the seed bank will germinate in open areas. The Municipal Foundation will direct more resources to clearing pines in adjacent areas in order to avoid reinvasion. Even if the Municipal Law that requires pines to be eradicated from the Santa Catarina Island by 2022 will most likely not be executed as expected, it provides a legal base for ongoing work in pine elimination and for the restoration of natural areas.

Acknowledgements

We thank the Florianópolis Foundation for the Environment (FLORAM) for funding the pine control work described in this article.

References

Barbosa Neto A.R. 2012. As relações socioambientais do Parque Municipal do Maciço da Costeira, Florianópolis – SC. Trabalho de conclusão de curso (monografia) de Bacharelado em Geografia. Universidade Federal de Santa Catarina.

Bravo-Monasterio P., A. Pauchard, A. Fajardo 2016. Pinus contorta invasion into treeless steppe reduces species richness and alters species traits of the local community. Biological Invasions. DOI 10.1007/s10530-016-1131-4.

Caruso MML 1990. O desmatamento da Ilha de Santa Catarina de 1500 aos dias atuais. 2nd ed. Editora da UFSC, Florianópolis – SC.

Dechoum MS, ELH Ghiel, RB Sühs, TCL Silveira, SR Ziller 2019. Citizen engagement in the management of non-native invasive pines: does it make a difference? Biological Invasions 21(1): 175-188. DOI 10.1007/s10530-018-1814-0.

Fischer FM, JM Oliveira, ALP Dresseno, VD Pillar 2013. The role of invasive pine on changes of plant composition and functional traits in a coastal dune ecosystem. Natureza & Conservação 12(1):19-23.

IBGE (2012). Manual de Classificação da Vegetação Brasileira. 2nd ed. Rio de Janeiro, IBGE.

Loftus WJ 2013. Strategic adaptive management and the efficiency of invasive alien plant management in South African National Parks. Master's Thesis. Nelson Mandela Metropolitan University.

Machado IF, LFB Moreira, L Maltchik 2012. Effects of pine invasion on anurans assemblage in southern Brazil coastal ponds. Amphibia-Reptilia 33: 227-237.

Pauchard A., R García, S Zalba, M Sarasola, R Zenni, S Ziller, MA Nuñez 2015. Pine invasions in South America: reducing their ecological impacts through active management. Pages 318-342. In: J. Canning-Claude (Ed.). Biological invasions in changing ecosystems – vectors, ecological impacts, management and predictions. De Gruyter, Berlin.

Prefeitura Municipal de Florianópolis, FLORAM, IPUF 2020. PMMA – Plano Municipal de Recuperação e Conservação da Mata Atlântica. Florianópolis – SC, Brazil.

QGIS 2017. QGIS Geographic Information System. Open Source Geospatial Foundation. URL: http://www.qgis.org/ (accessed 11 May 2020).

Richardson DM, SI Higgins 1997. Pines as invaders in the southern hemisphere. Pages 450-473. In: DM Richardson (ed.) Ecology and biogeography of pines. Cambridge University Press, Cambridge.

Simberloff D., MA Nuñez, NJ Ledgard, A Pauchard, DM Richardson, M Sarasola, BW van Wilgen, SM Zalba, RD Zenni, R Bustamente, E Peña, SR Ziller 2009. Spread and impact of introduced conifers in South America: Lessons from other southern hemisphere regions. Austral Ecology. DOI:10.1111/j.1442-9993.2009.02058.x