ChristchurchNZ is proposing the redevelopment of Sydenham and Waltham, post-industrial brownfield areas in central Ōtautahi. Their vision is to create high-density residential areas, with a goal of increasing urban green space and achieving a 30% tree canopy target.

Due to the land-use history and nature of brownfields, there may be soil contamination present, complicating redevelopment and greening goals by limiting options for tree species survival.

This research project investigated the options available by considering the research question, "Which tree species are appropriate for urban greening and increasing canopy coverage in the Sydenham and Waltham industrial area?"

A literature review informed the early stages of research across five sub-themes: heavy metal contamination, urban greening, ecological restoration, urban redevelopment and climate resilience.

A range of research methods were employed, including spatial analysis of land cover and existing tree species in the study area, expert interviews, and systematic literature searching of contaminant-tolerant tree species.

The results identify a list of trees which are most likely to be resistant to heavy metal soil contaminants and may therefore thrive in and enhance the urban environment. These trees will be presented to ChristchurchNZ and future developers as a customised and comprehensive tree species index to help achieve the tree canopy and urban greening goals in Sydenham and Waltham.

The redevelopment of urban brownfelds – former industrial areas – has received growing interest from

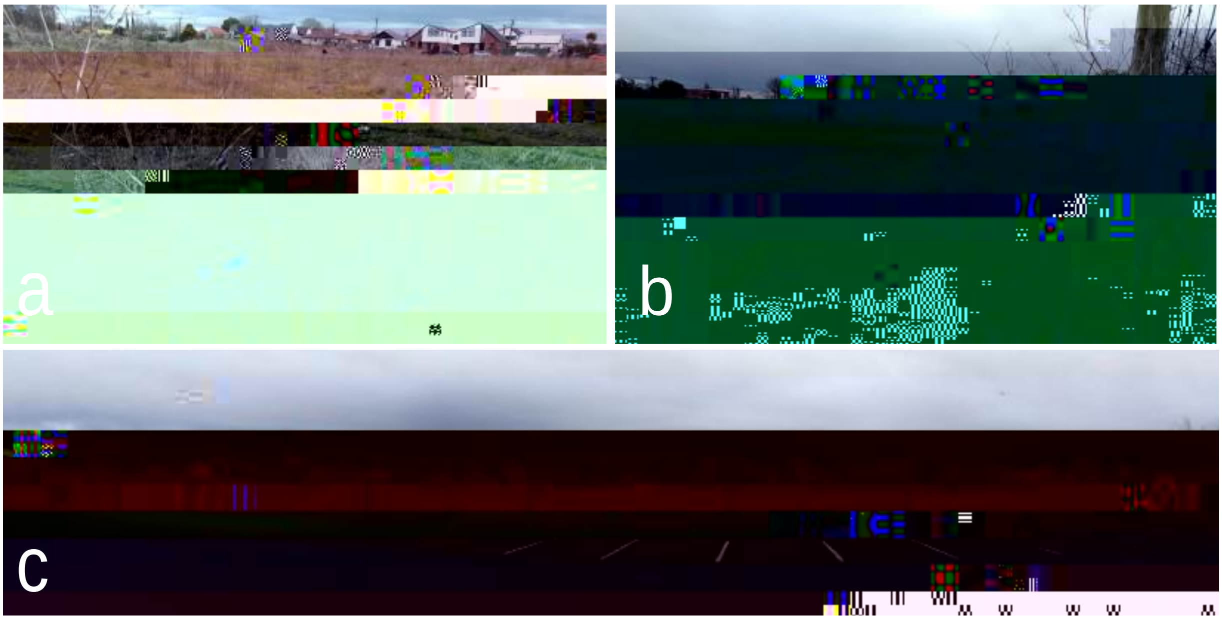
The 2.5km^2 site is underlain by laterally and ver tcally variable soils, comprising fuvial and estuarine deposits of silt, sand and gravel (Pa tle Delamore Partners, 2022a). The par tcular soil types within the area are Taitapu 21, a gley, poorly drained loamy soil, and Kaiapoi 17

Heavy metals are nonbiodegradable and pose a major hazard to human health, through exposure pathways including dermal contact, inhalation and ingestion (El-Zeiny and Abd El-Hamid, 2022). Depending on exposure, health impacts can include acute symptoms such as diarrhoea, fever and vomiting; chronic effects such as lung cancer and kidney, respiratory, and cardiovascular damage; neurotoxicity/brain damage; and death (Nwaichi and Dhankher, 2016; El-Zeiny and Abd El-Hamid, 2022).

A plethora of remediation methods exist for heavy-metal contamination, including in situ (on-site) methods, such as caps/barriers and phytoremediation – the use of plants to uptake contaminants from the soil. Ex-situ methods involve removal and treatment off-site; these include soil replacement and washing (Chen et al., 2016). While in-situ techniques are typically lower cost and reduce the risk of secondary contamination and ecological disturbance, their remediation efficiency is often lower. Conversely, ex-situ techniques have higher remediation efficiency for a greater variety of contaminants, but incur high costs (Williams, 2006).

Urban trees provide a number of ecosystem services – benefits that people derive from the presence of nature within the urban environment (Zhong et al., 2020). These include trees' ability to reduce the urban heat island effect by lowering surface and ambient temperatures through shading and evapotranspiration (Morakinyo et al., 2017), sequester CO_2 through photosynthesis (Lin et al., 2018) and reduce [illegible]

The largest area of soil or grass cover was iden t fed as a vacant plot at 32 Burke St, between Montreal and Orbell St ( ). Approximately 20,853m^2 in area, this site was previously a tex t le manufacturing complex (Pa t le Delamore Partners, 2011) and now contains a mix of debris from demolished buildings and topsoil (Site Solu t ons Ltd., 2014). Two other signi f cant areas of grass cover were iden t fed as Buchan Playground, a park on the corner of Wordsworth St and Buchan St ( ), and a large empty plot at 574 Moorhouse Ave ( ).



: Vacant plot at 32 Burke St, photographed from Orbell St facing south-west, north-west and

shows the loca t on, species and crown spread of current trees present on the site. The cluster of trees in the lower centre of the map are mostly contained inside Buchan Playground, containing among others Pin oak, alder, elm and kōwhai trees.

: Map of current tree species' loca t ons within the area of interest, showing crown spread (the average diame

The tree species selec t on index ( ) lists trees tolerant to heavy metal contamina t on.

: List of tree species tolerant of heavy metals, either by exclusion or accumula t on.

Botanical Name	Common Name	

(Continued)

Magnolia grandiflora	Pb, Cd[10]	Chalk, clay, loam, and sand. Prefers moist conditions.	18-24m	Yes
Platanus acerifolia	Cu*[11]	Chalk, clay, loam, and sand. Medium to wet conditions suitable.	20-30m	Yes
Platanus orientalis	Pb, Cd, Cr[12]	Clay, sand, loamy soil. Tolerates dry, moist, wet conditions.	30-35m	Yes
Platycladus orientalis	Pb, Cd[13]	Chalky, clay, loamy, sandy. Prefers moist but well-drained	9-12m	No (Park tree)

Populus

The na tve trees table ( ) provides informa ton on the na tve tree species suitable for the area based on soil type.

: List of na tve trees suitable for soil types of the site, made with informa ton adapted from Lucas Associates Ltd. (2011) and Greenwood (1951).

Botanical Name	Common Name	Soil moisture tolerance	Ideal soil type	Biodiversity benefits
Cordyline australis		Tolerant to both wet and dry	Taitapu 21, Kaiapoi 17	Fruit for birds and insects, nectar
Dacrycarpus dacrydioides		Prefers wet/ swampy areas	Taitapu 21	Fruit for birds

Poten tal soil remedia t on op t ons and their advantages and disadvantages are listed in .

: List of soil remedia t on methods and their advantages and disadvantages, made with informa t on adapted from Chen et al. (2016), Khalid et al. (2017), and Evanko and Dzombak (1997).

Remediation Method	Description	Advantages	Disadvantages
Caps and Barriers (horizontal and vertical)	Physical barriers to contain contaminated material	One of the cheapest options Widely applicable to heavy metal contaminants Barriers help to prevent contaminant migration	Soil resources being covered and unproductive Breaches in caps and barriers are expected over time
Soil Replacement	Replacing or partly replacing contaminated soil by non-contaminated soil, to dilute/ eliminate present contaminants	Maintains the productivity of the land Simple to implement, and effective	New soil can be costly (especially productive topsoil)

There are a number of otherwise useful tree species that are excluded from the city council’s list of approved trees, for reasons ranging from invasiveness, poor suitability for Christchurch’s climate, to disease suscep tbility and hybridisa t on risk. For example, Willow (*Salix*) trees have demonstrated a high e f ec t veness for phytoremedia t on by accumula t ng a wide range of heavy metals (Labrecque et al., 2020), but preventing hazardous icy road conditions (Qing and Ying, 2011), as well as providing passive solar heating during winter to save building energy use (Huang et al., 2015).

The a t ributes of trees which possess the greatest carbon sequestra t on ability include having a large diameter at breast height and being evergreen (Weissert et al., 2017). Unlike deciduous trees, evergreen species have a capability to sequester CO_2 year-round (Gratani, 2020) and therefore could play an important role during the autumn and winter months when urban emissions of CO_2 are elevated due to increased fossil fuel combus t on (Mitchell et al., 2018).

For promo t ng biodiversity, the cul t va t on of indigenous plants is essen t al, as they furnish fruit and habitat for na t ve insects and birds (Christchurch City Council, 2023a). An important concept gathered from our discussion with Colin Meurk was the di f eren t a t on between species richness and biodiversity; while Christchurch may have a diverse urban canopy, exo t c tree species tend to be present in much greater numbers than na t ves. Thus, while species richness is high, biodiversity is poor. He also emphasised that visible species such as birds gain a t en t on while insects – just as important for biodiversity – are o f en forgo t en. Many na t ve insects have adapted to survive exclusively on na t ve plant species (C. Meurk, personal communica t on, September 8, 2023).

Although na t ve birds will feed on some exo t c trees such as English Oak and Sycamore in comparable amounts as on indigenous trees (Gray and van Heezik, 2015), the predominance of exotic, often deciduous trees in Christchurch means there can be food shortages for native birds during winter months. With the excep t on of kōwhai, na t ve trees aren't classi f ed as suitable for streets in the council's list (Christchurch City Council, 2023d), and therefore indigenous plan t ngs should be priori t sed in o f -street spaces. High-density and medium-rise buildings in Sydenham and Waltham will save space to allow for greater integra t on of urban green space, o f ering opportuni t es to create core sanctuary habitat for wildlife (Igna t eva et al., 2008).

Trees could play a signi f cant role in the design of an urban environment for Sydenham and Waltham to be both a t rac t ve to residents and conducive to wellbeing. In the absence of private gardens, visible street trees can provide nature experiences to residents of high-density housing (Cox et al., 2019) and greater amounts of neighbourhood trees and gardens may improve residen t al sa t sfac t on (Buys and Miller, 2012). Further, the posi t ve physical and psychological health impacts of trees may be enhanced by urban green space design that takes human preferences into account; people generally perceive deciduous and densely-leafed trees with high crown-size-to-trunk-height ratios as the most attractive (Gerstenberg and Hofmann, 2016). Meanwhile, reduced temperature and ambient light levels by evergreen trees during winter may have nega t ve impacts on health, such as increasing Seasonal A f ec t ve Disorder (de Vries et al., 2013; Salmond et al., 2016).

The greening of brown f eld land also presents opportuni t es to recon f gure underused landscapes to serve new func t ons, such as transport links for pedestrians and cyclists (Sanches and Mesquita

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Louis Grant and Elizabeth Rowell

Oriental Plane tree on Disraeli St

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