Assessing the Role of Vegetation in Enhancing Infrastructure Heat Resilience

Case study: The marketplace of Iitti

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Abstract

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Title of the thesis

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Abstract

The subject of the thesis was the identification of eligible plant species with regard to heat resistance for the marketplace of Iitti, Finland. The thesis was conducted as a part of the Steps to prepare for climate change -project and aimed to explore the possibilities of utilizing vegetation as a means to mitigate the effects of climate change.

The main objective was to identify which plant species are suitable for the location in question and can provide shade to paved surfaces while also withstanding extreme weather conditions such as heat waves, heavy rain, and storms. To achieve this goal, the research involved a literature review of the urban heat island (UHI) effect and predicted growth zone changes. Also, a dialogue with the municipality of Iitti, on-site observations, and a semi-instructed interview with an expert in the field were conducted.

The results of the thesis can aid in the creation of adaptation plans for other municipalities in southern Finland in the near future that will be dealing with similar climate-related issues.

Keywords

green infrastructure, heat resilience infrastructure, urban heat island effect, vegetation

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1 Introduction

The impacts of climate change have grown significantly, and they are predicted to further intensify in the years to come (IPCC, 2022). Despite the focus on reducing the effects of climate change, adaptation, and readiness strategies are equally important. Municipalities play a crucial role in preparing for the consequences of climate change, and their actions must transition from reactive to proactive and preventive measures if they are to be effective.

Various greenhouse gas scenarios predict that the annual mean temperature in Finland will rise at a similar rate by the 2030s, but from there on, the temperature increase has four possible scenarios. The curves in Figure 1 illustrate the average findings of 28 global climate models for four Representative Concentration Pathways (RCP) greenhouse gas scenarios: RCP8.5, extremely high emissions; RCP6.0, high emissions; RCP4.5, moderate emissions; and RCP2.6, low emissions (Ruosteenoja et al. 2016a).

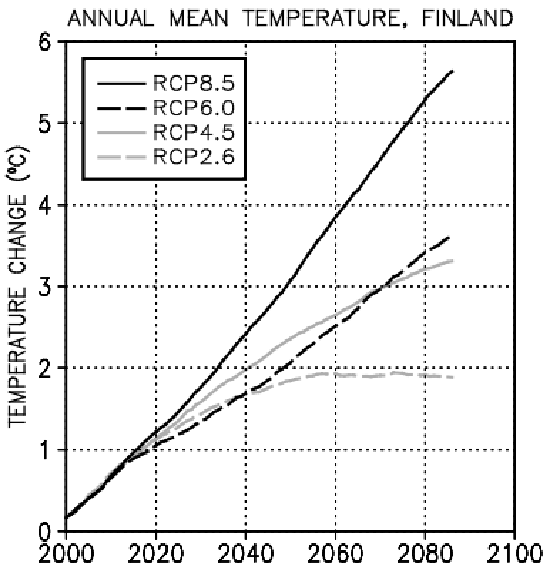


Figure 1 Projected multi-model mean changes in annual mean surface air temperature in Finland (°C) over the years 2000 to 2085 (Ruosteenoja et al. 2016a, 24)

Green infrastructure and heat resilience infrastructure are two critical factors in the adapting and readiness strategies, and something municipalities must focus more on. Green infrastructure helps for instance to manage stormwater, reduce the urban heat island (UHI) effect, and provide biodiversity increment (McCarty et al. 2021, 1; Sunita et al. 2023, 12).

Vegetation provides shade to paved surfaces and cools the surroundings, while reducing the risk of heat-related environmental and health issues and enhancing the overall quality of life in urban areas (McCarty et al. 2021, 3). Heat resilience infrastructure, on the other hand, signifies technologies and measures created to handle extremely hot weather, which is anticipated to increase in frequency and intensity as a result of climate change. This infrastructure includes air implementations such as conditioning facilities, shaded locations in public areas, and heat warning systems. (Stone et al. 2019.)

It is vital to incorporate green infrastructure and heat resilience infrastructure with broader perspectives into municipalities' adaptation and preparation strategies to increase their resilience against extreme heat and other extreme weather events. According to Fukuoka (2022, 253), this can be achieved, for example, by establishing shaded areas in public spaces like marketplaces, parks, and playgrounds in cooperation with community organizations and private developers. To make sure that these strategies serve every member of the community, municipalities must consider both the social and economic effects of using them. Following this approach, the municipality of Iitti joined the Steps to prepare for climate change -project to raise climate change awareness and to acquire new adaptation and readiness strategies.

Hence, the purpose of the thesis is to improve the planning of climate change adaptation and preparedness strategies in the municipality of Iitti by providing a case study about the possibilities of utilizing vegetation as a means to mitigate the effects of climate change. Also, the thesis aims to encourage practical readiness preparation by introducing suitable plant species, particularly in the context of heat resilience, to be used in the marketplace of Iitti and finally, to inform municipal decision-makers and staff about the impacts of climate change and increase climate awareness in general.

2 Background of the thesis

2.1 Objective of the thesis

The thesis is a part of the Steps to prepare for climate change -project, which is carried out in cooperation with LAB University of Applied Sciences and the municipality of Iitti. The goal of the project is to promote adaptation to climate change, prevent risks, and create awareness of disaster preparedness and resilience in Finnish municipalities.

Before the project commenced, a survey was conducted in 2022 to determine the municipality's current degree of preparedness and adaptation to climate change. The results of the survey indicated that improving communication and increasing municipal staff awareness were the most urgent needs in terms of climate change adaptation.

The overall goal of the thesis is to strengthen stakeholder collaboration, enhance planning for climate change adaptation and resilience, encourage the implementation of doable preparedness measures, clarify the needs and actions of the municipalities in the Päijät-Häme region, and produce information on the effects of climate change for municipal decision-makers and staff. The topic of the thesis is delimited and discussed together with the project coordinators and the contact person of the municipality of Iitti.

The thesis explores the possibilities of utilizing plants to aid with climate change adaptations and weather-related preparation. The research area will be the municipality of Iitti, with a particular emphasis on the marketplace of Iitti, also referred to as Kausala's marketplace. The study examines appropriate plants that can survive harsh weather, such as heat waves, torrential rain, and storms, and shade the asphalt infrastructure, focusing on heat resilience. The chosen plant species are to withstand the global warming forecasts for the next 50 years.

In addition to a conversation with an Iitti town official, on-site observations in the marketplace will be carried out to obtain a more comprehensive outlook of the location. An interview with a subject field specialist will further help with the suggested plant species list, but the report will also comprise of a review of literature on the UHI effect and predicted growth zone changes to better understand the current circumstances and to assist in the selection of appropriate plants.

2.2 Methodology of the thesis

To achieve the goal of the thesis, a literature review is chosen as the research method, as it provides a critical overview of the current state of the topic and makes possible research gaps visible. The literature review on enhancing the role of vegetation in heat resilience infrastructure is carried out as a part of the Steps to prepare for climate change -project, which is funded by the European Regional Development Fund (ERDF) and the Regional Council of Päijät-Häme and coordinated by LAB University of Applied Sciences in co-operation with the municipality of Iitti. The results are used as preliminary work for a pilot development plan to be implemented in 2024 and aim at providing sustainable solutions for the project.

Besides a literature review, a semi-structured interview with an expert in the field is conducted to gain more knowledge about suitable plants and vegetation plans for the marketplace. Mr.Timo Koskinen, who is the chairman of Hämeenlinna's Society of dendrology and has an extensive history of botany in various roles agreed to be interviewed and offer expert opinions for the research. Also, the contact person of the municipality of Iitti is contacted to make sure the results of the thesis are feasible for them.

To conduct the literature review, keywords are first chosen and then several searches are carried out in academic search databases. Relevant articles and books are then listed and analysed, and areas of controversy are identified, as well as any gaps that might exist in research to date are highlighted. The goal of the literature review is to critically provide a comprehensive overview of the current state of knowledge and propose new topics for future research. (Efron & Ravid 2019, 2-3.)

For the thesis, the following keywords were chosen, green infrastructure, heat resilience infrastructure, urban heat island effect, and vegetation. Next, several searches in LAB Primo and EBSCO databases were carried out using different combinations of keywords, and the results were listed. The relevant articles and books were analysed. The results are presented in detail in the following parts.

3 The urban heat island (UHI) effect phenomenon

3.1 General characteristics of UHI

The UHI effect is not a new phenomenon but has been researched greatly in major cities and metropolises around the world over the last fifty years (Voogt & Oke, 2003). The term urban heat island describes the relative warmth of a city in comparison to its rural surroundings. There are two common types of UHI effects, surface UHI and air temperature UHI, but they are interconnected and thus often analysed together. The causes of UHIs are interrelated, as many studies show, but the main cause of UHI is the release of solar radiation energy that has been stored in the city's structures and asphalt-covered surfaces at night. (The Planner's Workbook, 2014; Lauriola, 2016; Hayes et al., 2022.)

Presented in Figure 2 below, the general warming effect of higher buildings is illustrated as temperature changes (°C) after sunset, as they cause some of the heat to become trapped in the street canyons between them, although this occurs more significantly in bigger cities. In addition, human activity, such as waste heat from district heating and transportation, contributes substantially to the formation of UHIs, in particular during the winter. Moreover, the absence of vegetation in cities reduces evaporation, leading to a less noticeable cooling effect. Lastly, seasons, the city's geographical location, and its urban structure also play a defining role in the characteristics of the UHI phenomenon. (The Planner's Workbook, 2014; Armstrong and Lopes, 2016; Susca and Pomponi, 2020.)

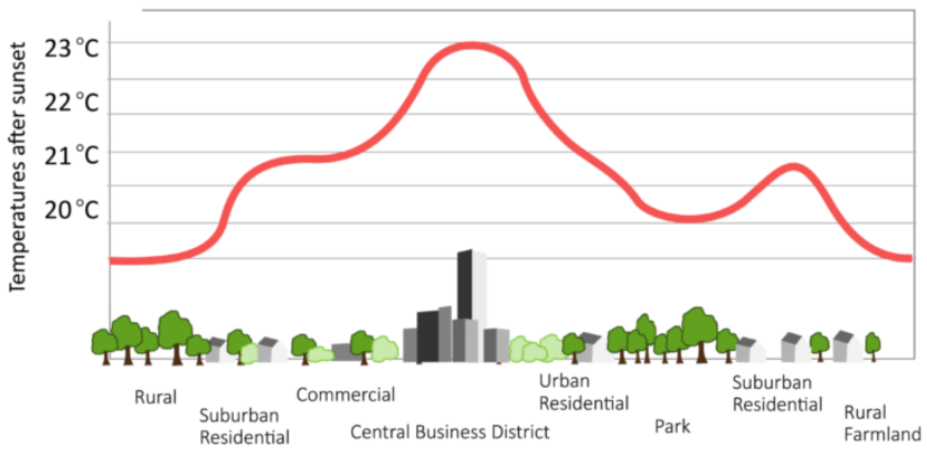


Figure 2 Urban heat island profile (Metlink - Royal Meteorological Society)

There is an ongoing debate about the UHI effect and whether the differences in the regional variability derive from the number of impervious surfaces or aerodynamic factors between urban and rural areas. Traditionally it is thought that the daytime UHI intensity is caused by the urban-rural difference in vegetation and the fact that urban areas have more impervious surfaces, but a study completed in North America has found that spatial variations of day-time UHI intensity can also be explained by the changes in the efficiency with which urban and rural areas conduct heat from the land surface to the lower atmosphere. (Zhao, L. et al., 2014; Li, D. et al. 2019.)

According to a recent study by Mentaschi et al. (2022), the temperature in city centres can be 10 – 15 degrees Celsius warmer than their neighbouring rural areas in summer, and previous research has also found similar results. The magnitude of urban warming is highly variable over both time and space. On average, the urban temperatures can be 1 – 3 degrees Celsius warmer, but under appropriate meteorological conditions (calm, cloudless nights in winter) air temperatures can be more than 10 degrees Celsius warmer than surrounding rural environments. (Kusaka & Kimura, 2004.)

Thus far, the UHI effect has not been extensively studied in Finland, because of its geographical location and a lack of metropolitan areas in the past, but there have been some projects in the capital city of Helsinki and other bigger cities such as Turku and Lahti during the last few decades (Drebs et al., 2023). In Helsinki, a simulation dataset of a microclimate was produced in 2023 by Ecoten – Urban comfort. The dataset aims to understand the cause-effect relationship between the built environment and extreme heat impact in neighbourhoods. (Ecoten – Urban comfort; Avoindata.fi, 2023.) Also, The Department of Geography and Geology at the University of Turku carried out a project called ILKKA from 2012 to 2014 to study the urban climate using a fixed network of measuring devices and produced a planner's workbook on a climate-proof city (Climate-Proof City – The Planner's Workbook, 2014).

In a study by Drebs (2011) the capital city Helsinki was measured in regard to mean UHI effect formation from July 2009 to June 2010 with a scanning vehicle. The results are illustrated in Figure 3, which gives a comprehensive overview of the UHI effect. Temperature differences are presented in Kelvin and the most prominent differences are visible in built-up areas with higher buildings, though copious urban sub-centres with raised temperatures are also visible.

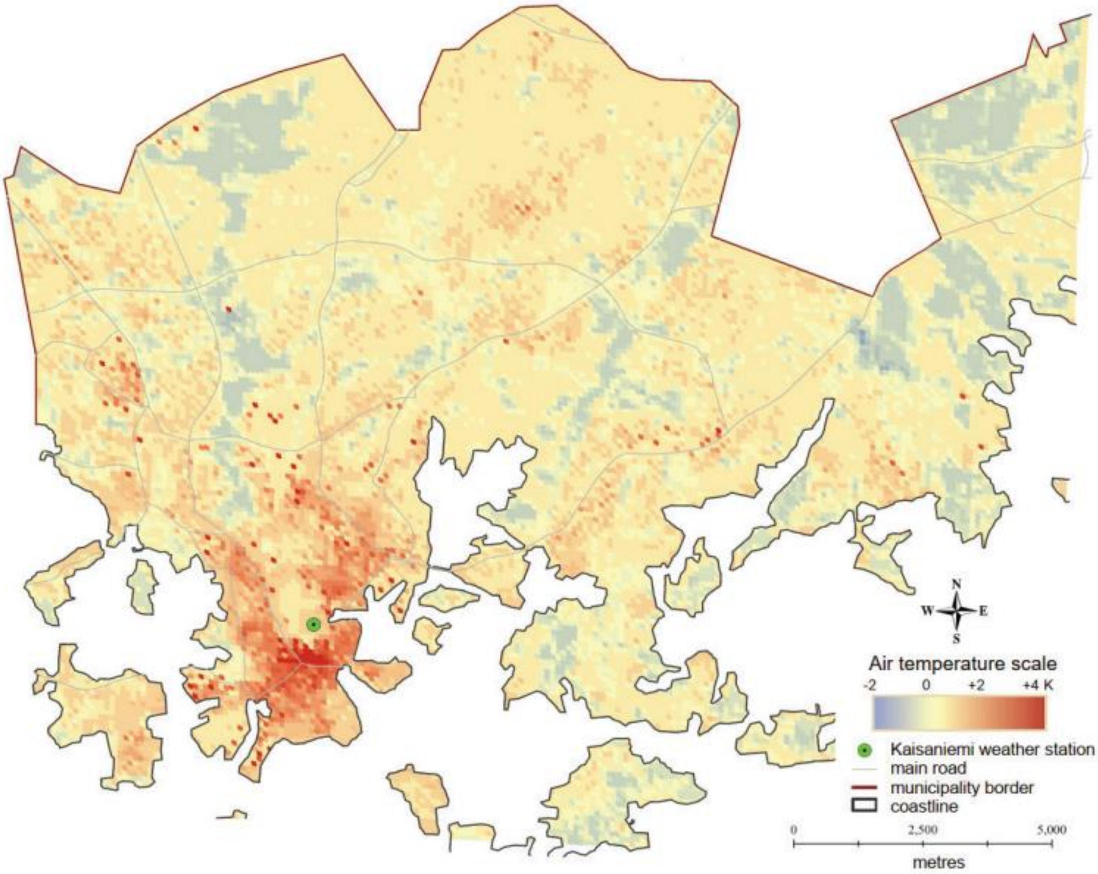


Figure 3 A mean UHI effect measured from July 2009 to June 2010 in Helsinki (Drebs, 2023, 86)

According to a recent review of UHI research at higher latitudes (Drebs et al., 2023), UHI has both positive and negative impacts on the urban infrastructure but the effects on building materials are still, for the most part, unexplored. Thus, there is still a need for future research in general and also in the higher latitudes, because of the challenges of comparing UHI characteristics between different cities due to their geographical features. The northern hemisphere is seeing an increase in the consequences of climate change, which implies that the UHI effect will also become more significant in the future and deserves more attention.

3.2 The UHI effect and climate change

According to the Sustainable Development Goals (SDG), currently over half of the global population is living in urban areas, and the figure is expected to reach 70 percent by 2050 (United Nations, 2022). This growth rate puts a strain on not only the infrastructure, energy supply, and sustainability of the cities, but also on the urban materials which contribute to the formation of UHIs. The use and design of the urban environment affect the city's total energy budget and can predict when the UHI effect is experienced the most (Hayes et al., 2022, 22).

Climate change increases the UHI effect because of, for instance, heat waves and precipitation fluctuations, but urban infrastructure and anthropogenic actions also play a role in the effects. Building materials such as concrete and asphalt reflect only a small portion of the incoming radiation when compared to vegetation and they have a higher heat capacity, which leads to absorbed solar energy within them. The current way of urban landscaping leaves little room for vegetation, which in turn limits the amount of heat dissipation that would otherwise be accomplished by evapotranspiration. Due to these reasons, the urban environment absorbs and holds onto substantially more thermal energy and results in faster temperature changes compared with more natural areas. (Hayes et al., 2022.)

As the UHIs form, energy demand in the cities will rise as the buildings require more air conditioning and cooling, causing higher electricity costs and a need for increasing power supply (Li, X. et al., 2019). The excessive heat generated by the UHI effect also impacts the infrastructure. Asphalt can deform and prolonged exposure to high temperatures can deteriorate building materials, including concrete and steel. (Lima et al., 2023) This means a reduced service life and increased maintenance costs for the cities.

3.3 The effectiveness of vegetation in reducing the UHI effect

There have been many studies about the use of vegetation in reducing the UHI effect, for example in a study by Bianco, L. et al. (2017), where vertical green walls were built and tested for one year in Italy to examine the external surface thermal resistance and insulation. The results showed reduced external surface peak temperatures in the summer season, and in winter a reduction in heat losses, and an increase in insulation.

According to Millward et al. (2014), trees and vines that give shade to build surfaces have a significant role in reducing the UHI effect, especially bigger trees with complete canopies. In their study, it was found that big trees, located 5-10 metres from the building wall, had the biggest impact on the temperature during a period of high solar intensity, with an average temperature differential of 11.7 degrees Celsius. In Figure 4 there are three buildings presented, facing in different directions, and their daily measured temperatures, where values indicate degrees cooler at shaded sites compared with their sun-exposed complement. Chart A represents an east-facing building, B a south-facing building, and C a west-facing building, and time of day is presented on the left side, and months are separated by columns. The figure shows that the best shade is provided on the west-facing building (C), and the least on the east-facing (A).

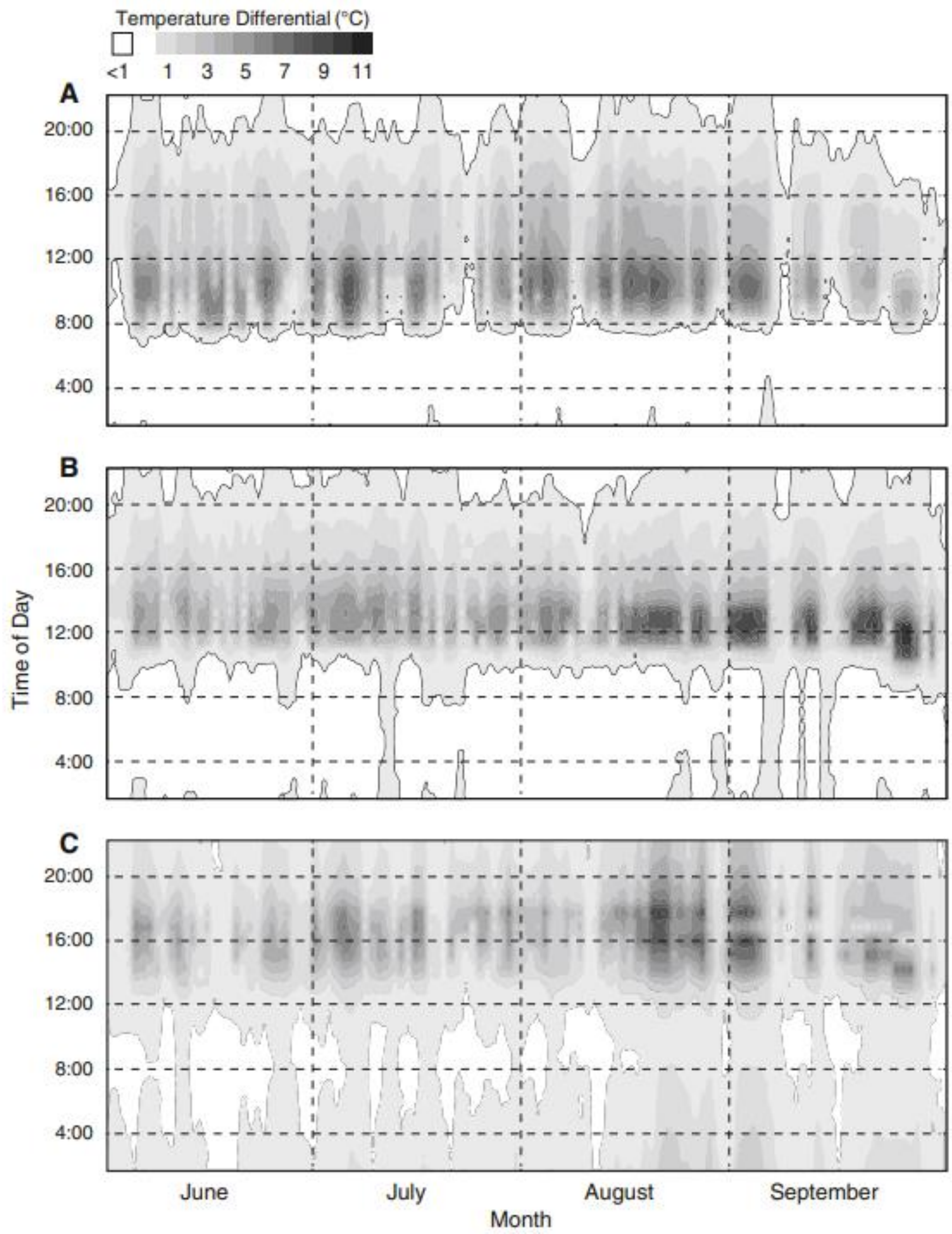


Figure 4 Temperature differential surface (°C) showing the diurnal influence of tree shade on mitigating the rise in built surface temperature (Millward et al., 2014, 1051)

The study also showed that when it comes to reducing the temperature rise in built surfaces on a building's south and west sides, perennial vines proved as effective as trees. They offer a compatible alternative to shade trees in areas with limited soil volume and space. Vines can also be planted close to the buildings, whereas trees need more space and distance, not to mention the time they acquire to grow and create full canopies.

4 Growth zone changes in Finland

4.1 The current climate of Finland

According to the Köppen climate zone classification, Finland is part of a snow and forest climate zone with a damp and cold winter type. In a closer inspection, Finland is divided into five main climate types, pictured in Figure 5 from south to north: hemi boreal, south boreal, mid boreal, north boreal, and hemi arctic. The Köppen climate zone classification is the most widespread classification, which is based on precipitation and temperature. The borders of different climatic zones are set based on precipitation and temperature because of the requirements of various plant species. (Ilmatieteenlaitos, a.)

Figure 5 Climate zones in Finland (Ilmatieteen laitos, a)

Furthermore, Finland can be divided into eight vegetation zones based on the suitability for the growth and prosperity of fruit trees and woody ornamental plants, as illustrated in Figure 6. The vegetation zones are defined by the length of the growing season, the sum of effective temperatures, and winter conditions. Vegetation in Finland has to withstand snow and frost conditions, but it is also affected greatly by the Baltic Sea and numerous lakes and rivers that carry wind throughout the country. (Ilmatieteen laitos, b.) The geographical location of Finland makes it versatile in nature, but also challenging to predict how the vegetation zones will develop in the future as the effects of climate change intensify.

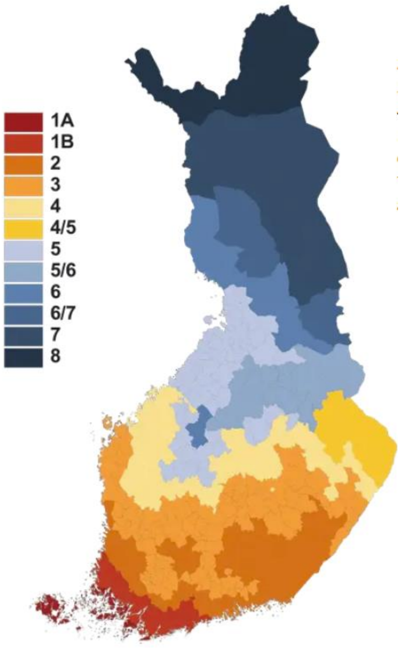


Figure 6 Vegetation zones in Finland 1A-8 (Ilmatieteen laitos, b)

Finland's climate is characterized as a mix of maritime and continental climates. The average temperature in Finland is higher than expected in its latitude because of the Baltic Sea and warm air flowing from the Atlantic Ocean, warmed by the Gulf Stream. The warmest mean temperatures are measured in the southwestern parts and cooler temperatures are located in the northeast, as illustrated in Figure 7. January is typically the month experiencing the most variability, with around ten degrees Celsius difference between southern and northern Finland, but the gap narrows down in June and July to about five degrees Celsius. (Climate Change Knowledge Portal, a.)

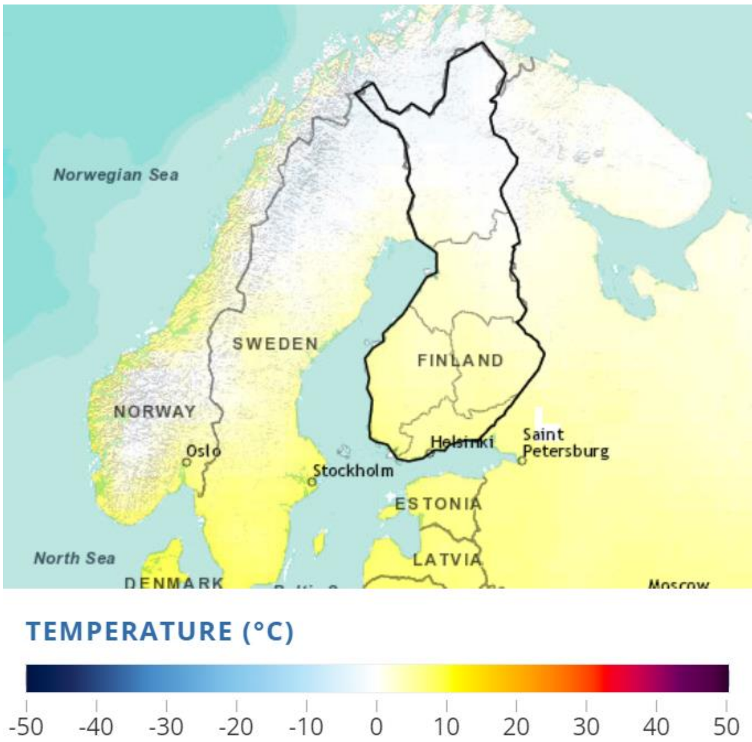


Figure 7 Observed climatology of mean temperature during 1991-2020 in northern Europe (Climate Change Knowledge Portal, a)

Precipitation is irregular in Finland, and the weather changes rapidly. The average annual precipitation ranges from 600 to 750 (mm) in the south and central Finland, slightly lower along the coast, and between 450 and 650 (mm) in the north. The lowest amount of rainfall is received in February, March, and April, followed by a gradual increase until summer or early autumn, and a decrease towards winter. (Climate Change Knowledge Portal, b.) Vegetation has to withstand both rainy and dry seasons, as well as long winters with differing snow covers and less sunshine.

Illustrated in Figure 8, the variability, and trends of mean temperature across the seasonal cycle during 1971-2020 in southern Finland show a visible increase in the mean annual temperature. The coloured dots represent different decades, the dark grey dotted line represents the current annual climatology trend, and the mean temperatures are on the left side of the chart. The general pattern during the measured time period is also consistent with the progression of climate change. The seasonal changes every month show an increase in temperatures too. Following these findings, climate preparedness planning can anticipate the ongoing warming trend and strive to mitigate the negative effects.

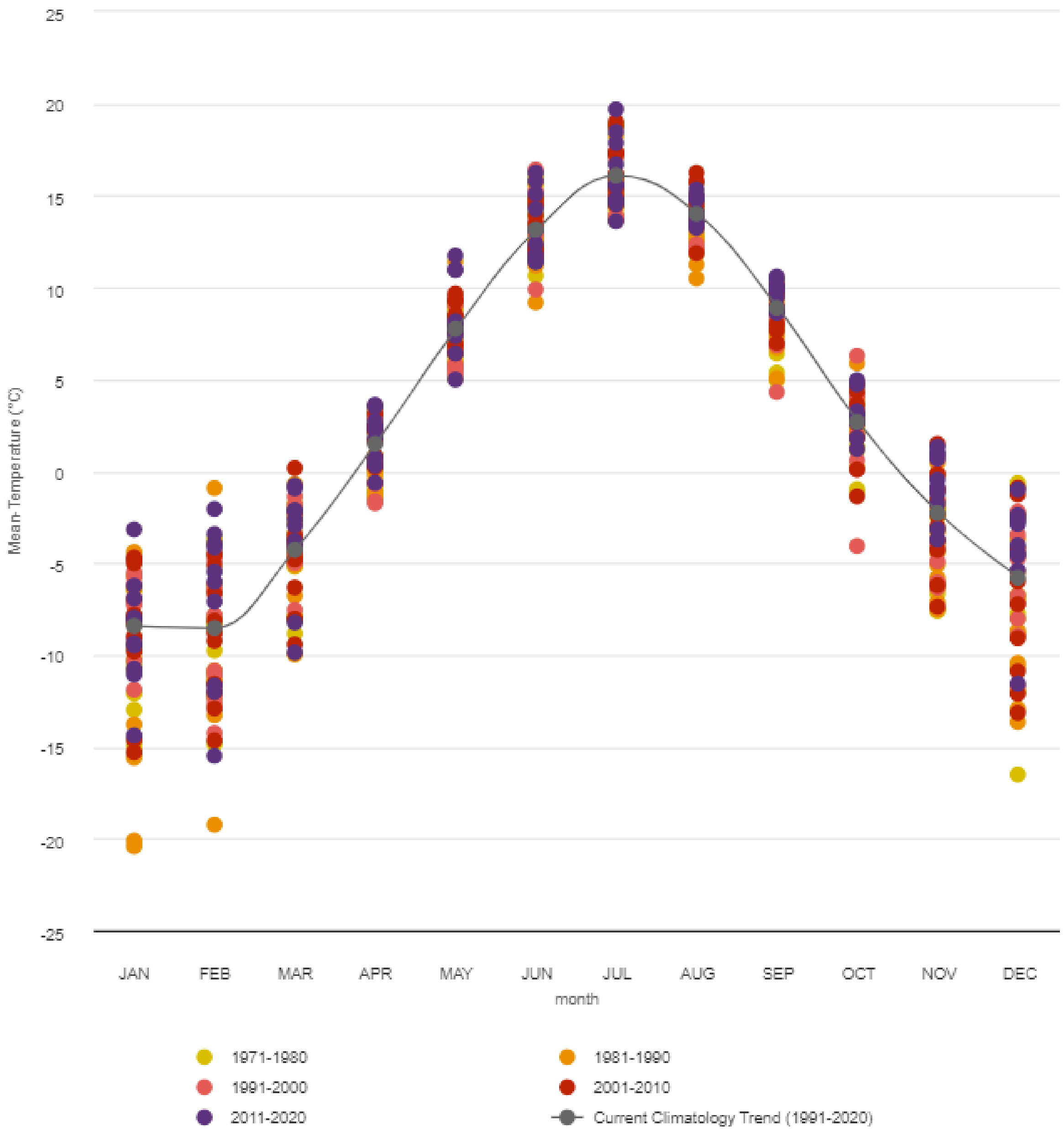


Figure 8 The variability and trends of mean temperature across the seasonal cycle from 1971 to 2020 in southern Finland (Climate Change Knowledge, b)

4.2 The predicted climate changes of Finland

As presented in comprehensive analyses of climate change by the Finnish Meteorological Institute and the Climate Change Knowledge Portal (Climate guide, 2017; Climate Change Knowledge Portal, c), Finland will experience significant shifts in temperature, precipitation, snow cover, and sea levels in the future, with more distinct changes during winters than summers.

According to the Köppen climate zone classification, the predicted change to Finland means that winters will become milder and summers longer. In Figures 9 and 10 the change from the year 2020 to 2060 forecasts that colder winters move to North and Central European climate reaches the southern parts of Finland. (Ilmasto-opas.)

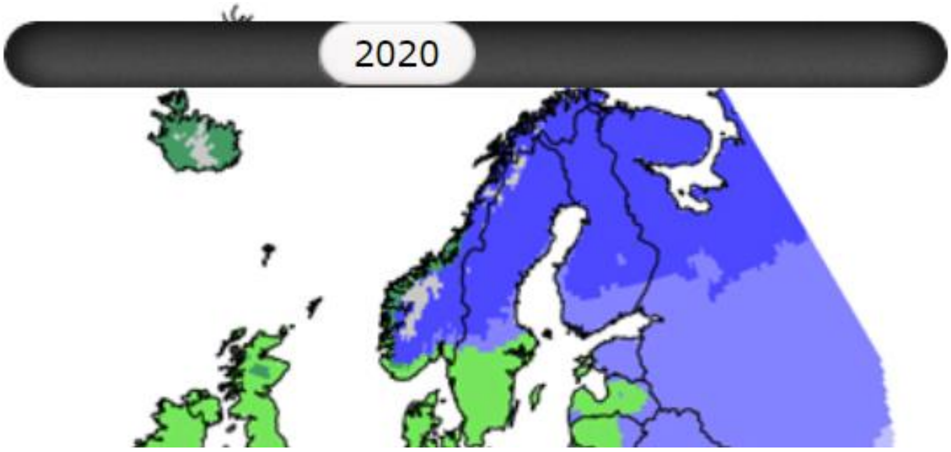


Figure 9 Climate zone illustration, the year 2020 (Ilmasto-opas)

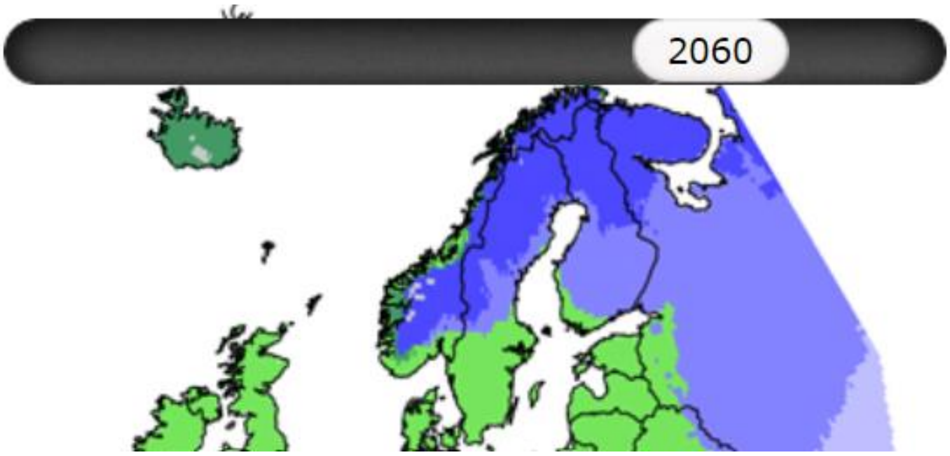


Figure 10 Climate zone illustration, the year 2060 (Ilmasto-opas)

In the following Figure 11, is an illustration of the mean temperature for 2040-2059 in Finland, which is expected to rise by a maximum of 16 percent compared to the reference period marked with a black dotted line. The different coloured lines represent different scenarios, or Shared Socioeconomic Pathways (SSPs), which are meant to provide insight into the forecasted climates based on defined emissions, mitigation efforts, and development paths. Because of Finland's geographical location, temperatures will rise more rapidly and to a greater extent than the global average, and for example, heat waves are forecasted to become more frequent and longer lasting.

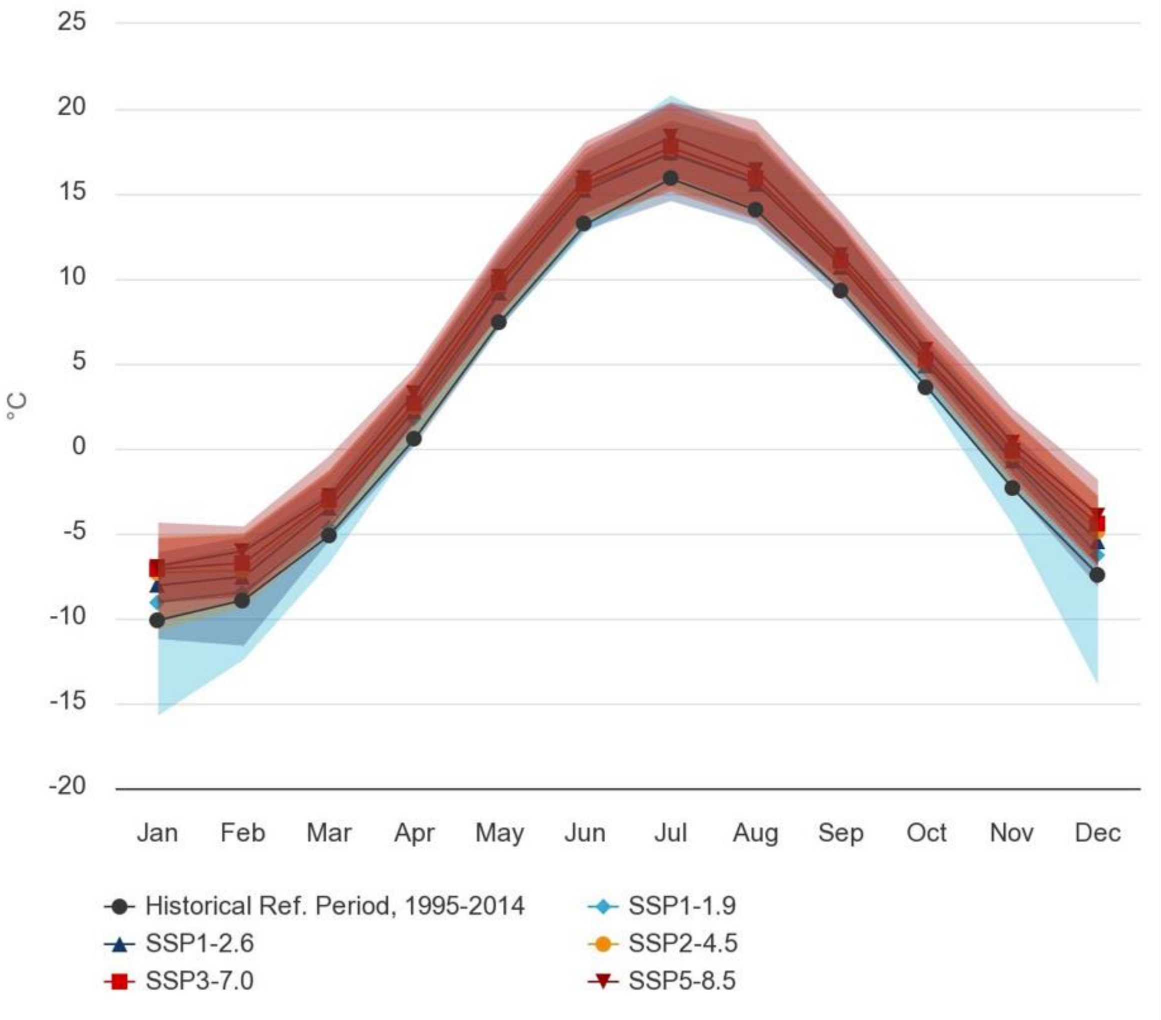


Figure 11 Projected climatology of mean temperature for 2040-2059 in Finland (World Bank Climate Change Knowledge, c)

Other predicted changes include a decline in the duration of the snow cover and depth, which results in challenges for soil load-bearing capacity during mild and rainy winters. Also, the amount of sunshine during winter will decrease, and on the other hand, precipitation in winter is expected to increase and the rising sea levels in the Baltic Sea are a concern for coastal regions. (Climate guide, 2017.)

Ruosteenoja et al. (2016b, 18) present, that the growing season in Europe will lengthen by 1.5 – 2 months by the end of the century in the RCP8.5 scenario, a representative concentration pathway scenario, which is a climate projection, based on 28 global climate models.

In another study by Ruosteenoja et al. (2019, 4447) it is suggested, that the thermal spring season is expected to start earlier and the thermal autumn season to end later. The thermal summers will lengthen by some ten days and winters will shorten at an even higher rate of change, and the likelihood of having years without a thermal winter will increase significantly by 2040-2069. Furthermore, according to another study, there is a consensus that the northward migration of agro-climate zones could be twice as rapid in the coming decades than over the last 40 years (Ceglar et al., 2019).

Presented in Figure 12 below, the forecasted thermal growing season changes show that with more severe climate change (red line), the growing season is expected to change quite rapidly in the next decades from the beginning and the end correspondingly. The blue line represents a more moderate climate change, and the days of years (Julian days) are illustrated on the left side of the charts. The sum of growing season days -chart (right-hand side) demonstrates a 500 – 1000 days increase in the coming decades depending on the rate of climate change.

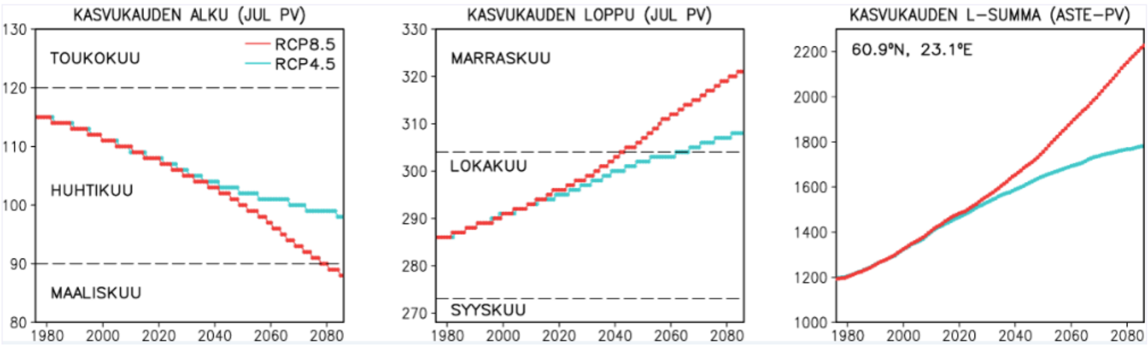


Figure 12 Thermal growing season beginning (left), ending (middle), and mean heat summation (right) chronological development in Southwestern Finland from 1980 to 2080 in 30-year moving averages (Ruosteenoja et al. 2016b, 3)

The changes in the growing season mean, that the current plant species might not be able to adapt to the change fast enough, which leads to plant species migrating to the north. According to Mr.Koskinen (2023), the common spruce, for example, is expected to migrate away from the current growth zone one, as it does not thrive in the heat and requires more reoccurring rains.

Apart from plant species migrating, plant pests will migrate also as the climate changes. Future urban planning needs to acknowledge migration, as Mr.Koskinen (2023) reminds us. Fortunately, cities are focusing more on biodiversity, sustainability, and experimentation, with which the amount of pests can be limited naturally (Turun kaupunki, 14). Many potential pests and diseases are migrating to Finland, which can pose a threat to deciduous trees, for example, *Ophiostoma ulmi* (Hollanninjalavatauti), which is a most famous tree disease, and approaching Finland as well. Another new disease, that affects lime trees, is *Caliroa annulipes* (Lehmusetanainen), and it can cause significant damage to the leaves. (Turun kaupunki, 6; The Finnish Association of Landscape Industries, b.)

5 Vegetation suggestions for the marketplace of Iitti

5.1 Location of the marketplace

The municipality of Iitti, located in the Päijät-Häme (Figure 13) county in the southern part of Finland belongs to the vegetation zone two, which is a zone known for its lakes and fields (Ilmatieteen laitos, b).

Figure 13 Location of Iitti (Maanmittauslaitos)

However, when choosing suitable plants for a specific location, the microclimate and extreme weather conditions also play a crucial role in the success of plant growth and must be considered (Koskinen, 2023). The marketplace of Iitti is in the centre of Kausala, approximately 2240 m^2 (Figure 14), and an open place, surrounded by lime trees, low bushes, and streets on three sides and a one-story building on one side (Image 15).

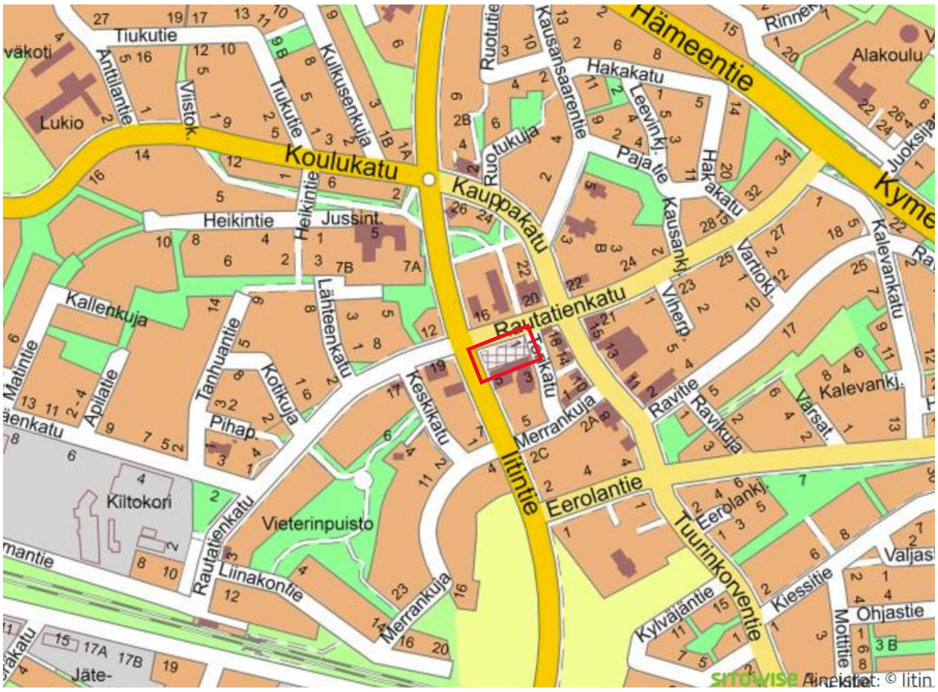


Figure 14 The centre of Kausala Iitti (Adapted from IITTI karttapalvelu, 2023)

Image 15 The marketplace of Iitti, Kausalan tori, west side. (Image: Anu Talasranta)

The present lime trees already provide shade to the surrounding pavements, but the actual marketplace is plain, and has only a few summer plants added for decoration, as seen in Images 16 and 17. The general characteristics of marketplaces include an open plan, as fairs and events require space for organization, and it should remain that way. What is to be considered, are the plants and trees surrounding the marketplace and to ensure that they are sustainable and heat resistant.

Image 16 The marketplace of Iitti, Kausalan tori, east side (Image: Anu Talasranta)

From the green infrastructure point of view, the current structures such as the platform of the marketplace can be examined for adding vines around it.

Image 17 The centre of the marketplace of Iitti, Kausalan tori, west side (Image: Anu Talasranta)

5.2 The selection criteria for suitable plants

When analysing and choosing suitable plants for the marketplace, there are many factors to consider. The plants and trees must resist heat and extreme weather, be suitable for vegetation zone two, they need to be affordable, and their production also needs to be sustainable. One way to ensure sustainability is to choose FinE (Finnish Elite) plants, which are native plant species. FinE is a Finnish trademark by the Finnish Association of Landscape Industries organisation, which deals with urban and rural landscape management in Finland. (The Finnish Association of Landscape Industries, a.)

The selection criteria for perennial plants entitled to use the FinE trademark in Finland include being authentic, healthy, and suitable for Finnish conditions. To obtain the trademark the plant has been either tested comparatively at multiple locations or there is a long-term experience of the plant's characteristics and success. Moreover, FinE plants are added from tested parent plants which have been cleared of plant diseases and pests. (The Finnish Association of Landscape Industries, a.) By choosing FinE plants the longevity and success of the plants can be further guaranteed.

According to Mr.Koskinen (2023), it can be more economical to acquire some plants from well-established gardens such as Mustilan puutarha, which has tested plant species in Finland for over a hundred years. The current trend according to Mr.Koskinen, however, is to purchase less expensive plants from the Netherlands and even to choose plants that do not thrive in the particular environment, for example, thujas, which are vulnerable to frost.

Another factor to consider when deciding on suitable plants for the marketplace, is that the plants should require little maintenance, which means that they do not need frequent cutting or fertilizing, need reoccurring planting, or do not produce large fruits, which would increase the workload of the local gardeners (Helsingin kaupunki, b). By acknowledging the maintenance costs of the chosen plants, the budget for the proposed plants can be kept reasonable in the long run, although some maintenance will be expected in any case and that is tolerable.

Many cities highlight biodiversity in urban city planning and add a variety of different plants in the same area or use novelty plant species with regard to heat and torrential rain resistance. Having multiple plant species decreases the risks of spreading pests and diseases. (Helsingin kaupunki, a., Turun kaupunki, 13.) Summer plants are an easy way to test new plant species in the location, as one can test different flowers every year, and variety in plants also means more biodiversity. According to Mr. Koskinen (2023), the majority of perennial plants thrive south of the city of Oulu, because in the north there is less moisture and more daylight in the summer.

Mr.Koskinen, (2023) suggested preferring perennials for the location, because they require less maintenance and can be left in the ground for winter. He also emphasized that the autumn leaves can be left in the soil as they provide insulation for the plants from the snow, this advice goes also for the stems of plants, although the general outlook might then be compromised. Perennials are also preferred because they withstand heavy rains well and take oxygen from the roots, furthermore, grasses and sedges are often overlooked, although they are good plants for dry conditions. When thinking about the maintenance of the selected plants, good gardening makes sure not to plant any plants too early, as frost is more dangerous for the plants than dry seasons.

5.3 Limitations for plant species

When selecting viable plant species for the marketplace, the characteristics of the location need to be considered. The marketplace is an open, asphalt-covered space with traffic on three sides and a commercial building on one side. Any new trees need space, and they need to be durable to withstand the current conditions.

Below is a list of important aspects for consideration when selecting potential trees according to the urban plant guide:

- the space required by the tree
- resistance to road de-icing salt
- prickliness: for example, thorns can pierce bicycle tires
- maintenance: leaves and berries cause slippery roads and stain the environment
- availability of adequate-sized saplings.
  (Helsingin kaupunki, b.)

For perennials and bushes the limitations to consider are similar according to the urban plant guide:

- height of the bush
- growth pace of the bush
- brittleness
- resistance to road de-icing salt
- durability to withstand snow plying
- prickliness: for example, thorns can pierce bicycle tires

- need for maintenance.
  (Helsingin kaupunki, c.)

Selecting suitable plant species according to the limitations above delimits the plant list, and heat resistance and adaptivity to climate change make the suggestions even more comprehensive.

6 The plant species suggestions

In the following are the proposed plants for the marketplace of Iitti for future acquirement. They are categorized into six categories following the categorization of FinE-plants.

According to Mr.Koskinen (2023), plants that are leathery-leaved, hirsute, and considered rockery plants, are resistant to drought and can withstand extreme heat. Examples of such plant species include *Stachys byzantina* (Nukkapähkämö), *Antennaria dioica* (Ahokissankäpälä), and *Anaphalis margaritacea* (Helminukkajäkkärä). Nukkapähkämö is a bigger version of Ahokissankäpälä and it thrives in sunny conditions. Helminukkajäkkärä on the other hand, is a large silvery plant with white blooms and it blossoms in August, it is also an excellent choice for the marketplace, it is also patulous. Mr.Koskinen also suggested trying *Actinidia kolomikta* 'Vitakola' (Minikiivi / kiinanlaikkuköynnös) as it thrives in sunny conditions, but it needs to be sheltered from frost in the winter. It also produces small edible fruits, which can cause more maintenance costs, if it is planted abundantly.

6.1 Trees

Picture	
Name	***Populus tremula 'Erecta'*** **(Pylväshaapa)**
FinE plant	No
Growth zone	I-VI
Height	8-17m
Blossom	May

Table 1 Populus tremula 'Erecta' (Pylväshaapa) (Hankkija.fi, Pylväshaapa)

Populus tremula 'Erecta' is a narrow tree that grows in a column. The trunk of the tree is grey, and the branches point upwards quite steeply. The leaves are green, round-tipped, and serrated. The tree grows fast, blossoming in the spring with catkins. The leaves are reddish in the spring, green in summer, and yellow in autumn. (Table 1) (Puutarha.net, Pylväshaapa.)

Picture	
Name	***Ulmus glabra* (Vuorijalava)**
FinE plant	No
Growth zone	I-IV
Height	15-25m
Blossom	April - May

Table 2 Ulmus glabra (Vuorijalava) (Puutarha.net, Vuorijalava)

Ulmus glabra is a tall and strong-structured tree with a gray trunk that darkens with age. The wood is hard and tough, and it withstands bruises and cuts well. The branches are sturdy and curve upwards, forming a beautiful canopy. The tree produces small, reddish flowers before leaves in the spring. After flowering, winged nuts are formed. The leaves are big, dark green, and rough on the upper side. The tree grows rapidly when young and has a long lifespan of approximately 200 years, up to 500 years. (Table 2) (Puutarha.net, Vuorijalava.)

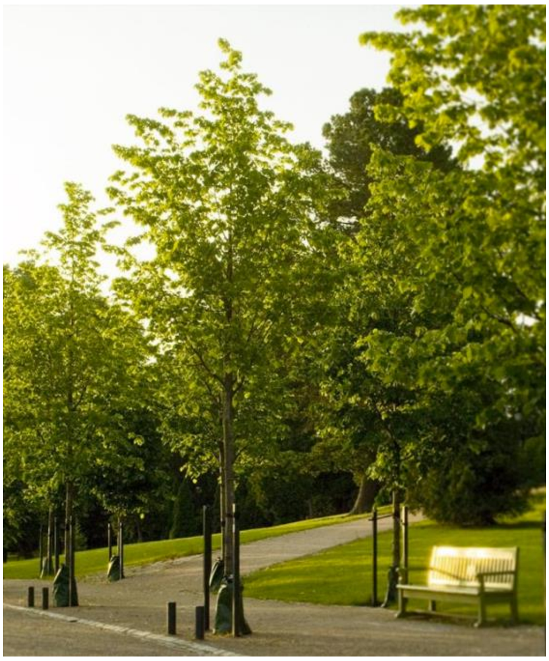
Picture	
Name	***Tilia x vulgaris*** **(Puistolehmus)**
FinE plant	No
Growth zone	I-V
Height	10-20m
Blossom	July

Table 3 Tilia x vulgaris (Puistolehmus) (Kekkila.fi, Puistolehmus)

Tilia x vulgaris is a large and commonly used tree in parks and avenues in cities. Its canopy is conical and wide, and it grows densely. The leaves are heart-shaped, broad, and serrated. The tree blooms in July with fragrant yellow-green flowers. The long-lived tree tolerates road construction, air pollution and wind well, captures dust, and provides protection against noise while also providing moderate shade. When the tree is located in dry conditions, the upright-growing park lime trees are exposed to aphids, which secrete sticky and staining honeydew. (Table 3) (Kekkila.fi, Puistolehmus.)

6.2 Shrubs

Picture	
Name	***Rhododendron x fraseri* (Kevätatsalea)**
FinE plant	Yes
Growth zone	I-III
Height	100-150cm
Blossom	May-June

Table 4 *Rhododendron x fraseri* (Kevätatsalea) (Taimistoviljelijät ry, Sirkka Juhanoja, 2018)

Rhododendron x fraseri, or commonly referred to as “Spring azalea” is a cross between Canadian and Japanese azalea, and a delicate and small deciduous shrub that is the most durable azalea in Finland. It grows slowly when young but branches abundantly. It blooms in late May and produces sterile butterfly-like, purple-pink, and fragrant flowers and has large, bright green and fuzzy leaves on both sides. Table 4) (Puutarha.net, Kevätatsalea.)

Picture	
Name	***Spiraea Chamedryfolia* (Kiiminginangervo 'Martti')**
FinE plant	Yes
Growth zone	I-VI
Height	150cm
Blossom	June

Table 5 Spiraea Chamedryfolia (Kiiminginangervo 'Martti') (Taimistoviljelijät ry, Sirkka Juha-noja, 2018)

Spiraea Chamedryfolia is a curving, upright, and dense shrub, that grows in five years to a one-metre width. The branches are angular and bare, grey-brown in colour, and the leaves are lance-shaped and dark green on the upper side, while greyish-green on the bottom side. The shrub blooms in early June and their colour turns yellowish in the autumn, but often with reddish hues. (Table 5) (Taimistoviljelijät, Kiiminginangervo ‘Matti’.)

6.3 Perennials

Picture	
Name	***Geranium sanguineum*** **(Verikurjenpolvi 'Hempukka')**
FinE plant	Yes
Growth zone	Thrives in sunny and dry conditions and nutrient-poor to moderately fertile soil.
Height	30-50cm
Blossom	June-August

Table 6 Geranium sanguineum Verikurjenpolvi 'Hempukka' (Taimistoviljelijät ry, Marjatta Uosukainen, 2018)

Geranium sanguineum has a shrubby growth habit and is dense and covering by nature. Its stems are usually red and hairy, while leaves are lobed, dark green, and delicate. The flowers are large and light pink. The plant has red autumn foliage, and it is suitable for rock gardens, meadows, and fields. The previous year's growth can be cut back, if necessary, in spring. The plant mass is to be left as a cover in autumn. (Table 6) (Taimistoviljelijät ry, Marjatta Uosukainen, 2018.)

Picture	
Name	***Thymus serpyllum* (Kangasajuruoho)**
FinE plant	Yes
Growth zone	Thrives in sunny and dry conditions with nutrient-poor soil
Height	5-10cm
Blossom	late June – August

Table 7 Thymus serpyllum (Kangasajuruoho) (Taimistoviljelijät ry., 2018)

Thymus serpyllum is a mat-forming plant, or a low semi-shrub. It has small, glossy leaves and small, lip-shaped, reddish-violet flowers. It flowers abundantly and is partially evergreen. The whole plant is fragrant. This plant is used in rock gardens, as a cover plant on slopes, and is a substitute for lawn. It thrives in urban areas and makes a good plant for bees. (Table 7) (Taimistoviljelijät ry., 2018, Kangasajuruoho.)

Picture	
Name	***Stachys byzantina* (Nukkapähkämö)**
FinE plant	No
Growth zone	Thrives in sunny and dry conditions, rockery plant
Height	20-40cm
Blossom	July – August

Table 8 Stachys byzantina (Nukkapähkämö) (Puutarha.net, Nukkapähkämö)

Stachys byzantina has velvety leaves which are gray-white and fuzzy and form dense leaf rosettes. The lip-shaped flowers are rose-pink and fairly indistinguishable in the upright, gray-fuzzy inflorescences. After blooming, the leaf rosette dies and causes the plant to shrink down gradually. The plant spreads in a mat-fashion with the help of runners. (Table 8) (Puutarha.net, Nukkapähkämö.)

Picture	
Name	***Anaphalis margaritacea* (Helminukkajäkkärä)**
FinE plant	No
Growth zone	Thrives in sunny and dry conditions
Height	30-60cm
Blossom	July – September

Table 9 Anaphalis margaritacea (Helminukkajäkkärä) (Puutarha.net, Helminukkajäkkärä)

Anaphalis margaritacea has silvery-white leaves which are slender and pointed, with fuzz below. The blooms are white spherical, and they bloom in bunches. It looks like a little strawflower. The flowers are clustered at the top of the stem and bloom for a fairly long time. The plant spreads by runners and attracts butterflies. (Table 9) (Puutarha.net, Helminukkajäkkärä)

6.4 Annual summer flowers

Picture	
Name	***Arctotis fastuosa* 'Zulu Prince' (Seittihopeasilmä)**
FinE plant	No
Growth zone	Greenhouse-grown, transplant outside when the risk of frost has passed.
Height	40cm
Blossom	June – August

Table 10 Arctotis fastuosa 'Zulu Prince' (Seittihopeasilmä) (Puutarha.net, Seittihopeasilmä)

Arctotis fastuosa 'Zulu Prince' is a white daisy-like flower with a unique, large silver-coloured centre and colourful stamens. It thrives in heat and drought and is modest with regard to soil. (Table 10) (Puutarha.net, Seittihopeasilmä)

Picture	
Name	***Gilia tricolor* (Kirjokiurunkukka)**
FinE plant	No
Growth zone	Thrives in sunny and dry conditions
Height	50cm
Blossom	June – October

Table 11 Gilia tricolor (Kirjokiurunkukka) (puutarha.net, Kirjokiurunkukka)

Gilia tricolor is a shrubby plant with dill-like leaves. Its flowers are purple or violet with a yellowish-white throat. It blooms abundantly and attracts butterflies. The plant is fast-growing. (Table 11) (Puutarha.net, Kirjokiurunkukka; Mustilapuutarha, Kirjokiurunkukka)

6.5 Vines

Picture	
Name	***Actinidia kolomikta*** **(Kiinanlaikkuköynnös)**
FinE plant	Yes
Growth zone	I-III
Height	2-3m
Blossom	June

Table 12 Actinidia kolomikta (Kiinanlaikkuköynnös) (Kekkila.fi, Kiinanlaikkuköynnös)

Actinidia kolomikta is an easy-to-take-care-of vine. It is fairly large, vigorous, and a perennial vine. It has large decorative leaves which are white-tipped in early summer and red-and-white speckled in late summer. It thrives in a sunny or semi-shaded location in fresh, nutrient-rich, and limed soil. The stiff stems do not attach by themselves, so they are tied around the trunk of a tree or to a trellis, but they can also be allowed to cascade down from a wall. (Table 12) (Kekkila.fi, Kiinanlaikkuköynnös.)

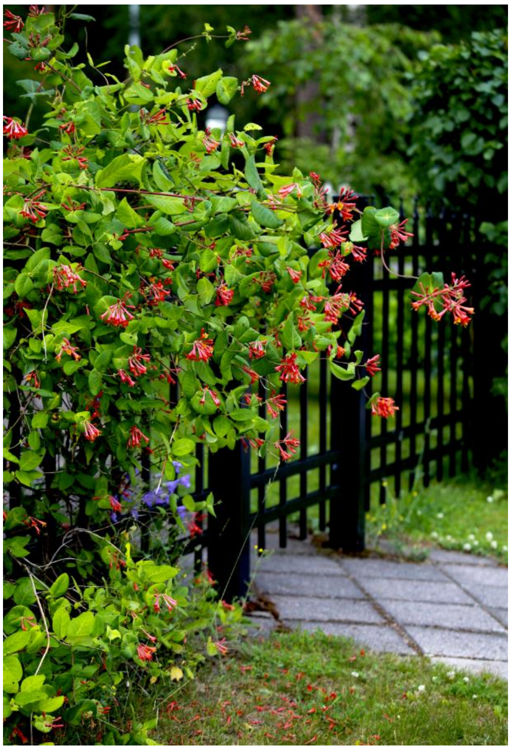
Picture	
Name	***Lonicera dioica*** **(Kevätköynnöskuusama)**
FinE plant	Yes
Growth zone	I-V
Height	3m
Blossom	June – July

Table 13 Lonicera dioica (Kevätköynnöskuusama) (Taimistoviljelijat.fi, Lahtinen M., 2018)

A bushy lilac with roundish leaves, which are unbroken-edged. Its small flowers are pale yellow/orange/purple-tinted. It is the most durable lilac, which twines itself around the support. (Table 13) (Puutarha.net, Kevätköynnöskuusama.)

6.6 Wild summer plants

Picture	
Name	***Veronica chamaedrys* (Nurmitädyke)**
FinE plant	No
Growth zone	Thrives in sunny conditions
Height	10-30cm
Blossom	May – August

Table 14 Veronica chamaedrys (Nurmitädyke) (Puutarha.net, Nurmitädyke)

A shrubby plant with large-toothed, heart-shaped, or tapered leaves. The small blue flowers are in sparse clusters. It blooms for a fairly long time and spreads easily as a mat. The plant prefers sunny and dry conditions. (Table 14) (Puutarha.net, Nurmitädyke.)

Picture	
Name	***Calluna vulgaris* (Kanerva)**
FinE plant	No
Growth zone	I-VII
Height	20-50cm
Blossom	July – August

Table 15 Calluna vulgaris (Kanerva) (Luontoportti.fi, Kanerva)

Calluna vulgaris is a perennial plant, which thrives in barren, sunny locations. It attracts butterflies and bees. The stem is upright, densely branched, and woody. It blooms in late summer, with the most abundant flowers in August. Its flowers are small, reddish-purple, but sometimes heathers can be found which cannot produce the blue-purple pigment, thus producing white flowers. (Table 15) (Luontoportti.fi, Kanerva.)

7 Conclusions and proposed solutions

In the thesis I have used the plant register provided by Puutarha.net, FinE -plants list by Taimistoviljelijät ry, and the urban plant guide by the city of Turku, from which I have gathered the key information about the chosen plant species. I have also benefited from the expertise of the chairman of the Finnish dendrology society, Mr. Timo Koskinen, who has provided me with practical and specialist comments to help in the selection process. Noting that there are hundreds of plants available, it must be highlighted that the plant species mentioned in the thesis are my suggestions based on the research of the thesis, not the only possible options available.

The proposed solution, the set of heat-resistant plant species, is a preliminary work to benefit the Steps to prepare for climate change -project and the municipality of Iitti in particular. The plant species are selected based on the specific conditions in mind, those being most importantly heat resistance and adaptivity to the future climate. The suggestions include common plant species but also species that could add biodiversity in the area and help to decrease the amount of plant pests in the future as well.

Testing different perennials, for instance, is an effective way of seeing which kinds of plants thrive in the location and they do not need to be replaced every year. The park lime trees that are currently planted at the marketplace of Iitti, are suggested to keep them in the future as well. They have a lot of good qualities, such as big leaves and general durability, and they will continue to succeed, as they tolerate heat and other extreme weather conditions.

The functions of vegetation in enhancing heat resilience in the urban context are numerous, as vegetation can mitigate the impacts of extreme heat on infrastructure by providing cooling shade, absorbing heat, and lessening the UHI effect in the city. There are also various advantages and disadvantages of adding vegetation into infrastructure design. Vegetation improves local air quality and lowers energy costs, but it requires upkeep and installation, both of which generate expenses. For the marketplace of Iitti, the focus is on the open space and its surroundings, but the current structures in the marketplace can also be used to add biodiversity.

8 Summary and discussion

The intensifying effects of climate change, as emphasized by the IPCC (2022), demand a versatile response that includes both mitigation and adaptation techniques at the country and municipality levels. While the focus on reducing the overall greenhouse gas emissions must continue, stress on readiness and proactive adaptation is also imperative. Municipalities play a critical role in this mission, requiring a transition from reactive to proactive and preventative measures to successfully handle the difficulties posed by climate change.

The temperature estimates for Finland, as reviewed in the previous chapters, indicate the unpredictability of future climate patterns, which emphasizes the importance of adaptive plans. The value of green infrastructure and heat-resilient infrastructure stands out among them. Green infrastructure is valuable because of its ability to manage stormwater, mitigate the UHI effect, and boost biodiversity (McCarty et al. 2021; Sunita et al. 2023). On the other hand, heat resilience infrastructure, including technologies such as cooling facilities, for instance, shade structures and green spaces, is becoming increasingly important in managing the increase of extreme heat events (Stone et al. 2019).

However, the successful integration of green and heat resilience infrastructure requires a comprehensive approach that considers both social and economic factors. Community engagement and cooperation with private developers, as demonstrated by Fukuoka's proposal (2022), are crucial to ensure that the plans benefit all parts of society. This approach is shown by the municipality of Iitti's participation in the Steps to Prepare for Climate Change -project, which aims to raise climate awareness and develop creative adaptation solutions.

The primary goal of this thesis was to contribute to better climate change adaptation and preparation planning for the municipality of Iitti. The thesis has provided practical suggestions that may be used to improve heat resilience by concentrating on the potential of vegetation as a tool to reduce the consequences of climate change because vegetation has a dual role in providing cooling and improving the liveability of urban environments. The municipality's commitment to proactive preparation is aligned with the emphasis on selecting suitable plant species for heat tolerance, particularly in the marketplace of Iitti.

The municipality of Iitti has some plans already for the development of the marketplace, for example, a micro forest has been discussed because it could add more shade yet be a separate space in the marketplace. This would create more airflow in the marketplace and add biodiversity when different vines and flowers could be used in the micro forest. By adding a bench or two, the liveability of the marketplace can be further enhanced, and the air quality be improved.

Lastly, the thesis was crucial in raising climate consciousness and knowledge among decision-makers and municipal personnel. As climate change continues, the insights learned from this thesis can help the municipality of Iitti and its decision-makers create flexible, sustainable, and climate-resilient urban environments and be better prepared for adapting to future climate.

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