Urban Tree Establishment

A Trees Outside Woodlands project report

July 2024

Contents

Executive summary

The research programme 'Trees Outside Woodlands' has undertaken a project investigating the barriers faced in urban tree establishment and trialling methods of improvement. The Trees Outside Woodlands programme is delivered in partnership between Defra, Natural England, The Tree Council, and five local authorities. Of these local authorities, Kent County Council has led the urban tree establishment project. This report has been developed by the partnership as research evidence and any related policy recommendations should consider this research in its wider context.

To explore potential solutions to the problems with urban tree establishment, this project has consisted of three strands outlined in the following sections:

1. **Trees and utilities study**. Utilities were identified as a particular barrier to urban tree establishment as they often compete for space and the needs of the tree are deprioritised. This desk-based study aimed to understand the conflicts between trees and utilities in England and to make recommendations to allow more urban trees to be established and retained.
2. **Trial of adapted Miyawaki method planting**. Across 4 local authorities, the innovative Miyawaki style of planting was trialled, alongside control plots featuring standard practice planting to compare their cost and survival rates.
3. **Trial of natural colonisation**. Kent County Council trialled natural colonisation and control plot planting across multiple sites exploring whether natural colonisation is a suitable cost-effective method for establishing tree cover in urban green spaces.

The urban tree establishment project has found that there are opportunities to improve the cost-effective establishment of urban trees through improved planting methods, maintenance, and design. These findings could inform and support national and local efforts to increase our urban tree cover. The key findings of the project are:

- Tree establishment in urban areas could be improved by encouraging the following of utility industry guidance on protecting existing trees and improved communication between tree officers and those involved in utility schemes**.**
- Trees should be considered in early design stages of infrastructure projects to avoid conflict between trees and utilities.
- Urban tree planting can be difficult and costly, and adapting the Miyawaki method appropriately to suit the challenges of individual sites can be a highly effective way of establishing trees successfully.
- A successful area of trees planted using the pilot's adapted Miyawaki method generally results in a fast-growing, dense thicket of trees, which are resilient to the challenges posed by urban areas to young trees and quickly provide ecosystem services.
- The long-term results of planting using the Miyawaki method are still unknown/speculative in the context trialled (on small plots in urban areas in the UK), although results on larger plots abroad have been very successful.

- The trial so far has shown the pilot's adapted Miyawaki method to be a cost-effective and reliable way of quickly establishing trees on experimental plots in comparison to control plots.
- Natural colonisation has failed so far in this project's plots. Some saplings were found in the first year of monitoring, which were subsequently outcompeted by weeds in the second year. It will be interesting to see whether this situation has changed or remained the same when further monitoring is carried out after an additional two years.
- The failure of the natural colonisation plots so far indicates that improvements might need to be made upon the method used to have success in urban areas. For example, ground clearance at inception, weeding and mulching around saplings when they are identified, choosing sites with nearby seed stock or suitable ground, and potentially selecting larger sites.

Further research is ongoing as part of the wider Trees Outside Woodlands programme including a project investigating the contributions of particular elements, or combinations of elements, of the Miyawaki method to the survival and growth rates of newly planted trees. The existing plots that were created as part of the 'trial of adapted Miyawaki method planting' and 'trial of natural colonisation' are being monitored until September 2025. Additional data will be collected from the adapted Miyawaki method plots including growth measurements and soil carbon and nitrogen comparisons pre- and post-planting.

Introduction

Urban trees can be defined as any trees which provide green cover in towns and cities. On average, towns and cities in England have 15% urban tree cover (Forest Research, 2017) and though there are many urban woodlands, many urban trees can be found outside woods across a number of settings including parks, school grounds, amenity areas, canal and river banks, along streets, and in domestic gardens.

Urban trees offer a huge range of economic, social, and environmental benefits. They help provide shelter and shade, regulate surface water runoff, mitigate air pollution, add visual aesthetics, increase property value, benefit health and wellbeing, and provide vital habitats (Woodland Trust, 2018).

The extent to which the benefits of urban trees manifest depend on their size and species. Trees that are well established provide more benefits than their younger counterparts, and the value they offer, though varied, is distinct. Long term establishment of trees, and understanding their value when replacing them, should therefore be a key focus if their benefits are to be realised. For example, one study by the University of Leeds found that in order for carbon sequestration parity to be achieved, up to 38 saplings would be required to replace a mature tree depending on its condition, species and stature (Rolls et al., 2021).

Though the benefits of urban trees are well documented they face several challenges which negatively affect their survival and establishment. Tree planting in general is perceived as challenging, particularly as higher temperatures due to climate change are creating more extreme weather events such as long periods of drought, all of which can be fatal to young trees. The 21st century rise in pests and diseases also places increased pressure on trees (Daegan, 2023), for example research suggests that 70-80% of ash trees could be lost due to ash dieback in the UK (Tree Council, 2020). In urban settings, trees also face additional problems negatively impacting their survival and establishment due to their location in built up areas. These include soil compaction, urban heat island effect, competition for space with utilities, vandalism, poor access to water, and the lack of adequate long-term aftercare and maintenance (LTOA, 2014). There are also concerns that these trees are not sufficiently protected by legislation and that there are insufficient requirements for them to be considered during utility planning stages, and during utility works or maintenance (see section 1).

Despite the value they bring to people and the surrounding environment, the challenges to planting and survival of urban trees mean they are perceived to be relatively difficult and expensive to plant and maintain. It is therefore critical to understand how urban trees can be established quickly, to mitigate some of the increasing pressures from climate change and deliver other benefits including ecosystem services. Finding planting methods that are cost effective, well considered, and encourage establishment is therefore key to tackling this problem.

1. Trees and utilities study

This study was conducted by AJS Flood Risk Consulting in March 2023. It aimed to:

- Bring together existing literature of how trees and utilities interact.
- Understand the current working practices of utility companies working around trees.
- Assess the effectiveness of current legislation and guidance.
- Discuss a range of possible solutions and present recommendations for their implementation.

To achieve its aims, this research included two main strands. Firstly, a literature review of all existing legislation and guidance concerning the interaction between trees and utilities alongside the evaluation of case studies of situations that have or have not worked well. Secondly, engagement with the people and organisations encountered in the review through two surveys; a stakeholder survey designed for tree officers and other tree related professionals, and a utility company survey. The surveys aimed to gather information on the awareness and usefulness of a range of guidance documents and potential solutions to overcome the barriers to urban tree planting. The analysis of the results was synthesised into a report, the full version of which will be published shortly.

The **key findings** of the report were:

- Utility industry legislation at the time of publication does not contain provision to protect trees from damage or removal.
- Current guidance on utilities and trees should protect trees sufficiently if followed, but without legislative backing can be ineffective as the guidance is not always used.
- Lack of communication between different departments within local authorities and with external organisations means tree officers are often unaware of utility schemes that affect trees, and a lack of resource in local authorities restricts the ability of tree officers to work proactively with utility companies on local solutions.
- Conflicts above ground are easier to overcome through good initial tree selection and good arboriculture working practices, while conflicts below ground are complex and relate predominantly to the lack of coordinated planning in the sub surface space of urban areas.
- Retrofitting trees into urban spaces is very costly so trees must be considered in the early design stages of infrastructure projects.
- Survey results indicate the current guidance is perceived as good by stakeholders and the issues are understood by the utility companies, but the common use of sub-contractors means work on the ground does not always adhere to guidance.
- Trees in close proximity to utilities are viewed as added complications to maintenance and renewal of infrastructure, and where mitigating measures are not taken during tree planting, the roots have the potential to damage underground utilities.

Examples were laid out, both nationally and internationally, of good working practices and effective planning and communication that allow urban trees to be retained and established. These were used to support the following recommendations made by the authors (AJS Flood Risk Consulting) which were drawn from the literature review and survey:

- **Planning reform**. Create a National Underground Design Code to regulate and make better use of sub surface space.
- **More legal protections for trees**. Put trees on par with other street infrastructure so that existing legislation will more effectively protect existing trees.
- **Transforming guidance into legislation**. Update the existing guidance in line with recent advancements and evidence and make it mandatory through legislative changes.
- **Payment for ecosystem services**. Explore this as a funding mechanism for urban tree establishment.

This report was presented to the Trees and Design Action Group (TDAG) who bring together stakeholders from a range of disciplines to improve knowledge and good practice to support urban trees. The findings were also incorporated into GreenBlue Urban’s Highways and utilities guide.

2. Trial of adapted Miyawaki method planting

Introduction

Urban trees provide so many well documented benefits to both people and nature, yet they face many barriers to establishment. More extreme weather events such as prolonged periods of drought or flooding can make it difficult for young trees to survive and establish to a point of being self-sufficient. In urban areas trees are also subjected to acts of vandalism which are detrimental to their growth. It can be difficult to find appropriate land and where trees have been planted by local councils, pressures facing local authorities can often mean they are not able to care for them.

As a result of these challenges, survival rates within the first three years are often low, meaning that tree planting in urban areas is often perceived as unreliable and costly. Exploring tree planting methods that are appropriate for an urban setting, realistically deliverable within local authorities, and that promote high survival and establishment are therefore key to informing cost-effective choices and delivering the benefits of trees to urban areas.

The Miyawaki tree planting methodology proposes a way of establishing trees with the potential to withstand some of the pressures facing urban trees. Developed by Japanese botanist Dr Akira Miyawaki, the method's original objective was to restore native forests on deforested or degraded land. The method has since formed the basis of the 'micro wood' concept, where small urban plots of land can be densely planted on poor or degraded soil with a variety of native tree and shrub species to create biodiverse woodland habitats (Defra, Forestry Commission, 2023). At the time of project inception, there was only thought to be one such plot in the UK and it was therefore a concept that required practical research.

The pilot aimed to trial this method to understand how it can be delivered by a local authority, how trees planted using the method might establish within the first years of planting and how cost effective the method is when compared to standard practice planting.

The following sections describe the experimental Miyawaki trials implemented by the project in four of the partner local authorities; Kent (lead), Chichester, Norfolk and Cornwall. Firstly, the pilot is outlined and the principles of the Miyawaki method are described, then the trial design is explained including the Miyawaki and control plot specification. The results from the first two years of data are used to outline the total plot costs, survival rates, and cost per tree, which is then accompanied by a discussion.

Pilot outline

This project trialled an adapted Miyawaki method at 16 different sites across the four participating local authorities. The experimental Miyawaki plots were planted alongside control plots which used standard practice planting[1] to compare the results of each planting approach on the same site (see table 2). A cost analysis was conducted across all the plots to understand the cost effectiveness of the Miyawaki experiment approach compared to the controls.

The main research questions underpinning the project were:

- Is the adapted Miyawaki method planting a cost-effective way to deliver increased urban tree cover?
- Are there additional benefits / effects of the method?
- How can local authorities be supported to deliver the adapted Miyawaki planting method?

Miyawaki method outline

The broad outline of the Miyawaki method is to; conduct a full site analysis, grow plants from seed sourced locally, and plant indigenous pioneer and secondary successional tree species closely together to quickly achieve a climax canopy (Nargi, 2019). The method also requires soil improvement via aeration and enriching the biome with organic material and mycorrhiza.

The Miyawaki method has been used successfully to recreate thousands of hectares of forest rapidly, predominantly in tropical Pacific regions for the purposes of water retention, stabilising eroding land and protection against natural hazards such as coastal defences against tsunamis and typhoons (Miyawaki, 1999).

Though initially designed for tropical climates and large scale purposes, the reported success the Miyawaki method has in quickly establishing and restoring woodland suggested it was worth investigating for applicability in a UK context.

Key aspects of the methodology can inform an **adapted Miyawaki method**[2] suitable for tree establishment in the UK climate and in much smaller urban settings. In this scaled down and practical approach, a variety of native tree and shrub species are densely

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[1] Standard practice planting refers to that standard method of planting employed by the participating local authorities at the time. A more detailed explanation can be found in the control plot specification below.

[2] The key differences between the adapted Miyawaki method used in this pilot and the original method are that stock grown from locally sourced seed was not available, trees were sought from local nurseries instead. The plots were also significantly smaller in this pilot meaning that a full site analysis including existing vegetation was not completed. The original method is designed to be adaptable to specific site needs.

planted in a small area that is intended to be self-sustaining after 2-3 years and to replicate the natural processes of a biodiverse woodland habitat. The soil is also aerated and improved with organic material such as mulch or mycorrhizal tea. This approach is therefore particularly suited to urban areas where soil is degraded. It aims to create a small naturalistic secondary growth woodland style area and rapidly increase the biodiversity potential of a site.

Though there was theoretical potential that an adapted Miyawaki method could be a practical option in urban areas of the UK, at the beginning of the project there had been no practical application which tested the viability of the method, compared to usual planting practice, and its cost effectiveness.

Trial design

This pilot aimed to test an adapted Miyawaki method as a means of successfully establishing trees in urban spaces in England. To understand the results both in terms of tree establishment [3], and the cost effectiveness, the Miyawaki plots were planted alongside control plots containing standard practice planting. Standard practice planting in this instance means the typical approach taken by local authorities when establishing trees in urban spaces. The specifications for both the Miyawaki and control plots are outlined below.

Miyawaki plot specification

There are 4 main guiding principles underpinning the pilot's adapted Miyawaki method for tree planting:

- **Densely planting a mix of native tree and shrub species:** planting 3-5 stems per square meter to increase competition and symbiosis, aiming to speed up growth and maximise ecosystem services.
- **Aerating or rotavating soil:** where ground is severely compacted, digging the soil up to a meter deep allows space for tree roots and beneficial soil fauna to spread. This was achieved in a variety of ways, with mini diggers, spades etc.
- **Adding biological enhancements such an inoculation with beneficial microorganisms and organic material:** introducing nutrients back into the soil, particularly where it has been degraded, aims to kickstart an ecosystem that will aid newly planted trees.
- **Maintenance:** Once planted, the plots were maintained with watering, mulching and weeding for the first 2-3 years.

[3] In this context, the term 'establishment' means survival after 2 years.

Across this pilot, varying applications and combinations of these components were implemented. Where possible the plots were planted using the full pilot adapted Miyawaki method (all four principles above), however not all the plots contained every component. In some cases, this was due to the limitations of the site and/or availability of materials within the local authority. As the Miyawaki methodology is not prescriptive, it allows for site specific adaptation.

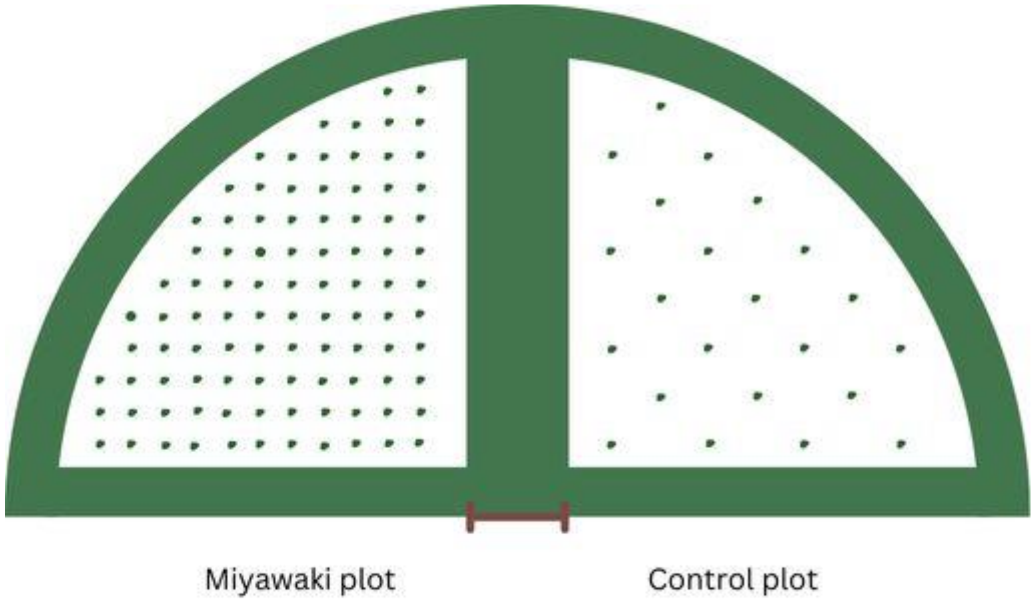

Figure 1. Diagram shows an example of the planting density where the Miyawaki plot is densely planted with at least 3 trees per sqm, with a corresponding control plot where trees are planted at 1 tree per sqm as per standard practice planting, with a 3 metre wide grass strip separating the 2 plots. The dots are indicative of planting density, not of layout.

Control plot specification

The adjoining control plots were separated by a 3 metre wide strip (see figure 1). The method used for the control plots followed standard practice planting within participating local authorities, which is typically pit/notch planting into uncultivated ground. The control plots were all planted with 1 stem per square metre, with work carried out by the same contractor as the experimental plots. Standard practice planting also indicates that trees should be watered and mulched post planting.

Though it is recommended that newly planted young trees are adequately cared for by applying water and mulch whilst they establish, constraints of local authorities mean that this maintenance is not always carried out. The overarching aim for this pilot is to understand how Miyawaki plots compare to standard practice planting. Therefore, owing to different standard practices across local authorities, there was variation across the plots. However, a paired approach was used to ensure that each control plot was specific to its paired experimental plot. For example, where watering was possible at the site, it was done on both the control and the experiment equally. The control plots were planted at the same time, by the same people, and all the trees across the control and Miyawaki plots were sourced from the same nursery. This approach enabled the trials to be representative of a real-world context of delivery through local authorities. To see the exact specification of each of the paired plots, please see the table of plots below at the end of the ‘implementation’ section (table 2).

The table below summarises the specification for both the Miyawaki and control plots, and thus their differing variables.

Table 1: summary of adapted Miyawaki and control methods.

Plot treatment	Miyawaki Experiment	Control
Ground preparation	Yes	No
Soil enhancements	Yes	No
Tree density	3-5 per square metre	1 per square metre
Tree specification	Whips	Whips
Watering	Yes	Yes
Mulch	Yes	Yes

Implementation

Site selection

Each of the sites across all four participating local authorities were in urban areas with some degree of public access. The areas fell under a range of locations and landowners including schools, borough and district council owned land in the form of urban fields and recreation parks, and housing association land manged by resident and community groups. Project officers narrowed down and selected potential sites by considering availability, air pollution hot spots, areas with below average tree cover, sites that could connect existing urban habitats and areas with high levels of development or higher levels of deprivation. Also considered was soil condition, only sites that were suspected to have degraded soils were selected, so that soil decompaction methods were not used on intact soils, and as the purpose of this trial was to understand if the adapted Miyawaki method could aid tree establishment in these conditions.

The sites were subject to underground service and utility checks through consultation with appropriate departments within the local authority such as the highways and planning teams. Where necessary, residents and/or community leaders were consulted through public notices and parish council meetings. A memorandum of understanding between the landowner and the local authority was agreed and signed which stated that the selected land could be used for trial purposes, and that control would be handed back after March 2025 when the project comes to an end.

Tree selection

1. **Miyawaki**

Tree selection at each site was determined by:

- The site geology and soil type.
- The local native species of that area, including those that are rare or locally extinct. Publicly available pollen core data was used to assist this process.
- Availability of trees at local nurseries.

As per the Miyawaki method, the five major species that are most commonly found in the area makes up the majority of the species mix. Common supporting species and minor species constitute the rest. Each of the species are allocated to different layers in the mini woodland; shrub, sub-tree, tree, or canopy.

2. **Control**

For the control plots, the same species selection and proportion of trees were used as the Miyawaki plots to enable comparison. They were also sourced from the same nursery at the same time to the same specification, including size.

Site preparation

1. **Miyawaki**

Labour and materials were procured including tree guards and stakes where required. Organic material such as comfrey or alkanet tea were procured locally, as well as mycorrhizal fungi.

The groundworks were then carried out where the earth was decompacted. This was done by a range of methods such as the use of a mini digger where the ground was dug to 1m depth. In other instances, the ground was rotavated, or the soil was aerated using an auger.

Following this, fencing was erected around the whole site, encompassing both the control and Miyawaki plots. This was a protective measure against pests such as rabbits and was intended to work as a deterrent to potential vandals to also preserve the integrity of the trial plots as much as possible.

2. **Control**

Grass around the base of the tree was cleared or supressed with mulch.

Planting

1. **Miyawaki**

The trees were planted unsystematically with the aim of creating as natural a formation as possible into the freshly turned earth, with slower growing trees nearer the outside perimeter. Mycorrhizal fungi was added during planting as per the method outlined above, and organic liquid feed and mulch were applied following planting. The trees were either pit planted or slit/notch planted, depending on the favoured method of the local authority.

2. **Control**

In some plots, mulch was applied to the base of the tree. The trees were planted using the same method as their corresponding Miyawaki plot.

Maintenance

1. **Miyawaki**

Miyawaki plot maintenance involved the removal of debris (i.e., rubbish) and weeds. The plots were also watered during the summer period following their planting, and in some instances on a yearly basis afterwards. This was due to particularly long periods of drought in some regions. In some cases, mulch was also reapplied in the first two years where it was deemed necessary for weed control.

2. **Control**

The control plots were watered at the same frequency as their corresponding Miyawaki plots. No other maintenance was carried out as is consistent with local authority usual practice.

Table 2: Details of all the plots can be found in the following table.

Pilot information	Soil Preparation								Maintenance					
Local authority	Year	Plot name	Plot type	Plot size (sqm)	Trees planted	Ground preparation	Soil microbes	Organic material	Liquid feed	Mulch Y1	Watering Y1	Mulch Y2	Watering Y2	Mulch Y3
Chichester	21/22	MRC	Miyawaki	105	315	Rotavated	Y			Y	Y			
Chichester	21/22	MRC	Control	107	107						Y			
Chichester	21/22	EBW	Miyawaki	165	495	Rotavated	Y			Y	Y			
Chichester	21/22	EBW	Control	165	165					Y	Y			
Chichester	21/22	EBG	Miyawaki	108	324	Rotavated	Y			Y	Y			
Chichester	21/22	EBG	Control	70	70					Y	Y			
Chichester	21/22	PM	Miyawaki	383	1145	Rotavated	Y			Y	Y			
Cornwall	21/22	CPS	Miyawaki	300	450	Soil turned to 1m	Y	Y	Y	Y		Y		
Cornwall	21/22	CPS	Control	300	150					Y		Y		
Cornwall	21/22	CSSG	Miyawaki	300	450	Soil turned to 1m	Y	Y	Y	Y		Y		
Cornwall	21/22	CSSG	Control	300	150					Y		Y		
Cornwall	21/22	CSSF	Miyawaki	200	120	Weed clearance	Y	Y	Y	Y		Y		
Cornwall	21/22	CSSF	Control	200	40	Weed clearance				Y		Y		
Kent	20/21	PW	Miyawaki	177	531	Soil turned to 1m	Y	Y	Y	Y	Y	Y	Y	Y
Kent	20/21	PW	Control	177	104						Y		Y	
Kent	20/21	FF	Miyawaki	250	750	Rotavated					Y		Y	
Kent	20/21	FF	Control	250	243						Y		Y	
Kent	20/21	SR	Miyawaki	195	585		Y	Y		Y	Y	Y	Y	Y
Kent	20/21	SR	Control	195	195						Y		Y	
Kent	20/21	SV	Miyawaki	119	357	Soil turned to 1m	Y	Y	Y	Y	Y	Y	Y	Y
Norfolk	21/22	SH	Miyawaki	185	559	Soil turned to 1m	Y	Y	Y	Y	Y			
Norfolk	21/22	SH	Control	185	186					Y	Y			
Norfolk	21/22	FK	Miyawaki	100	313	Soil turned to 1m	Y		Y	Y	Y			
Norfolk	21/22	FK	Control	100	102					Y	Y			
Norfolk	21/22	NW	Miyawaki	100	313	Soil turned to 1m	Y		Y	Y	Y			
Norfolk	21/22	NW	Control	100	102					Y	Y			
Norfolk	21/22	SPR	Miyawaki	100	313	Soil turned to 1m	Y	Y		Y	Y			
Norfolk	21/22	SPR	Control	100	102					Y	Y			
Norfolk	21/22	HLD	Miyawaki	185	559	Soil turned to 1m	Y			Y	Y			
Norfolk	21/22	HLD	Control	185	186					Y	Y			

Data collection

Monitoring: Nearly all the plots were planted during the winter period of 2021/22. Data was collected three times per year via walk-over survey of each plot by local authority officers.

The data collected from both the Miyawaki and control plots during these surveys included:

- Number of alive trees
- Number of dead trees
- Species of dead trees
- Assessment of likely cause of death
- Observed additional biodiversity colonising the plots
- Additional relevant information regarding the context of the survey

The survival data used in this report was gathered in the autumn of 2023.

Soil testing: Soil samples were taken at the point of planting for lab testing. Carbon and nitrogen content were assessed.

Cost monitoring: The plot costs were recorded at the point of implementation. Additional maintenance costs were recorded periodically. The costs include:

- Tree costs, broken down by species. Where this cost included guards and canes this was notified. Whether the tree was bare root or cell grown was also recorded.
- Labour hours and costs. Where volunteer labour was used, their hours were still recorded.
- Consumable costs. These include:
    - Tree stakes
    - Tree guards
    - Weed mats
    - Wood mulch
    - Mulch mats
    - Fasteners/cable ties
    - Nails screws
    - Watering
    - Biochar
    - Other soil improvements
- Infrastructure costs. These include:
    - Tools
    - Heavy machinery
    - Metal fence post
    - Wood fence post
    - General wood fence
    - General metal fence
    - Deer fencing
    - Rabbit fencing

- Metal field gate
- Wood field gate
- Wood pedestrian gate
- Metal pedestrian gate
- Benches
- Interpretation boards

Results

Table 3 below shows how much each plot cost to implement and maintain, how many trees were planted, and how many of those trees have survived.

- Roughly treble the number of trees were planted in the Miyawaki plots than the control, as per the experimental design due to the high density of planting.
- The total cost is comprised of the cost of trees, labour, consumables (such as water and mulch used to maintain the plots) and capital costs for infrastructure.

Table 3: Total cost of corresponding control and Miyawaki plots with number of trees planted and survived.

Local Authority	Plot ID	Control plots			Miyawaki plots		
		Total trees planted	Total trees survived	Total cost per plot (£)	Total trees planted	Total trees survived	Total cost per plot (£)
Chichester	EBW	165	74	7997.989	495	292	9541.233
Chichester	EBG	70	23	3877.864	324	91	6929.532
Chichester	MRC	107	31	4007.577	315	121	4956.44
Chichester	PM	N/A	N/A	N/A	1145	1109	8609
Cornwall	CPS	150	94	1494.933	450	364	2706
Cornwall	CSSF	40	14	369.6	120	77	670.3833
Cornwall	CSSG	150	102	1800.35	450	278	3011.417
Kent	FF	243	223	3956.329	750	722	6007.311
Kent	PW	104	85	2915.321	531	530	7417.709
Kent	SR	195	168	3647.704	585	565	5806.466
Kent	SV	N/A	N/A	N/A	357	341	4701.21
Norfolk	FK	102	8	1752.901	313	226	2553.03
Norfolk	HLD	186	21	2672.621	559	518	4090.844

Norfolk	NW	102	79	1695.401	313	276	2495.53
Norfolk	SH	186	19	2612.621	559	559	4030.844
Norfolk	SPR	102	18	1194.188	313	308	1669.661

Tree survival

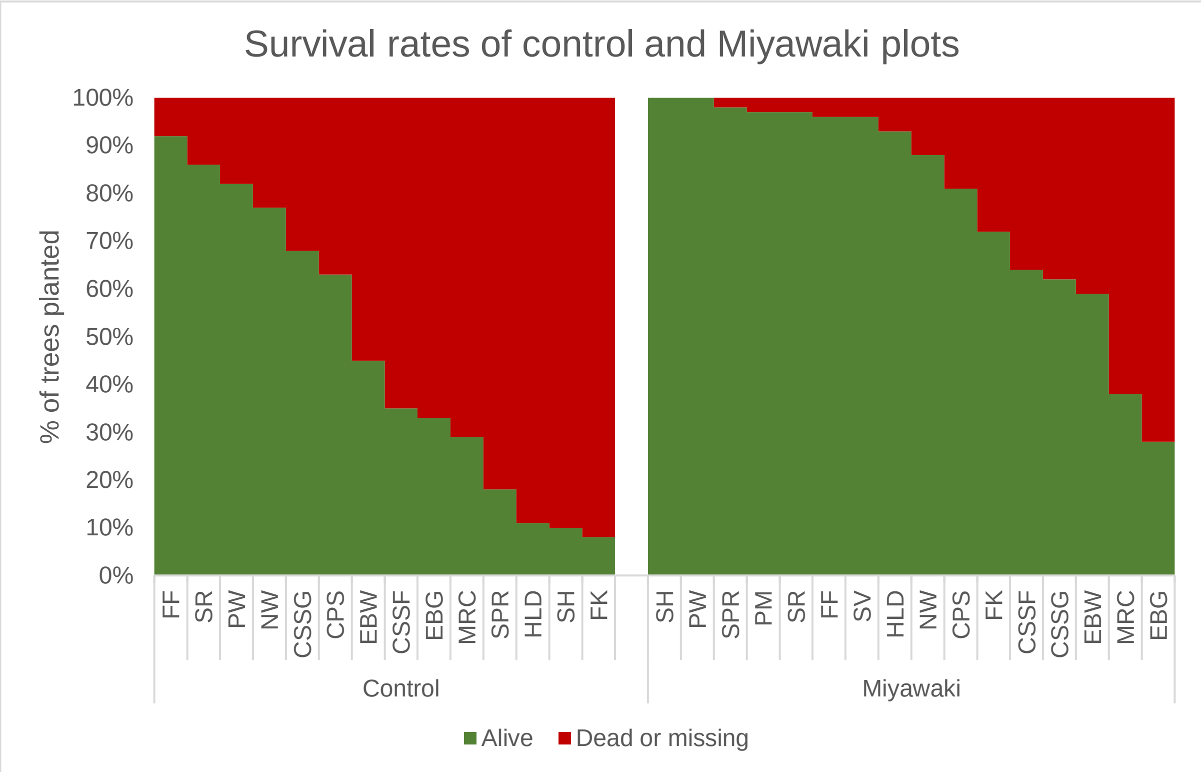

Figure 2: Heatmap showing the survival rates of the control and Miyawaki plots, where each bar represents a plot.

The graph shows the Miyawaki plots had a high survival rate, on average 79%, compared to the control plots which saw an average survival rate of 47%. These results are statistically significant, see appendix A for details of analysis.

Monitoring data indicated that where death occurred in both Miyawaki and control plots, the main cause was attributed to drought, followed by competing vegetation. The latter was more applicable to the control plots, however there was an instance where the straw mulch used in the Miyawaki plot contained seeds which sprouted, therefore providing competition for the tree whips. There were also instances where the trees either rotted or cooked inside their guards, which occurred more frequently in the control plots.

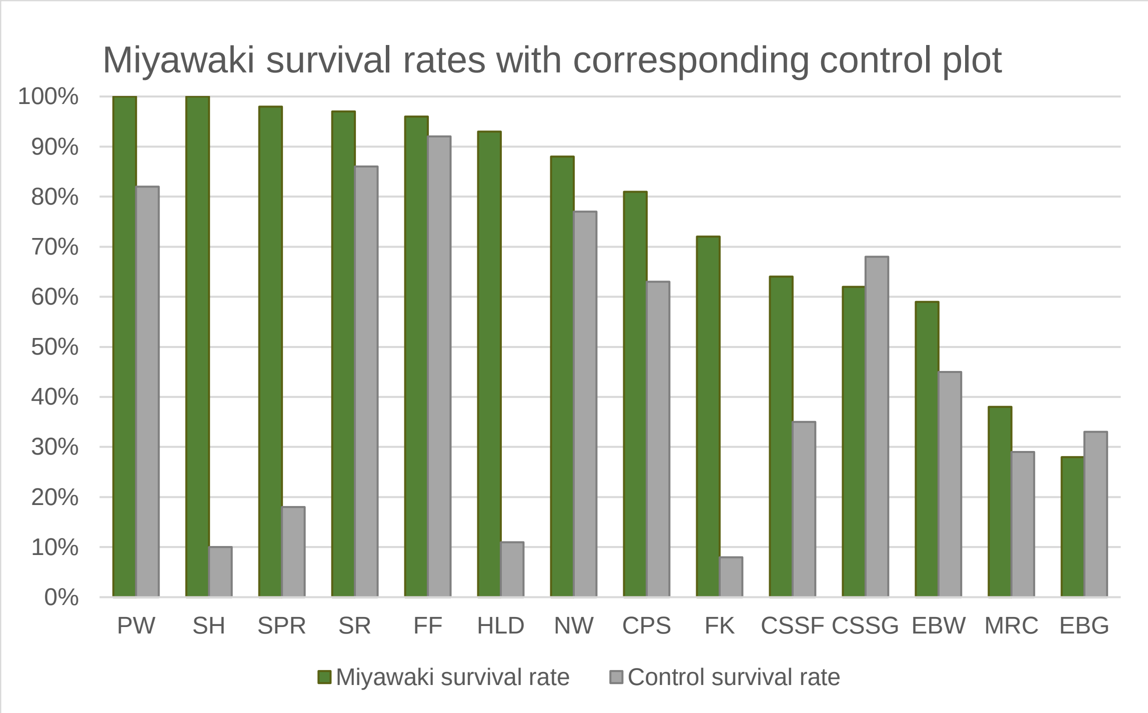

Figure 3. Survival rates within Miyawaki plots compared to each corresponding control plot. Where a Miyawaki plot did not have a corresponding control, it has been omitted.

Each paired bar is a combined Miyawaki plot and a control, which allows for comparison between the plots at each site. At each site, both plots contained the same soil type, were exposed to the same weather, and planted by the same people, to minimise any potential influence these factors may have had on survival.

On average, there is 30% difference in survival rate between the control and Miyawaki plot at each site. All but 2 of the sites (CSSG and EBG) saw a higher survival rate in the Miyawaki plot. In the case of CSSG, this could be explained by the specific plot design. This site is in school grounds, with the path and benches in the middle of the plot. It is thought that where the benches nearest the Miyawaki side were more frequently used resulting in more interference and compacted earth, causing potential damaging effect on the survival of the trees.

At 4 sites (SH, SPR, HLD and FK) there is a significantly higher survival rate in the Miyawaki plots than their corresponding control plots. All of these sites were in Norfolk, and the comparatively larger difference is driven by particularly poor survival rates in the control plots. Similarly, sites at Chichester had the lowest Miyawaki survival rates (EBW, MRC and EBG). This suggests there is a relationship between local authority and survival rate for both plot types, which could be due to materials used, contractors, site type or maintenance methods. For example, Chichester used the least amounts of additional organic material of all the local authorities and applied no additional mulch after implementing their plots, which could be a factor in the lower survival rates in the Chichester plots (see figure 3, plots EBG, MRC, EBW).

Costs

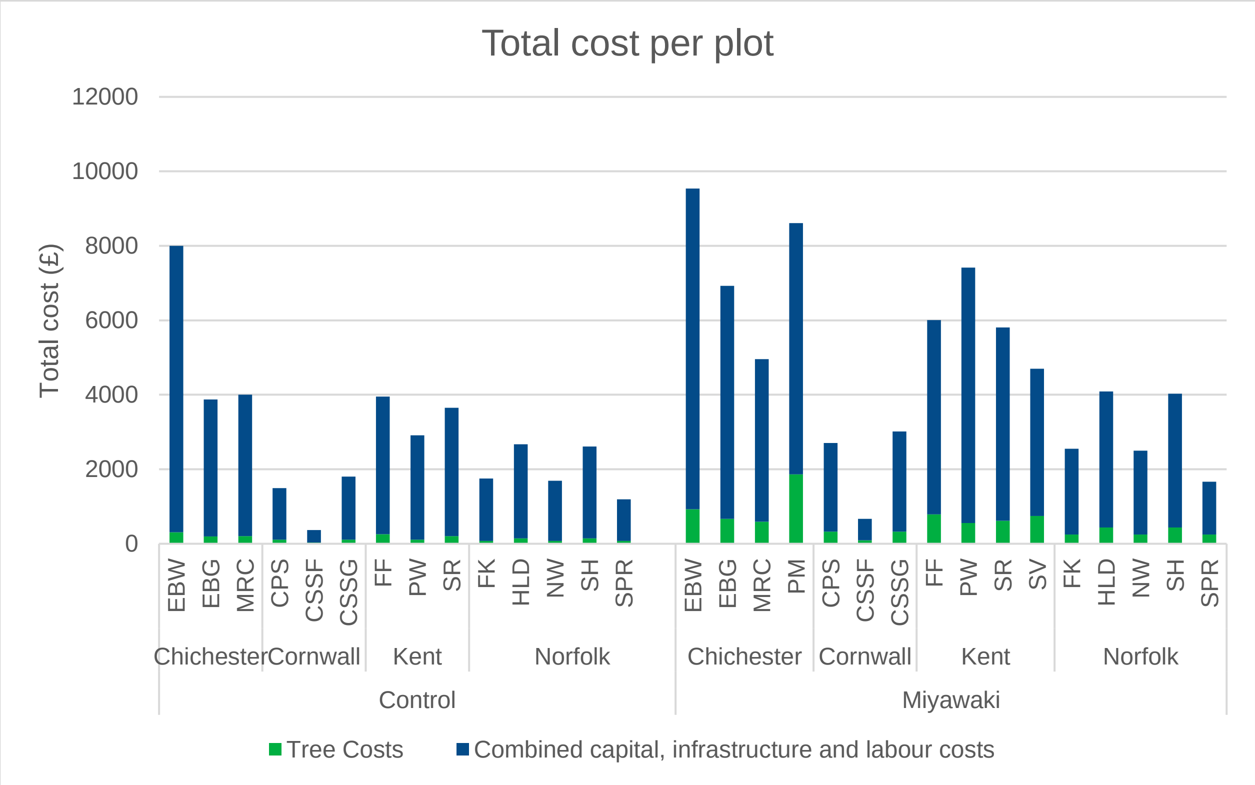

Figure 4. Total cost per plot for each control and Miyawaki plot by cost type. Each bar represents a plot. Labour, infrastructure, and consumable costs have been combined due to how they were recorded.

Overall, the Miyawaki plots had a greater total cost compared to the control plots. However, there is high variability in costs within the treatment groups, and within each pair. For instance in Chichester, MRC has less of a cost differential between treatment groups than in EBG. The higher overall cost of the Miyawaki plots can be attributed to four main factors associated with the Miyawaki method:

- Increased consumable materials such as the organic material used during planting and additional mulch post planting.
- Increased labour due to the necessary ground works.
- Increased cost of trees as the Miyawaki plots have at least three times the number of trees.
- Increased cost of labour due to this increased volume of trees.

As a result of there being these four different components to the overall higher cost, there is variability in how this affects the total cost in practice across the local authorities. For example, in Norfolk the cost of the only available organic material used during planting was comparatively higher than the other local authorities, leading to greater consumable costs. Similarly, the cost of labour also varies regionally, and where it is more expensive, there is an associated increase in cost for ground works and tree planting. This impacts the Miyawaki plot costs more than the control plots, as there is more work required for implementing the plots. On the other hand, labour costs can be reduced where volunteer labour is used, as seen in and Norfolk where volunteers were used for tree planting, so the only labour cost was for the installation of the fencing which is the same across both Miyawaki and control plots in all cases. Where this labour variable is reduced by the use of volunteer labour, it therefore results in a closer difference in overall cost between the Miyawaki and control plots, as can be seen in Norfolk.

Tree costs also vary across the local authorities due to local nursery prices, though this is generally accounts for the smallest proportion of the total cost. The variability between local authorities is also mirrored in the control plots, where there is also huge variability in total cost, such that some control plots are more expensive than other (non-paired) Miyawaki plots. For example, the Chichester EBW control plot was more expensive than all Miyawaki plots in other local authorities.

There is no single common factor that drives the greater cost in the Miyawaki plots. It can be any, or a combination of any of the factors listed above depending on locality. This is demonstrated by splitting out the plots by local authority, as in figure 5, where trends can be found within the local authority. Overall, a combination of these factors results in a greater cost associated with a Miyawaki plot compared to its control, as the Miyawaki method requires more inputs.

There is, however, still a degree of variability in total plot costs within each of the local authorities. This variability is usually caused by plot differences, including size, accessibility, and differences in the adaptation of the Miyawaki method used to implement the plots.

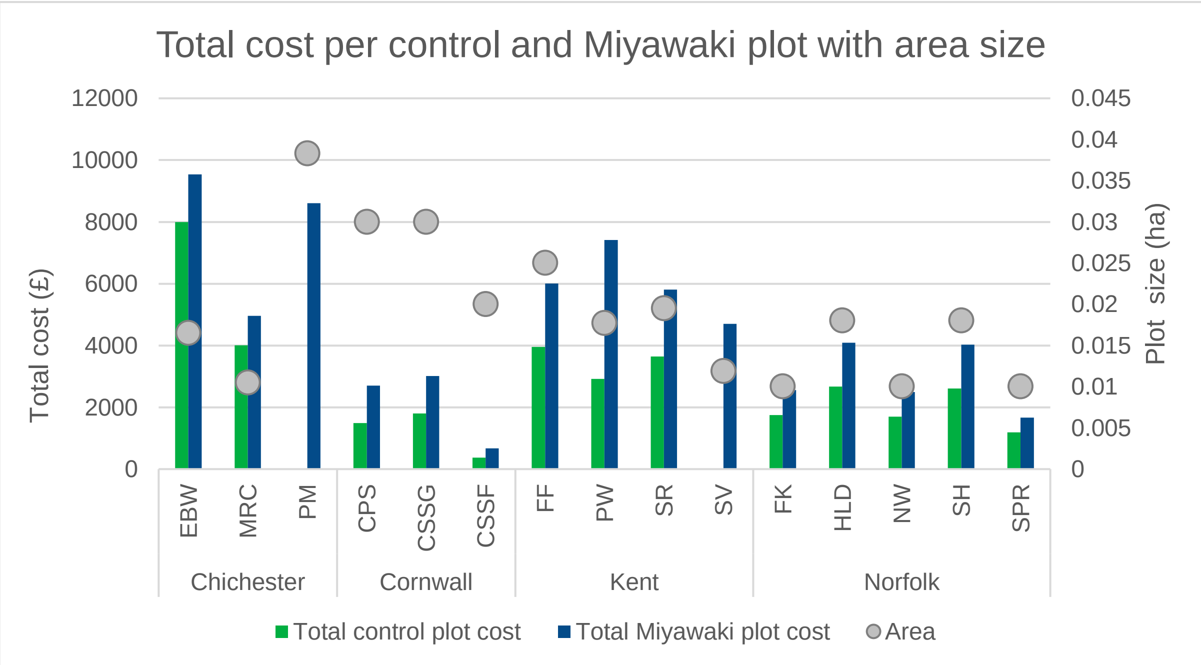

Figure 5. Paired bar chart with total costs for control and Miyawaki plots at each site, with corresponding area. For PM and SV there were no control plots at these sites.

When the total costs for both the control and Miyawaki plots are paired with their area size, a loose trend can be seen within the local authorities. For Chichester, Cornwall and

Norfolk, there appears to be a relationship between total plot cost and area size within the local authority, i.e., greater plot size may increase the plot cost, as might be expected.

However, this trend is less clearly seen among the plots in Kent than within the other LAs, suggesting that there may be additional variables that also influence the overall cost per plot. The trend for increasing cost with increasing size of plot also breaks down somewhat when viewed across the different LAs. In particular, the costs for the plots in Cornwall appear to be lower than might be expected, given their size, compared to the other LAs. This suggests that there may be both random factors that influence the costs of individual plots, and more systematic factors that may lead to the costs within a single LA being higher or lower than the average.

Figure 5 shows that the Cornwall plots had lower costs for all the components i.e., the trees, labour, infrastructure and consumables, despite their comparative larger size to other plots in other local authorities.

However, there is no indication there is a relationship between plot size and total plot cost across all the local authorities, and therefore plot cost cannot be standardised according to size. In policy terms, this poor overall relationship between plot size and total plot cost across LAs may make it challenging to standardise plot costs according to size.

Cost Effectiveness

Survival data taken together with the cost data collected over the course of the project, enable a comparison of cost per planted and cost per survived tree across both plot types.

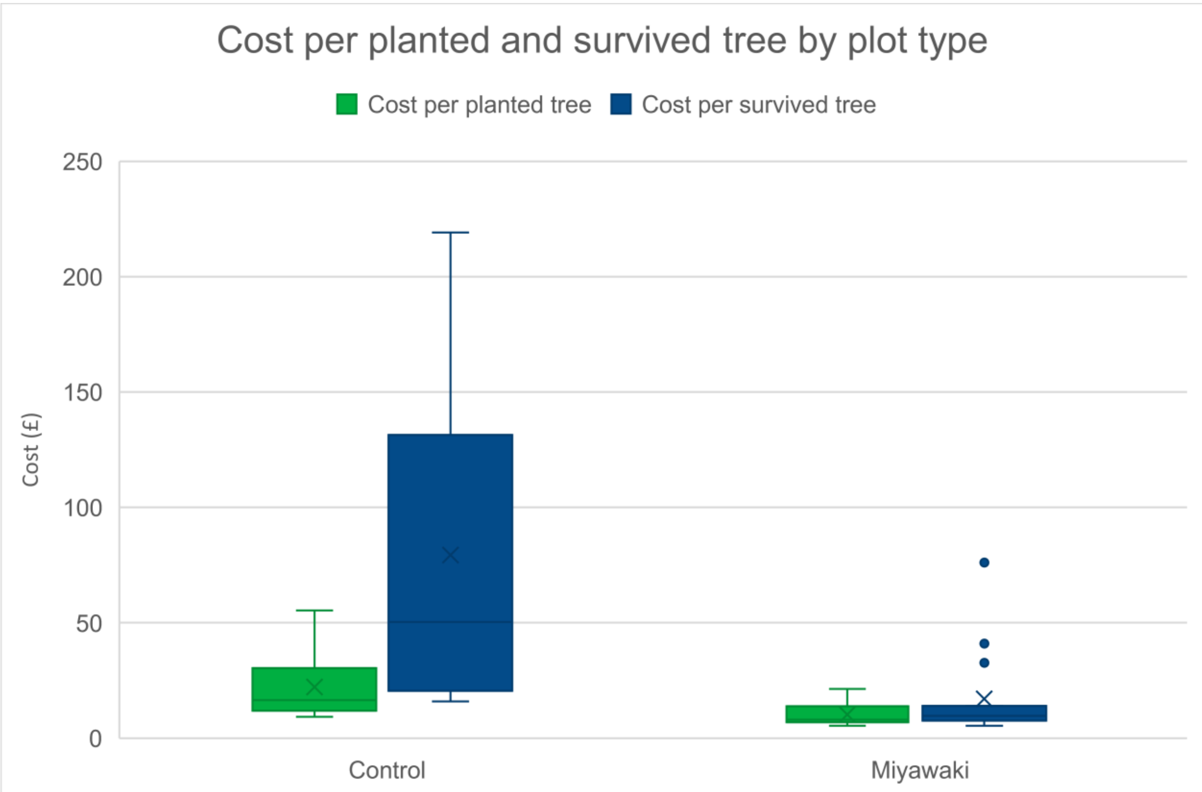

Figure 6. Cost per planted and survived tree by intervention type.

Table 4. The mean and median average cost per planted tree and cost per survived tree for the two plot types.

		Cost per planted tree	Cost per survived tree
Control	Mean	£ 22.11	£ 79.38
Control	Median	£ 16.45	£ 50.32
Miyawaki	Mean	£ 10.20	£ 16.97
Miyawaki	Median	£ 7.99	£ 9.66

Figure 6 shows that in our samples, the average costs per tree were higher and more variable in the control plots with standard practice planting, than in the Miyawaki method plots. This was the case for both planted and survived trees, but the difference between control and Miyawaki was much more pronounced when considering survived trees (those that had survived to the end of the monitoring period).

This is due to the difference in survival rates between the two plot types. The cost per survived tree when planted and maintained under Miyawaki conditions is both lower and has much less variability than control plots. Their survival rates are higher and more reliable, so the distribution of the survived cost is smaller and the average cost is lower than those on the control plots.

Additionally, there is a greater difference between the cost per planted tree and the cost per survived tree in the control plots than there is between these two costs on the Miyawaki plots. This is also true of their distribution. Again, this shows how the more consistent survival rates across the Miyawaki plots gives a more consistent cost per established tree, where the control is very varied. This is also evident in the variation across the different averages shown in table 4.

Plot images

Below are photographs taken by project officers of plots CPS, PW, SPR, EBG. In each photograph the trees planted using the adapted Miyawaki method are visibly larger. The exact same size trees were planted in paired experimental and control plots.

Image 1: CPS plot with control on the left and Miyawaki plot on the right. Taken in June 2023.

Image 2: PW plot with control on the left and Miyawaki plot on the right. Taken October 2023.

Image 3: SPR plot with Miyawaki plot on the left and control on the right. Taken October 2023.

Image 4: EBG plot with Miyawaki plot on the left and control on the right. Taken October 2023.

Discussion

Variability of implementation

This pilot wanted to explore how trees planted in the Miyawaki method compare to those planted using standard practice. However, the pilot also aimed to understand how the method can be practically interpreted by local authorities. There was therefore a degree of variability in how the Miyawaki plots were implemented, due to a number of factors such as the availability of materials, labour, and the chosen method of ground works. The trials were designed to be guided by the Miyawaki principles with the aim of investigating how local authorities could practically implement Miyawaki plots within their local area, and to understand their associated costs. As a result of this non-prescriptive approach, each local authority implemented their Miyawaki plots using slightly different methods that were most appropriate or achievable, which must be considered as a backdrop to the survival and cost results.

Survival

Despite the variability in how the Miyawaki plots were implemented, these plots showed a high overall survival rate of 79% and a lower variability of survival rates than the control plots, where the approach was more standardised, but the average survival was only 47% and was also more variable.

Although further testing and replication of the Miyawaki method is needed before evidence is conclusive, these results indicate that in these urban situations where land is degraded, using elements of the Miyawaki method can result in relatively reliable and high survival rates for newly planted trees. However, it is recognised that the sample size was relatively low with not all factors controlled for, and that this project has gathered monitoring data from only the first two years of planting. This is a limited amount in terms of tree survival, although monitoring of these plots is planned for a further two years.

As described in the methodology, there were four main components to the Miyawaki method; the dense planting of a diverse mix of species, ground works, the addition of organic material when planting, and maintenance through the repeated provision of mulch and water. This trial was not designed to disentangle the contributions of these individual components to understand how each of these individual components, or any of their combinations, effects survival. However high survival rates across the Miyawaki plots have informed how further tests can be designed, which will be the subject of further studies outlined below. In the meantime, observations collected from the project officers during their monitoring surveys give some indication of how individual components of the Miyawaki method may have influenced survival.

The summer of 2022, the year in which all Cornwall, Chichester and Norfolk plots were planted, was especially hot as temperatures exceeded 40 degrees, with long periods of drought. These were challenging conditions for newly planted trees, particularly in Norfolk, where it was especially dry, which could have been a contributing factor to the lower survival rates in the control plots. However, in these drought conditions, the Miyawaki plots across all the local authorities still managed a high survival rate, and a higher survival rate than the control plots, although both plots were watered at equal frequencies and with equal amounts per area.

Further testing and analysis would be needed to fully understand how the drought affected the plots. Observations to date suggest that the density of the trees in the Miyawaki plots may have led to greater shading and reduced air movement and therefore helped with water retention and transpiration, which aided their survival in hot dry weather. The Miyawaki plots were also mulched across the entire plot, whereas where mulching was applied on the control plots, it was placed around the base of each whip at a 25cm radius. The greater volume of mulch on the Miyawaki plots may also have helped to retain soil moisture across the whole site, rather than in discrete patches.

Mulch also helps to supress competing vegetation which can otherwise overcrowd and deplete the resources surrounding the tree. Project officers reported during their monitoring that the control plots had a greater volume of weeds which was thought to be impeding the growth and survival of the newly planted whips. Interestingly, this correlates with the result from one of the Miyawaki plots at site EBG, where the mulch used on both the control and Miyawaki plots contained weed seed. The mulch then produced a high volume of weeds which crowded out trees across the whole site, but the Miyawaki plot to a greater extent due to the higher volume of mulch used, resulting in a lower survival rate on this site on the Miyawaki plot.

There is little to suggest at this point how the addition of organic material effected tree survival, similarly with the diverse mix of species. Further research is planned to investigate this in phase 2 of the project.

Growth rates

Not only did the Miyawaki plots see higher survival, but observations gathered by the project officers show their growth rates were also significantly higher, and the trees were substantially larger than their control counterparts. This can be seen in the photographs of the plots in the results section above.

Again, the available data cannot explain how the Miyawaki plots achieved this result, and the pilot has not specifically measured the growth rates to know the extent of their difference. However, this result aligns with the suggestions which underpin the method, i.e., that dense planting of the trees encourages competition and quick growth, and the additional organic material improves the soil to allow for successful root development. As a result of this higher growth rate, the Miyawaki plots may deliver ecosystem services quicker than the trees planted in the control plots during this time. The ongoing plot monitoring will include measuring growth rates in 2025.

This overall early establishment success and growth rates shown in the Miyawaki plots can provide land managers with trees that overcome the difficulties associated with early establishment, and the plot can subsequently be managed to suit specific needs. For example, in urban areas the quicker growth allows for a more instant impact, which may also reduce the impact of vandalism. Whereas on the control plots, across the pilot over half of the planted trees have been lost, and they have not grown to the same height, leaving the risk that survival rates could fall further and reduce the impact of the plot.

Cost effectiveness

The results show that the initial cost of implementing the Miyawaki plots were consistently higher than that of their corresponding controls. This is to be expected due to the additional labour and resources required by the method, and also the increased volume of trees. The results also indicate how the cost of implementing the plots varied across the local authorities due to the range of implementation methods as outlined previously. Where the costs varied within the local authorities, plot size is shown to be an influential factor, however other factors must be at play that also influence cost both between and within local authorities, as demonstrated by this trend breaking down when viewed across all local authorities.

However, the cost effectiveness of the approaches is better understood when comparing the cost per planted tree with the cost per survived tree for both methods. This is because the cost per survived tree considers the survival or potential establishment of the trees, which is where the focus is most valuable. Trees which fail to survive do not deliver any benefits are therefore not only a waste of money, but also incur other negative impacts such as the carbon cost of repeatedly replacing dead trees in urban settings.

The consistently high survival rates of the Miyawaki plots means that the cost per survived tree is kept lower and less variable (the mean cost is £16.97 and the median cost is £9.66). By contrast the lower survival rates of the control plots mean that the cost per survived tree is much higher than both the cost per planted tree, and also the cost per survived tree in the Miyawaki plots (the mean cost is £79.38 and the median cost is £50.32). In this way the Miyawaki plots can be viewed as a more reliable method of ensuring tree survival over this period of time, thereby making it a more cost-effective approach for getting trees established in the early stages than standard practice planting.

A question that arises here is whether the increased survival rate of the Miyawaki plots is sufficient to mean that they would be more cost effective than their paired control plots, even if the planting density was the same for both plots. Assuming the Miyawaki survival rates stayed the same, analysis shows that for half of the paired plots, the Miyawaki plots would still have a significantly higher number of alive trees compared to their controls. In these cases, assuming also that implementation costs were the same (except the tree costs, when of course they should be lower, as shown in the ‘results: costs’ section above), this means the cost per alive tree would still be cheaper in the Miyawaki plots than the controls in half of our trials, if the planting density had been the same.

At this stage the finding is that the Miyawaki plots seem to have a more reliable early establishment rate compared to the controls, meaning the initial investment, whilst relatively high, represents a more reliable way to ensure trees survive the first two years of establishment. This finding has been true even in variable climatic conditions, which are likely to be more prevalent in the future due to climate change.

Due to the time-limited nature of this project, the discussion around the cost effectiveness of the methods can only be considered in relation to early establishment. Establishment of trees particularly in urban areas can be perceived as costly and unreliable, as outlined in the introduction. However, due to the rapid early establishment rates, the Miyawaki method could provide a cost-effective way of overcoming particular challenges of growing trees in the urban environment, such as drought, vandalism, and degraded soils.

Control method of planting

Though it is not clear from the data currently available how each of the Miyawaki components effect survival, it is clear the Miyawaki plots in our pilot study do have a significantly higher survival rate than the control plots, where there is an average survival of 47%. Though this pilot has a small sample size, the lower survival rates add to the existing anecdotal evidence that the standard methods of tree planting in urban areas is unsuccessful around half the time.

This is an important finding alongside the benefits of the Miyawaki method. While the Miyawaki method is still early in use in UK urban contexts and there are various aspects about the method and its application which need further investigation, what is shown from the poor survival of the control plots is that improvements are needed to the current approach. Theoretically, the standard method of tree planting should have all the necessary components for tree survival and establishment within the first few years of planting. However, the pilot benefits from real world application of this theory and demonstrates that not only is it inconsistently applied within local authorities, i.e., there are instances where watering or mulch hasn't been applied, but also where it has been fully applied, survival is still inconsistent.

While these trees may perform better with consistent maintenance approaches like watering, weeding, and mulching, the Miyawaki method seems to be more robust against the various challenges of planting in urban settings. This may be partially due to the prescriptive nature of planting using an established 'method', resulting in a more consistent and effective approach. Alternatively, it could be as a result of the fast-growing nature of the trees planted with the Miyawaki method, that they are able to be more quickly at a stage that they are able to cope with the various challenges of their urban setting, and / or the constraints of the local authority in delivering maintenance.

Unknown futures

This project will monitor these plots until September 2025, after which further research will be needed to understand how they perform over the longer term. Beyond the end of the project, the management of the plots will be handed back to the landowner, from which time they can choose how to manage the plots. While recommendations and guidance documents will be issued regarding long term management of the plots, there is a risk that the plots will be manually thinned or removed altogether. Therefore, this project is unable to explore the hypothesis of the plots' long-term survivability and structural development, and at the moment can only discuss the success of the Miyawaki plots in terms of their survival in the first two years compared with standard practice planting, as per the results.

There is a question as to what significance or implication this early establishment has on the longer term survival of the trees. As stated previously, though there has been an increase in new Miyawaki plots across England over the past 5 years, all the plots are still very young. Subsequently there is little evidence to draw on to support ideas of how these Miyawaki plots could look in the future, so discussions around this remain speculative.

One theory is that the Miyawaki plots could operate like a mini woodland, with self-sustaining layers, as per the larger pioneering Miyawaki forests in Japan. Another is that due to their smaller area size, the plots would naturally self-thin as larger trees out compete the smaller ones, so that in 50 years' time the plots contain a handful of semi-mature trees. For the control plots, at this stage due to their lower survival rates and relative size, it is unclear as to what their longer term survival might look like, despite the standard nature of their planting. In the best case scenario, if all the trees that are still alive survived over the next 50 years, the trees might again naturally thin with the end result therefore being similar to that of the Miyawaki plot.

However, in this speculative scenario where the plots might look similar in 50 years-time, there may be differences in benefits delivered by the two plot types during this period. For example, they might provide different biodiversity benefits as the different planting densities create different habitats. The thicket-like nature of the Miyawaki plots could provide a good environment for birds, while the increased vegetation in the control plot could provide good conditions for invertebrates. However, the total ecosystem services provided by the Miyawaki side might be greater due to the volume of trees and as their early establishment means they provide seed, pollen and nectar more quickly.

An alternative hypothesis is that the trees in Miyawaki plots will not self-thin effectively, and will instead become tall, weak, and crowded, making them prone to problems such as windthrow. There is little evidence of this so far, but as stated previously it is too soon to be sure. However, there is no certainty as to whether or not the quick growth will contribute to long term health or survival of the trees, and more research is needed in this area.

Public engagement

Across all the plot locations, local residents and communities were engaged by the landowners throughout the planning process, and signage was erected to explain the experiment and the Miyawaki method. Project officers reported anecdotally that the public engaged positively with the plots by regularly asking questions and offering supportive comments.

Vandalism is cited as a common challenge to establishment of urban trees. This occurred at three of the control plots where the whips were snapped and / or ripped from the ground and there was also one instance of a gate to the enclosure being stolen. But there were no reports of vandalism to the Miyawaki plots. It is thought that the dense nature of the planting provided a thicket like environment that acted as a deterrent as it was difficult to penetrate or damage. It is also possible that experimental nature of the plots also garnered curiosity.

The positive public reception of the Miyawaki plots show how they have the potential to deliver social and wellbeing benefits at a greater rate than trees planted through standard practice planting, due to faster growth. In some instances, the early engagement with the public resulted in the recruitment of volunteers for planting, which not only delivered the additional benefits associated with tree planting, but also helped reduce the total cost of implementing the plots.

Looking ahead

As previously mentioned, this project is conducting ongoing monitoring on these plots until September 2025, to collect more robust survival data and understand more about the important first 4 years of tree establishment using the Miyawaki method.

In addition, further research is being undertaken to try to understand whether there are particular elements of the Miyawaki method, or a combination, that contribute more to the strong survival and growth rates. This is important to understand as there are elements of the Miyawaki method that are financially costly that could possibly be tweaked. If it could be understood which of the components is particularly driving survival, then the overall cost of implementing the plots could be reduced if not all the components are found to be necessary for certain outcomes. There is also a particular focus on understanding which methods are best used for manual ground decompaction, or even if it is necessary. In many urban areas, the soil is compacted which can make it difficult for roots to establish. But there are concerns that digging up to a metre deep can damage the soil further and release carbon at a volume that exceeds the amount that a young Miyawaki plot can sequester. As the initial trial design reported on here was intended to scope out the possibilities of the method in urban settings, this question cannot yet be answered by the research so far.

Conclusion

Urban tree planting can be difficult and costly. The average survival rate across the control plots in this trial is slightly less than 50%. Although this pilot has a relatively small sample size, this result corroborates anecdotal evidence that urban tree planting is unsuccessful around half the time. Therefore, there is an opportunity for improvements to be made to tree planting methods to increase success rates and cost efficiency.

The adapted Miyawaki method plots in this pilot, which were trialled as a possible method of improving tree planting in urban settings, saw an average survival rate of 79%. Additionally, early growth rates have been higher in Miyawaki plots than controls. Again, this pilot has a relatively small sample size (which is not balanced between treatment types) and length of evaluation (1-3 years). Therefore, conclusions drawn around this survival data are only short-term and indicative. However, after 2-3 years, the pilot’s adapted Miyawaki method plots generally resemble a dense thicket of young trees and the control plots are largely areas of long grass with some individual trees around waist to shoulder height.

These results imply that this method gives newly planted trees early resilience to challenges particularly prevalent in urban tree planting, such as drought, soil degradation, and vandalism. The experimental plots suffered from these effects less than the control plots, probably due to the additional mulch/soil enhancements and taller, denser growth. These elements of the adapted Miyawaki method can create plots that are cooler and retain more water, are less easy to vandalise, and kickstart restoration to degraded soil. The trees are also on track to provide the ecosystem services that will benefit urban areas more quickly (access to nature, biodiversity, carbon capture, pollution buffering, flood mitigation, and cooling), as they are growing faster and producing substantially more biomass in the early years post-planting.

Therefore, the adapted Miyawaki method seems to be highly effective for improving tree planting success in urban settings. However, it is important to reiterate that this experiment and the use of the method in general in these UK urban contexts is relatively new in tree planting terms, and therefore the long-term results of the method can only be speculated based upon knowledge of tree characteristics in other contexts or using other planting methods.

It is also important to consider the cost-effectiveness of the method. The total cost of implementing the adapted Miyawaki method was more expensive than the control method, which is due to the increased inputs of trees, organic materials/mulch, and labour (for ground preparation, planting an increased number of trees, and maintenance). However, whilst it is unclear how many trees will survive longer-term in both experimental and control plots, at this stage the cost per planted tree was lower on the experimental side, and still lower was the cost per survived tree. This is due, respectively, to the increased number of planted trees and higher survival rates on the experimental side. The costs on the experimental side were also less variable than the control, due to greater consistency of survival rates when using the adapted Miyawaki method. This reliability is an important benefit in the current UK context of tree cover targets.

Although further trial replication would be required to make firm conclusions, this research suggests that this adapted Miyawaki method can be a successful, relatively fast, reliable, and cost-effective way of establishing young trees in UK urban contexts.

There is potential to cause damage to soils through this method, through digging over to a depth of 1m, and therefore careful consideration should be given as to whether the planting site requires this intervention or if it could cause more harm than good and release carbon into the atmosphere through oxidation of soil organic carbon. However, on degraded soil where carbon levels are low and there is not an existing healthy microbiome, the Miyawaki method can improve the soil to help trees to grow well on the site without causing unnecessary damage (as there is little soil organic carbon to release through disturbance).

Therefore, elements of the Miyawaki method could be beneficial to consider when planning new tree planting if:

- The site conditions would pose a risk to tree establishment from heat/drought, vandalism, or poor/degraded soils (if the soil is not degraded, the method could potentially be further adapted to reduce the soil interventions),
- The site would benefit from a fast growing and dense area of tree cover (or there is a plan to thin the trees if desired)

Essentially, the method is a framework for giving planted trees the best chance of survival in difficult conditions. Not all situations would benefit from every element of the method, and therefore the elements used should be carefully selected where appropriate to maximise success whilst avoiding unintended consequences or unnecessary costs. Research is ongoing into the impacts of the separate elements and will be published in due course. However, it is clear from the data so far that when appropriately applied, the method can have reliably high early survival rates and encourage rapid growth in young trees despite challenges posed by difficult sites for tree establishment.

3. Trial of natural colonisation

Introduction

In urban contexts trees are perceived as difficult and costly to establish. This project has been looking at these challenges and trialling the Miyawaki method as outlined in section 2. This is an intensive method of establishing trees, but at the other end of the scale is natural colonisation which, by comparison, requires little intervention.

Natural colonisation is a process whereby woodlands develop from stock or seed in situ. Trees and shrubs are able to disperse their seed and pollen over large distances meaning that if an area is left, then the seeds have an opportunity to grow and naturally occurring species can colonise the space.

Natural colonisation has many benefits:

- Cost effective – no upfront cost of trees and lower costs of additional works and maintenance.
- Sustainable – very low intensity of management needed.
- Adaptation - stock comes from the surrounding landscape meaning that the potential trees should be locally adapted to the prevalent conditions. As such they could be more resilient to local conditions and pest and diseases.
- Diversity - the process supports the genetic diversity of native trees and allows for a diverse range of species to occur, often more so than if trees are planted. This can be far more beneficial to wildlife and therefore increase the biodiversity of a site.
- Biosecurity – there is no risk of introducing pests and diseases onto the site through the movement of plant material.

- Natural colonisation can be a way of procuring continuous cover which is where a woodland or group of trees have layers of different species, age and size of tree. Where this successfully occurs, they work together in a system and therefore deliver benefits such as improving water quality. However, results can be unpredictable.
- Naturally occurring trees also have more mychorizal fungi in their root systems which supports the soil and the uptake of water and nutrients.

Natural colonisation has been successful at a number of sites which are rurally situated and on a larger scale. However, the process has not been trialled as method of tree establishment in urban areas. This pilot investigated the feasibility of this approach on smaller plots in urban contexts.

Pilot outline

Natural colonisation plots were identified and fenced at three locations in Kent in February 2021. To understand their development compared to a standard approach to urban tree establishment, the plots were paired with a control plot.

The pilot set out to answer the following research questions:

- Is natural colonisation a cost-effective way to increase success and enhance the benefits of urban tree establishment in comparison to traditional planting schemes?
- Is natural colonisation a more effective approach to boosting urban biodiversity in comparison to traditional planting schemes?

Trial design

Site selection

The sites were selected based on availability (the landowner consenting to plant trees) and proximity to existing trees. They were assessed for their suitability through desk-based groundwork checks. Sites were also chosen based on where urban trees might typically be planted by the local authority, considering air pollution hot spots, areas with below average tree cover, sites that could connect existing urban habitats and areas with high levels of development or higher levels of deprivation. The sites had no existing tree cover but contained grass or other vegetation. All three sites were owned by local councils who then engaged with the public regarding the nature of the trials.

Planting

The control plots were planted to similar specification as the Miyawaki control plots (see section 2 – pilot outline), employing standard methods (typically used by the local authority) – i.e., one tree (whips) per sqm of a mix of native species, slit or notch planted with stakes and guards, then watered[4]. The paired control and natural colonisation plots were separated by a three metre strip.

Fencing was erected around the entire plot to protect it from disturbance or disruption. No other preparation was made to the natural colonisation plots. This was to create the appropriate conditions to trial a minimally interventionist approach to natural colonisation, i.e., where little interference occurs to allow for natural processes.

Control and experimental plots had equal basic maintenance of watering and rubbish removal.

To trial a different approach, at one of the plots (plot ALL, see table 5) the vegetation was trimmed back and the top layer of soil was rotavated to encourage natural colonisation.

Monitoring

Walk over surveys were done on both control and experimental plots. Survival data was collected on the control plots, and any occurring tree species were recorded in the natural colonisation plots.

Results

Table 5: Number of trees planted and survived/colonised per control and corresponding natural colonisation plots, with cost per plot.

Local Authority	Plot ID	Control plots			Natural colonisation plots		
		Total trees planted	Total trees survived	Total cost per plot (£)	Total trees planted	Total trees survived	Total cost per plot (£)
Kent	ALL	95	43	4320.77	0	0	2242.83
Kent	HUD	113	64	4494.67	0	0	2305.33
Kent	WIL	188	151	4560.44	0	0	2434.49

The natural colonisation plots failed to establish any trees. It was observed that at two of the sites (HUD and WIL) oak tree seedlings did appear in the spring of each year, but these were not present by the autumn. It is thought that the vegetation crowded out the seedlings and provided too much competition for the seedlings to survive. Alternatively, the shading out could have aided diseases such as oak downy mildew, which can have a

[4] For the natural colonisation control plots, no mulch was applied.

severe impact of oak regeneration. The seedlings tended to occur in the areas where the grass was flattened by mammal tracks, or around the edges near the fence, again where there was less grass. Naturally colonised trees were also observed at all three of the control plots, but again these were crowded out as the summer progressed and the ground cover increased.

At ALL, there were no observed seedlings at any point. However, the grass and other competing vegetation at this site was a lot more vigorous than at the other two sites, suggesting the removal of vegetation only at the start of the experiment was ineffective.

Image 5: HUD site, where the natural colonisation plot is on the left and the control plot on the right.

Discussion

As trees failed to establish through natural colonisation processes, in this pilot natural colonisation was not a cost-effective method. However, the observations made throughout the trial offer some potential avenues for further testing.

The presence of saplings at two of the sites in the spring of both years indicates that there was local seed present to initiate the natural colonisation process. The third site where seedlings did not appear was situated 10 meters away from established trees, whereas the other two were just 5 meters away. However, it is unclear as to whether this difference in proximity is a factor in this case, particularly as most species of trees can disperse seed over the larger distance.

Where seedlings did occur, the main barrier to the establishment of trees was the competing ground cover and vigorous growth of vegetation. This suggests that the sites selected were not suitable for natural colonisation processes without additional interventions or application of weed control. For instance, where trees do occur in the spring the area surrounding them could be mulched and the tree itself guarded against pests. Though this would require additional labour and maintenance from the local authority or land manager, this could assist the natural colonisation process.

However, the viability of this approach can not be understood from this trial. Given that a main barrier to tree establishment in urban areas is the lack of time and resources available at local authorities to care for them, assisting the natural colonisation process might not be an attractive option. Fencing around natural colonisation plots requires an initial capital cost, and time and labour would be required if the local authority were to tend to seedlings as and when they appear. Additionally, our results from this limited trial suggest that there is no guarantee that seedlings would appear, as in the case of one of the trial plots.

Conclusion

The results of the natural colonisation trials indicate that natural colonisation processes are initially occurring in urban areas. However, the presence of additional vegetation found in the typical areas where local authorities might want to establish trees acts as a barrier to the initial seedlings establishing. Creating the right conditions at an early stage by controlling weeds and protecting the trees may assist the natural colonisation process and increase the likelihood of survival, but this was not tested in this study. Further research is needed to understand the viability of this approach, particularly as it would require intervention from local authorities, both in selecting and preparing appropriate sites with fencing and also in applying protective measures in a timely manner once seedlings have sprouted.

Project Conclusion

The project set out to investigate the barriers faced in urban tree establishment and trial methods of planting/establishment that were hoped to improve survival rates and cost efficiency. Three workstreams were implemented: a trees and utilities study, a Miyawaki method trial, and a natural colonisation trial.

Each of these workstreams found that there is potential to improve urban tree establishment. The two trials found that standard planting methods (see ‘trial design’ in sections 2 and 3) used by local authorities have early survival rates of around 50%, leaving room for improvement. The trees and utilities study found that tree establishment could be improved with consideration of trees in early design stages of infrastructure projects, improved communication between tree officers and utility projects, and increased use of existing utility industry guidance on protecting existing trees. The project’s findings for potential improvements for tree establishment all focus on improving/increasing consideration of tree establishment at the outset, rather than further down the line of planting/building projects, to improve cost-effectiveness and outcomes for trees. For example, retrofitting trees in infrastructure projects is difficult and expensive, as is replacing dead trees due to poor survival rates in tree planting projects. Whereas, involving trees in initial design of infrastructure projects and implementing tree planting methods that are site appropriate should result in more successful tree establishment.

The main findings of the project’s workstreams are:

- Conflicts between **trees and utilities** can be mitigated to improve tree establishment, by increased use of existing utility industry guidance on protecting existing trees, improved communication, and early consideration of trees in infrastructure design.
- An adapted **Miyawaki method** can be a cost-effective way of establishing trees in difficult urban settings.
- **Natural colonisation** on small urban plots has shown some signs of promise with saplings found, but as they were subsequently outcompeted by other plants further research is needed to understand whether this could be a viable method or if additional interventions are needed (e.g. mulching or weeding).

Plots created as part of the two trials will continue to be monitored until September 2025 and further research is ongoing to investigate the contributions of particular elements, or combinations of elements, of the Miyawaki method to the survival and growth rates of newly planted trees.

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Appendix A

Aim: analysis of Miyawaki trial data to answer the questions:

1. *Is there a significant difference in the survival rates of trees in Miyawaki plots compared to control plots?*
2. *Does the cost of planting influence tree survival?*

The dataset utilised was the Miyawaki Master excel file supplied by Fera.

Analysis

Data were tested to see if they met the parametric assumptions of normality, variance, independence and outliers. As one or more assumption was violated across all variables used, a non-parametric approach was adopted.

1. *Is there a significant difference in the survival rates of trees in Miyawaki plots compared to control plots?*

The hypothesis being tested was:

H_1: Trees in the Miyawaki plots are more likely to survive than trees in the control plot.

H_0: There will be no difference in the survival of trees from Miyawaki or control plots.

A Chi-square test was employed to determine if the number of surviving trees was significantly different between planting methods.

The output of the test was X^2 (1, N = 9877) = 964.71, p = < .00001. The result is significant at $p < .05$.

A further test, the 2 proportions test, also allowed for the null hypothesis to be rejected.

However, these tests only tell us that there is a relationship between surviving trees and method, not the direction of the relationship. To determine the direction of the relationship a contingency table was created to calculate probabilities for the outcomes. The contingency table showed that surviving trees in the Miyawaki plots contributed most to the Chi-square statistic (0.65).

2. *Does the cost of planting influence tree survival?*

The hypothesis being tested was:

H1: The cost of planting influences whether a tree survives.

H0: The cost of planting does not influence whether a tree is more likely to survive.

To test for significance in the relationship between the cost of trees and their survival the data used was cost per tree planted and alive trees, grouped by planting method. A Spearman's rank correlation coefficient was undertaken on the control and Miyawaki data. The output is a score of between -1 and +1 where -1 indicates a perfect negative association and +1 indicates a perfect positive association, 0 indicates no association. The outcomes were:

Control plot trees: $r(15) = .0882$, $p = .736$

Miyawaki plot trees: $r(14) = .0326$, $p = .217$

Therefore, the correlation between the cost of planting and the survival of a tree in both scenarios is considered very weak and non-significant.

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