HUNGARIAN UNIVERSITY OF AGRICULTURE AND LIFE SCIENCES

THESES OF THE DOCTORAL DISSERTATION

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The role of agroforestry in the urban environment

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1. BACKGROUND AND OBJECTIVES

Cities in the world face inequalities in the face of Climate Change. There are also global disparities within the cities affecting citizens' well-being, level of vulnerability to Climate Change and access to green spaces equally (EEA, 2024). As urban agriculture is in high demand in the world with more request for access to land and shows environmental and social benefits such as education around food, community bonding, social mixity, inclusion and biodiversity in the cities, urban agroforestry was assessed as a complement to this practice to see its potential to reduce impacts of urban sprawl, urban heat islands, spatial segregation and restore landscapes. Agroforestry is a traditional practice which is being reintroduced in European agricultural lands because planting trees in productive lands has several purposes and benefits. As agroforestry is slowly spreading and engaging more attention, some urban agroforestry systems are also starting to emerge and should also be explored for their possible positive impacts on the cities' environments and social well-being. Indeed, climate change scenarios cause cities to rethink their planning strategies for mitigating the impacts of climate change. Urban agroforestry is known and developed in the Pacific Islands and is a traditional practice in many countries. In Europe, forest-gardens were introduced by the English botanist Robert Hart who created a model for Temperate Climates.

According to the Nations Food and Agriculture Organization (FAO), 75 % of people will be living in cities by 2030. The FAO estimates that about 815 million people of the 7.6 billion people in the world, or 10.7%, were suffering from chronic undernourishment in 2016. Almost all the hungry people live in lower-middle-income countries. Needs also to be considered the waste of food and a drastic reduction of biodiversity due to urban sprawl caused by expansion of cities and the use of pesticides in agriculture and monoculture and also due to climate change. According to the FAO, amongst 6 000 plant species cultivated for food supply, 9 of them represent 66 % of the total agricultural production. Must also be considered the decline of pollinators, birds, bats, and auxiliary insects for cultures, and micro-organisms in the soils (Reporterre, 2019). Deforestation in the world is mainly caused by agriculture and carbon emissions mostly originate from cities. Added to the loss of biodiversity and the need in food provisioning, cities need to find solutions to mitigate urban heat islands and restore urban soils. Climate change scenarios have social impacts such as the emergence of eco-anxiety and refugees. The Covid-19 pandemic showed the need for people for more green spaces and connection to nature, as well as the need to maintain cultural activities. Agroforestry presents important known benefits such as increased biodiversity and protection of biodiversity, a better management of the water and the soil and agroforestry plots create carbon sinks. It is an old practice which has been replaced by monoculture. It can also bring new demand in organic food and prevent loss in varieties of edibles. What we buy and consume has an impact on the market. There is a need to bring food systems closer to consumers to reduce dependency on oil and enhance access to food and materials in cities. However, cities face pressure in demand for housing and numerous cities suffer

from lack of green spaces for reducing heat stress and cultivating. This thesis states that through strategic planning and adaptation of landscape designs for food systems and materials to these contexts with principles of agroecology, it is possible to have a diverse set of productive spaces in and around cities and reduce spatial segregation. There is also the European Union Soil Strategy for 2030 which states that soil must be preserved for its biodiversity and recycled (EU soil strategy for 2030, European Commission), meaning that there is a need to restore urban soils. This is why this thesis is focused on implementing agroforestry systems in cities. This thesis questions why and how agroforestry should be a land use in cities and a long-term practice. There is also the need to stop the use of pesticides in urban green spaces and to come back to local knowledge and know-hows with exchanges and to increase access to local materials and resources. According to the FAO, water management is also a challenge in sustainable food systems (FAO, 2023). And the question of soil erosion, biodiversity, pollution and desertification needs to be taken into consideration in landscape architecture. And there is the need to less depend on oil in producing food and materials and also in arts. In planning and landscape architecture, climate change impacts on cities must be assessed and answered to, as well as spatial segregation challenges and the creation of inclusive cities. Cities are spaces for transfer of knowledge and can play an important role for environmental education and the creation of resilient landscapes with social inclusion. There needs to be a co-design through community and expert engagement and adapt the urban agroforestry types to community foodways (Taylor J., Lovell S., 2021).

Flowchart of the thesis

Figure 1. Flowchart of the thesis. Paloma Gonzalez de Linares

1.1 Research question and hypothesis

This section presents the thesis question and hypotheses.

Research question

Why and how can agroforestry systems be integrated in urban green infrastructure plans as a land use with social inclusion, for a resilient and inclusive city, and at which scale?

Research hypothesis

1. Urban agroforestry can have several social and environmental purposes in the city and be part of a green infrastructure plan including the peri-urban areas. It can increase the accessibility and diversity of multipurpose green spaces in the city. A model can be created for its integration in green infrastructure planning.
2. Urban agroforestry governance and systems link biodiversity protection, local economy and social inclusion through arts. Public participation is important for transfer of knowledge and social inclusion.
3. Urban agroforestry should be planned with a participative assessment at the watershed scale, the corridor scale and the neighbourhood scale with participation of citizens and cooperation.
4. Urban agroforestry for arts reduces spatial segregation for access to shade and materials and contributes to creating circular and inclusive cities with landscape restoration. It can be adapted to different land uses for city resilience, community-building and transfer of knowledge.

1.2 Research goals

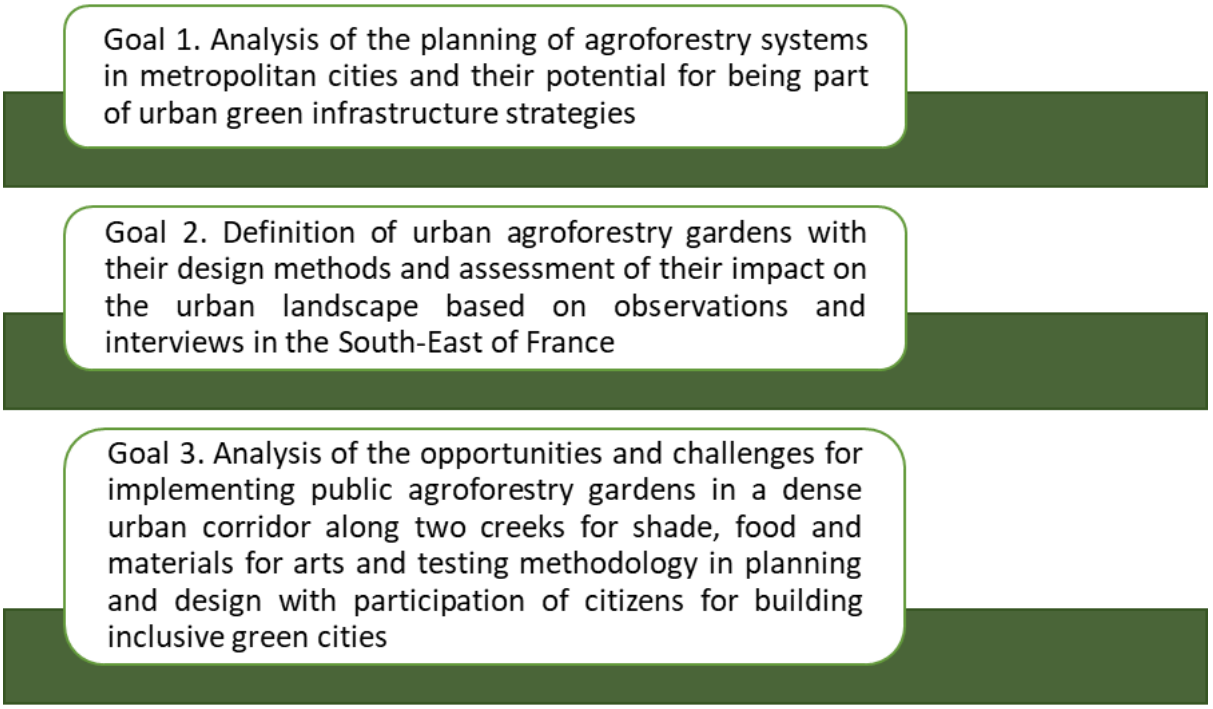

Figure 2. Thesis goals, Paloma Gonzalez de Linares

2. MATERIALS AND METHODS

Goal 1 Analysis of the planning of agroforestry systems in metropolitan cities and their potential for being part of urban green infrastructure strategies

This first goal is to assess why and how agroforestry systems were planned in five European metropoles. The methodology for this goal was to do five questionnaires in three French cities, one German city and one Belgium city: Nantes, Rennes, Montpellier, Donzdorf and Liège. The questionnaires were online with the metropole of Nantes, the Chamber of Agriculture of Rennes, an NGO in Montpellier managing a vitiforestry plot, a municipality representative of Donzdorf and a member of the Edible belt of Liège. These cases were chosen because of the will of the municipality for planning agroforestry systems in the urban and peri-urban area and because of the initiatives taken by NGOs and citizens and because they are all crossed by rivers. The information was found through conferences and documentaries. In addition to the interviews, a map analysis of the location of the agroforestry plots was made in the whole urban policy framework for green infrastructure planning at the watershed scale, with assessment of the protection of agricultural lands and urban forestry projects. The watershed scale was chosen because of the need in integrating the water cycle in agroforestry systems and rivers and creeks present interesting corridors to protect and value.

The questions were about the context and purpose, location and accessibility, citizen's involvement and management and challenges.

Goal 2 Definition of urban agroforestry gardens with their design methods and assessment of their impact on the urban landscape based on observations and interviews in the South-East of France

This goal focuses on the types and designs of urban agroforestry systems through on-site analysis and semi-structured interviews. The plots assessed are located in the South-East of France. Two of the agroforestry plots are located on drystone terrasses, two are in horticultural highschools and one is in an abandoned land from the motorway. These gardens are implemented by local NGOs and in the case of one, by teachers. These gardens were chosen because of the involvement of citizens and institutions in urban agroforestry and also because of the European MEDALUS program which was about Mediterranean desertification and land use. As Hungary is also facing struggles with desertification, these gardens were assessed to see the possibilities for urban and peri-urban agroforestry for this matter and how they are managed. As Hungary and Mediterranean cities are facing common challenges in the face of climate change, common research can be made with agroforestry, for example for soil erosion, drought and also fire risks.

The questions were about the governance, technics, artistic practices, surroundings and accessibility.

Goal 3 Analysis of the opportunities and challenges for implementing public agroforestry gardens in a dense urban corridor along two creeks for shade, food and materials for arts and testing methodology in planning and design with participation of citizens for building inclusive green cities

This goal is about finding potential spaces for agroforestry along the Rakos and Szilas creeks through a participative research, from Szada to Budapest and assessing the opportunities and challenges for implementing agroforestry systems in a corridor with the involvement of citizens and create a participative methodology in planning agroforestry in cities. The process of the landscape architect and the methodology for planning and designing urban agroforestry are assessed through field work experiences with the implementation of a public forest-garden in the 14th district of Budapest.
The main aspects considered to define good spaces for urban agroforestry were the ownership, the land use, the proximity to city dwellers, the accessibility of the plot, the size of the plot, the presence of pipelines and infrastructures on the plot, the connection to wildlife habitats and the equity in the distribution of green spaces in the city.

First, interviews were made with NGOs and experts in Budapest to assess the opportunities and challenges of creating an urban agroforestry corridor along the Rakos and Szilas creeks with social inclusion. The questions for the NGOs and experts in Budapest were about the purposes and challenges of urban agroforestry and their opinion about the possible locations for urban agroforestry plots.

Second, interviews were made in the community gardens along the Rakos and Szilas creeks in Budapest to assess the importance of community based agroforestry systems with their goals and obstacles (table 4). These interviews explain the challenges future agroforestry community gardens could face and the gardeners can be part of a potential network for exchanges of resources and knowledge for agroecological practices and connectivity between community gardens through a green network.

The questions were about the land accessibility, opportunities for community agroforestry gardens in Budapest, challenges for community agroforestry gardens in Budapest and garden connectivity.

Third, workshops were held in 2 schools in Budapest to assess the perception of schoolchildren on urban gardens and involve them in the planning process. The schoolchildren could paint and draw their ideal urban garden. The first workshop was in the Waldorf school in Kaposzta megye, Budapest, where 30 students between 15 and 16 years old took part during their Art class.

The second workshop took place in the Török Ignác Gymnasium in Gödöllő, where 13 students between 15 and 16 years old participated during their History and Geography class.

Before the sketching exercise a short introduction to urban agroforestry was given.

From all these actors interviewed a governance system can be drawn for urban agroforestry and community-based planning tools can be suggested. The present community gardeners, NGOs, decision-makers and experts interviewed are a potential network for the development of urban agroforestry along the Rakos and Szilas creeks.

From my initiative and for the benefit of this thesis, a test plot was created with the 14th district council of Budapest to meet with several objectives:

- involve local communities and assess the participative design possibilities for agroforestry gardens,
- assess the potential for urban forest-gardens and the impact of tree species on the soil,
- create a public agroforestry garden for educational purposes, food and arts,
- assess how urban agroforestry can be implemented according to the regulations and the limits and challenges.
- the process for the landscape architect was also assessed through experience in the implementation of the agroforestry system.

The project was to open a public forest-garden in the city of Budapest. The first step of this project was to meet with local NGOs and community gardeners to involve local communities and find a plot for a participative urban agroforestry plantation with the size of an average traditional Hungarian homegarden of 200 m2 (Vandenbroucke P. and Feher I., 2013). After giving a conference on urban agroforestry and the project at the KEK and with local NGO Cargonomia, the Vice-Mayor of the 14th district of Budapest expressed an interest in the project. The public forest-garden project was planted in 2018 and 2019 on a residential plot of land in the 14th district of Budapest, in Németpróna utca (figure 14). The plot was chosen because it was public and next to a school for visually impaired children and in a residential area. It belongs to the district council. It was implemented with an assessment of the land for the soil characteristics and contamination, the water drainage and the presence of vegetation and bioindicator plants. The plot is used for the purpose of the thesis to assess the potential of species on the urban soil and to build a method in planning and designing urban agroforestry public gardens with participation of citizens.

During the process of the planning of the public forest-garden, before and during the planning, several interviews were made with experts in permaculture, agroforestry, garden design and nature conservation to assess the best trees to plant but also to involve them in the project and create a network around the garden and share the project and opportunity. This helped in knowing the local species and networking with local actors in the field of agroecology and nature protection. Only endemic species were planted. These were local Quince, Apple and Pear trees, Mulberry, Mountain Ash, Hazelnut and Lime trees. According to an engineer in agroforestry in the university of Sopron, Quince is a very valuable tree. Later, aromatics and berries were planted in Spring 2019. To avoid isolation of the plot, a study was made to assess its possible inclusion in an agroforestry corridor through participative methods. The Rakos creek presents an opportunity for this corridor. A map of underground pipelines was also used to plan the plantation of the trees. It was recommended not to plant invasive species, toxic species or species with thorns. Sketches were made to present the possible species to plant and their functions.

The methodology used in the design of the system was to use the permaculture guild concept from the Permaculture Design, a consulting and design office in France, with different tree species, shrubs and aromatics from different families. All the energy in the garden would be used such as the leaves for composting and for mulching. A first plan would be made and the community would be involved in the plantation and later in the design so they can appropriate the space and adapt it to their needs and perception. There was the need to plan a watering system and a compost box and evaluate the potential people which could be connected and involved in the garden. They would be the direct recipients of the open public garden. The soil was assessed for its acidity, texture and contamination. Bioindicators were also searched with the identification of plant species, for example for the soil fertility, and the topography was analysed for the water flows.Through the participative plantation of the plants with citizens in the garden, some of the plants were donated. Indeed, the project was

open to donations with the principles of non-invasive species, toxic species and thorns. This was to involve citizens, share knowledge about species and encourage an appropriation of the space.

The effect of the planted trees on the soil was assessed in comparison with other green spaces and species in Buda campus and the campus of the MATE university in Gödöllö. These samples were made in Summer 2022 and took into account the agroecological methods and groundcovers in raised beds made by citizens and compost coming from community gardens. The goal is to analyse the organic matter under different tree species, in different soils conditions and with different ages. The Arboretum of the Budai campus of the University MATE in Budapest is 100 years old and has trees between 100 and 20 years old, the agroecological garden of the Budai campus has a parcel which used to be used as a nursery for ornamental trees and has been converted to agroecology for 15 years, the forest-garden of the campus of Gödöllö which was started by students 5 years ago and the public community forest-garden of Zuglo which is 2 years old. In the case of Zuglo and the agroecological garden of Buda, the soil is sandy and compost and sheep manure in Zuglo or hen manure and cow manure in Buda. In the case of Buda hay and cut grass are regularly added to the plot for mulching. In the case of Zuglo, the mulch is made with leaves, mainly from Populus. Under each tree species, 5 holes 10 cm deep were dug. The distance from the tree trunk was measured as well as from possible pavements and staircases.
The tool used to analyse the samples was the scanning device from Agrocares in the campus of MATE university in Gödöllö. The assessment was made while the citizens can use the plot for gardening and arts and appropriate it. The plot is also a teaching space in agroecology and agroforestry. The communication on the plantation event was made through social media and leaflets in the neighbourhood to involve citizens.

Szada

In Szada, a meeting was organised with the Mayor and the organisation of the Biodynamic garden. The Mayor provided the maps of the available municipality owned lands which could be used for the project.

Budapest

From the interviews with decision-makers, map analysis and on-site analysis, a map of possible plots for urban agroforestry development was made for Budapest. A base-map (Map 8) for the possible location of public agroforestry plots for food and arts and social inclusion along the Rakos and Szilas creeks in Budapest was made according to the land use map and interviews with the city council and exchanges with the bfvt and the 13th district council which has a local green infrastructure strategy plan to which urban agroforestry plantations could be part of.

3. CONCLUSIONS AND NEW SCIENTIFIC ACHIEVEMENTS

3.1 Conclusions

From this research I conclude that the main role of urban agroforestry is education with transfer of knowledge. The process to plan and design agroforestry gardens should be participative to assess the social and ecological purposes of the agroforestry systems according to the demographic, climatic and soil context. Art practices should be included for social inclusion and the plantation. The artistic approach can be with the design strategy such as land art and with the plantation of tinctorial plants. These tinctorial plants can be used on brownfields, in vacant lands and in hedgerows. Urban agroforestry can also be a solution to value and reuse green waste such as branches and leaves, dried flowers for artistic practices.

From this research several conclusions can be made and lead to guidelines for planning and designing agroforestry systems and reflect on the role of the landscape architect. The importance of the soil for planning and designing urban agroforestry systems was stressed through this thesis research. It is the most important element for landscape architecture. Then the transfer in knowledge about plants and biodiversity is important through landscape planning and design at a community scale.

<u>The steps in planning urban and peri-urban agroforestry are:</u>

1. **Plan at the watershed scale** in the green infrastructure plan: plan along rivers, creeks and water areas. Use heat maps to choose the agroforestry system for example to plan vitiforestry and species, the watering system and prioritise areas, use the keyline design, plan rainwater harvesting sites and phytoepuration with agroforestry gardens, parks and linear residential agroforestry hedgerows. Plan the green belt and community agroforestry gardens. Assess the landscape with landscape metrics.
2. Involve citizens at the **neighbourhood** scale and create agro-neighborhoods or agro-districts : create socio-ecological networks for resources such as green waste and management for agricultural landscapes such as hay, manure, plants and seeds.
3. Create socio-ecological agroforestry corridors with public participation through **participative mapping, sketching and drawing**: create the management plan for green waste and paths between the plots, meet with decision-makers, involve schools.
4. Design from the scale of the soil and existing ecosystems and vegetation.
5. Prioritise enclaved spaces and neighbourhoods with high heat stress rates.
6. Administrative boundaries need to be overcome to plan at the watershed scale. There needs to be cooperation between cities, researchers and citizens.
7. Planning at the watershed scale is also to manage wildlife habitats and corridors.
8. Socio-ecological corridors can be carried out with networks through education, training and participative designs.

9. Communication between plots and exchange of knowledge.
10. Exchange of knowledge and research in plant species and monitoring between researchers, engineers and citizen-based organisations with on-site practice and experiences. The landscape architect collects the information and transfers the information through his/her designs and with participative workshops.

Guidelines can be drawn for the plantation of species:

1. Landscape architects need to plan and design from the existing ecosystems, especially the soil conditions and characteristics.
2. The choice in species is according to the site location, the soil, the context and the purpose.
3. New species shouldn't be introduced in protected areas. It should remain protective and with endemic species.
4. Several trees, bushes, ground covers and flowers could be explored and planted for artistic purposes with environmental benefits in urban agroforestry systems.
5. The choice of species can be according to the albedo of the soil and the species already present on the site.
6. The Sorbus domestica and Sorbus aucuparia can be good multipurpose trees for cities because they are useful for stabilising slopes, they are resistant to drought and air pollution and are also useful for attracting birds in the case of Sorbus aucuparia or as a fruit tree in the case of the Sorbus domestica. The wood is also useful for woodworking. They can be planted in hedgerows.
7. Tilia species are good to plant in urban hedgerows.
8. Alyssum murale could be used for depollution on brownfields, to take away heavy metals especially nickel. It can be a green cover on spaces where production is impossible and in vacant lands close to high traffic roads.
9. The Robinia pseudoacacia woodlands shouldn't be used for paths because it can contribute to spreading the seeds.
10. The drawings from the workshops with the schoolchildren reveal that there need to be mainly water elements, wide canopy trees and green extensive covers in agroforestry garden and park designs.
11. Tinctorial plants can be planted.

The limits and challenges are:

1. No high pollinator attractors near jogging paths and sports areas. There needs to be a balance between the gardening activities and the other recreational activities.
2. Areas near high traffic agroforestry could be used for landscape restoration and biodiversity conservation and be an ornamental plantation.
3. Fruit trees should be avoided along paved paths or be planted so the fruit doesn't fall on the paved path.
4. According to the interviews, the main challenges are social inclusion for homeless and refugees and wildlife management. In the face of climate change, geopolitical instabilities and economic disparities, these issues need to be solved.
5. Vitiforestry needs to be planted at a far distance from high traffic and urban heat islands. It is best located in peri-urban areas.

6. Avoid the introduction of cows, they should stay outside of the city, in peri-urban areas because of methane and trampling.
7. Go from the existing species identified to plan, such as indicators of soil fertility.
8. Include agroforestry engineers in the process to plan the system.
9. Decision-makers need to find new participative planning tools to renew landscapes with agroforestry and build socio-ecological corridors and networks. The PPGIS is a solution for this matter.
10. New regulations need to be made by planners for the design of the water management systems of these agroforestry plots.
11. Landscape architects need to work with agronomy engineers in order to calculate the quantity of production which can be grown on a unit of land and plan the plantations.

The landscape architect has several roles to play in urban and peri-urban agroforestry.

He/she:

1. Finds land for agroforestry systems by using maps and with on-site analysis.
2. Assesses the urban soil and works at the plot scale to choose the agroforestry systems and species.
3. Makes concepts, sketches and designs with research in species and companion planting and according to the land use, the watershed scale, the location of the plot and local context of the climate, pollution and soil.
4. The landscape architect needs to plan, design and monitor the plantations with participation of researchers and institutions for social purposes and wildlife management.
5. Can play a role in connecting community-based agroforestry systems through creating socio-ecological corridors with agroforestry systems.
6. Can be a mediator between organisations and decision makers and citizens. Landscape architects are mediators between the regulations and on-site ecological, social and economic needs.
7. Provides and co-designs new spaces for arts with agroforestry systems with involvement of citizens.
8. Is also an artist and uses different mediums to communicate on designs and share knowledge. He/she can develop land art with urban and peri-urban agroforestry.
9. Renews landscapes with agroforestry for artistic purposes with involvement of citizens for the transfer of knowledge.
10. Needs to cooperate with agricultural engineers, decision-makers, farmers and citizens to organize the functions of the agroforestry systems and the management. With a participative method, the landscape architect plans resources around the plot and the network. He/she listens to the citizens and creates the master plans from exchange of knowledge and participative projects.
11. Has a role in education about trees and species to plant in cities and to renew landscapes with agroecological gardens and arts. The landscape architect can transfer knowledge and teach about trees and companion planting through the designs.

12. Makes keyline designs.
13. Leaves spaces for expression and participative planting and design by citizens. These spaces can be included in hedgerows.
14. Makes connections between technical and scientific research and arts in the designs.

The landscape architect faces several limitations:

He/she is limited by the fact that agroforestry and urban agroforestry are not a land use. This means that it is difficult to find long term plots for these practices. The watering management regulations need to be made and authorised by decision-makers. The emergency and challenge for the landscape architect is to find adaptive watering systems and species adapted to heat and drought and also mitigate desertification when it is present. More participative planning tools need to be created for involving citizens, NGOs decision-makers and experts with inspiration from the PPGIS method. Another tool such as a platform could be created for this purpose. The landscape architect can make suggestions to manage invasive species with experts. The plot needs to provide space for free plantations with some restrictions such as no poisonous and non-invasive species.

Governance system:

The landscape architect is a mediator between decision-makers and citizens. Decision-makers and city planners cooperate with researchers, agronomists and naturalists and with citizens, community gardeners and schools. The PPGIS and participative designs are used to involve citizens in the planning and design of agroforestry systems with waste management, water management, creation of paths and networks for resources. The Landscape Architect works with local garden animators for defining the management strategies and the self-organisation of the garden. Citizens also take part in participative planting and the maintenance of the plots. The city provides public land for cultivating with agroforestry systems.

Methodology for co-designing urban agroforestry gardens

From the interviews and the test-plot a methodology for co-designing landscape agroforestry landscapes can be created.

The people involved are experts, NGOs, community gardeners and voluntary citizens and institutions such as schools. There needs to be an assessment of the needs and wills and some workshops to express interests in agroforestry systems and imagine them. They can be designed in many different ways and enhance creativity in the city with exchange of knowledge.

Limits of the research

This research has some limits due to the lack of time. First, more farmers could have been included in the research to develop the peri-urban agroforestry systems and discuss the species which could be planted in goal 3. The perception of agroforestry from the farmers could be assessed and they could be connected to the urban gardens and the agroforestry corridor project. Second, the economic aspect needs further development but the potential for a circular economy and new economy based on local urban and peri-urban production was

revealed. Third, more assessment of the soil needs to be made for defining more possible plants for the agroforestry systems. Finally, the watering management needs to be discussed in a participative way between decision-makers, researchers and local NGOs and citizens.

Further research
The limits to the research lead to further needs and possibilities for research for the evolution of the agroforestry corridor concept. Mainly, the research in the economic and watering systems and selection of species resistant to drought for agroforestry gardens need to be made for planning and design of urban agroforestry gardens.
Finally, landscape architects could explore deeper knowledge about urban soils to define the plantation systems and species which would be adapted to the land.

3.2 New scientific achievements

Thesis_1: Definition of urban agroforestry

From the summary of the different benefits of urban agroforestry and its purpose in the literature review with the terminologies, I defined urban and peri-urban agroforestry.

Urban agroforestry links urban agriculture with urban forestry to create multipurpose green spaces in the city not only for production but also for well-being and therapy. Urban and peri-urban agroforestry are a practice where citizens grow local products in the city with agroecological principles for social and ecological purposes. Woody perennials are planted with non woody perennials in the city, with economic, environmental and social outcomes, like employment, productivity, social inclusion, solidarity economy, education, nature restoration and biodiversity. Peri-urban agroforestry is the implementation of agroforestry systems in the urban fringe and peri-urban areas for food, energy and medicinal production with an economic, landscape and socio-ecological interaction with the cities.

Urban and peri-urban agroforestry are interdisciplinary and include human ecology with a reflection on the management of resources. It is not only about producing, it is also about well-being and creativity with biodiversity in the city. Peri-urban agroforestry systems need to be linked to the urban agroforestry systems through landscape architecture research, for instance with a bioregional scale approach.

Thesis_2: Elaboration of a model for strategy planning of urban and peri-urban agroforestry in green infrastructure
From the questionnaires and location analysis of the four European cities in goal 1, I defined a model for strategy planning of urban and peri-urban agroforestry.

Based on my research different types of agroforestry systems can be created, in underused spaces and old farms, in a network in the urban and the peri-urban regions.
Agroforestry corridors could be created and included in the green infrastructure plans with connections between different cities, cores and patterns in the landscape such as prairies and

other existing wildlife habitats. The model created (Figure 47) needs to be applied at the watershed scale for the protection and management of water resources and finding the best locations for agroforestry systems. At the city scale, urban agroforestry is useful for reducing pesticides and pollution in water, valuing old fruit tree cultivars and traditional agricultural landscapes, providing local food and for education purposes. Urban vacant lands are opportunity spaces for greening with agroforestry systems and educating. Edible belts can be created, including different agroforestry systems. Urban and peri-urban agroforestry should be part of green networks with different agroforestry systems such as forest-gardens, alley cropping and orchards in core areas. Agroforestry systems can be implemented in corridors and provide food and resources to cities and within the surroundings of the cities. There can also be urban forests, but these need to be continuous and can create mixed patterns with urban agroforestry plots within cities. Agroforestry systems can be used to renew traditional landscapes and species and be part of urban forestry plans to protect urban water from pesticides. The outskirts of the cities should be protected with natural wildlife habitats.
Urban agroforestry also needs to be planned in enclaved neighbourhoods to create networks and open spaces to a green and blue network.
Urban and peri-urban agroforestry should be embedded in planning agendas and regulations as a land use and part of green infrastructure planning with a bottom-up approach through educational programs with participation of citizens and at the watershed scale for water management and a landscape analysis. The farmers should be included in the peri-urban areas in the agroforestry green infrastructure plan.

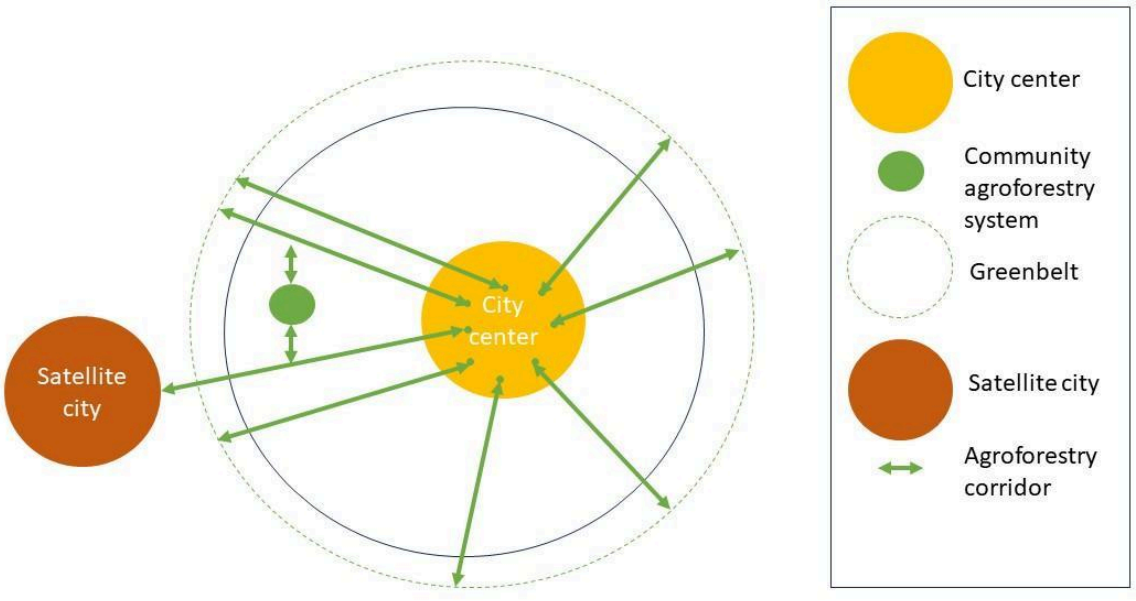

Figure 47. Model for urban and peri- urban agroforestry planning, Paloma Gonzalez de Linares, MATE, 2022

Thesis_3: **Definition of design principles and practices in urban agroforestry gardens**

Based on common findings through observations and semi-structured interviews in urban agroforestry gardens, I defined practices and principles for the design of urban agroforestry gardens and their impact on the urban landscape

Urban agroforestry gardens are plots with a high diversity of trees, bushes and crops from different families and varieties, that a community can use to cultivate, restore and recycle green waste, teach and organise therapeutic and artistic activities in, with participative designs. They don't have defined plots for single families but common growing food and materials with a common management system , based on companion planting. The watering system which is mainly privileged is rainwater harvesting and automatic watering systems. The plots are connected to other gardens and surrounding fields, on residential or institutional ground. They are spaces managed with a circular system and need socio-ecological networks to collect, reuse and exchange resources.
Even if urban agroforestry gardens are based on common principles, they can differ in their spatial arrangement and design, which makes each garden unique and creates a high diversity of gardens in the landscape.
Participative designs use smooth communication tools such as drawing and sketching. By providing spaces and tools for cooperating in designs for urban agroforestry, more resilience of communities is possible and common strategies can be created to adapt to climate change and monitor the landscapes and plants. Urban agroforestry plays a role in education and transfer of knowledge for adapting to climate change, observation and understanding of natural ecosystems and participating in the creation of gardens with different artistic and expressive approaches. Participating in designs of gardens and plantations can also be therapeutic, to take action in the face of climate change.
The potential for agroforestry to be a tool to mitigate fires through permanent management needs to be more assessed. However, it is a solution for maintaining ecological corridors.
What needs to be planned and monitored is water management and the adaptation of trees to climate change. These gardens show that agroforestry systems can be integrated in existing green environments and be part of ecological corridors in cultural agricultural landscape heritages. More research should be made to plant ground covers and reduce heat stress. Agroforestry can be a solution for the economy of water, with rainwater harvesting, automatic dripping pipes, a choice in perennial species which don't require much water and a work on the soil through mulching.
Urban agroforestry is a strategic method to open spaces, even with small parcels to a circular economy and transfer of knowledge. The circular economy and agroforestry designs from these case studies can be spread to the whole city plan and design with a strong network for finding and exchanging resources, maintaining and renewing traditional agricultural landscapes.

Thesis_4: **Creating socio-ecological corridors with urban agroforestry through participation and cooperation**
From the experience of the test-plot and the participative planning of an agroforestry corridor in goal 3, I can state that urban agroforestry creates multipurpose green spaces

in the city with participation of citizens to create socio-ecological corridors and agro-districts

Socio-ecological corridors are to link social needs with the proximity to nature and protection of biodiversity. Socio-ecological corridors can be created through the renewal of vacant lands, public open spaces and brownfields. According to the third goal, creeks, rivers and streams are good spaces for connectivity between rural, peri-urban farms and urban agroforestry gardens and creating corridors through planted hedgerows with equal access to the gardens which provide shade, food and materials to citizens. There should be equal access to the hedgerows and gardens with their proximity to inhabitants and their ergonomic design. This is why it is important to cooperate and co-design agroforestry systems, to answer as many social and ecological needs. The common hedgerows should not be difficult to manage by planting species which don't require a lot of water and maintenance (privilege trees, aromatics, wild flowers), avoid annual crops (keep these for the gardens). Urban agroforestry gardens also need to provide spaces of shade and depend on a fine assessment of the climatic context and the soil. Therefore there need to be wide canopy trees for shade included in the garden. For the planning and design strategy plants for urban agroforestry, tinctorial plants are suggested to be planted for artistic purposes with social inclusion and ecology.

Urban agroforestry plantations and spaces need to be integrated into existing land use plans which makes the planning process complex. The plantation will be different according to the land use type and the quality of the soil. There is also the need to take into account the proximity to water to avoid contamination. There is also the need in caring for the connectivity of the agroforestry plots with other green spaces in the city and to farms in the peri-urban areas. A reflection on the mobility between these areas is necessary with smooth mobility and public transport. Peri-urban agroforestry is for food provisioning to cities and for farming with proximity to cities. The economic balance and viability of urban and peri-urban agroforestry needs to be assessed.

There can be a diversity of social purposes for urban agroforestry gardens and they have to be participative designs for social inclusion. A base map for public urban agroforestry plots in Budapest could be made from interviews with decision-makers and the assessment of the land use map. With participative mapping tools such as a PPGIS, it is possible to involve citizens, decision-makers and NGOs in the planning and design of agroforestry plots with the definition of paths and resource management strategy plans. Drawing and painting tools are useful for exchanging ideas and decision-making and sharing and exchange of ideas. The youth need to be included in the decision-making through sketching and drawing. Also, local tinctorial plants can be used to create the designs.

When co-creating urban agroforestry gardens it is important to define clearly the roles of each stakeholder and to build a long-term cooperation with NGOs and institutions which work in social inclusion, health, ecology and biodiversity protection. There are several challenges in building community-based agroforestry corridors such as the wildlife management and the accessibility to softwares and the available time of each participant. There needs to be a social map of districts or neighbourhoods to use for planning urban agroforestry plots and defining priority spaces and social purposes.

These urban agroforestry gardens integrated in their districts or neighborhoods for

socio-ecological purposes can be spaces for finding information, materials and connecting neighbours and lead to the creation of agro-district, connected through the corridor for learning and exchanging ideas and knowledge. They can also include the connection to local market spaces.

Thesis_5: **From the three goals I can define the different stakeholders in urban agroforestry and their roles**
The main role of urban agroforestry is education with sharing, exchanging and transfer of knowledge for social inclusion, reducing spatial segregation and disparities in the face of climate change.

The main stakeholders in urban agroforestry are decision-makers, planners, landscape architects, research institutes, agroforestry engineers, institutes (schools, hospitals, care homes, homeless shelters) and citizens through NGOs or public consultations and participative designs and plantations.

1. Finding the place and planning of urban agroforestry gardens
   The decision-makers provide the land according to the planning from planners and landscape architects based on the pedoclimatic conditions, accessibility, heat map, land use map and infrastructures. Through cooperation with institutes, the landscape architects define the purpose of the suggested agroforestry plantations and their management system. They can also define a management plan for collecting and reusing green waste for example for artistic purposes.
2. Creation of urban agroforestry gardens
   On public lands, landscape architects cooperate with agroforestry engineers, research institutes in nature protection and social sciences to ensure protection of biodiversity and social inclusion. Citizens can participate in the design process and the plantations. The Landscape Architect transfers knowledge through his/her designs by reusing and recycling spaces with urban agroforestry. The species need to be adapted to the local climatic context and soil and reduce heat stress.
3. Management of urban agroforestry gardens
   The managers of the urban agroforestry gardens depend on the ownership (institution or public) but can be organised by a garden animator, public gardeners or civic organisations. On public lands, the city council or district council should communicate the events of the garden in partnership with the gardeners.
4. Monitoring of urban agroforestry gardens
   The monitoring of the plants is required. It should be by agroforestry and forestry research institutes in cooperation with the landscape architects and citizens.

Thesis_6: **Elaboration of the guidelines for planning and designing urban agroforestry**

Based on the results of the three goals which include interviews, landscape analyses, urban agroforestry garden observations and experience with a test-plot and a

participative planning for an agroforestry corridor, I defined guidelines for planning urban agroforestry and the scale.

I have defined several guidelines as well as limits and challenges to urban and peri-urban agroforestry.

1. **Integrate urban agroforestry systems in the watershed scale and bioregional scale** through cooperation, a landscape and urban diagnosis and mapping tools to collect information about the biodiversity in the landscape. Some brownfields need to be left to rewild. The brownfields used in the city are those from the industrial past, to clean the soil, store water and provide shade. There should be shelterbelts to protect from winds and soil erosion.
2. **Assess the landscape** and prepare for planning and design and monitoring. Assess the contexts of the spaces with land use, infrastructure, heat maps, sealed soil maps and green cover maps as well as on-site analysis and collection of existing plant species.
3. Build networks through socio-ecological agroforestry corridors with urban agroforestry gardens with public participation through a **participative mapping and design strategy such as the PPGIS at the city scale to connect different institutions and neighborhoods to the gardens, define the purposes of the agroforestry systems, cooperate and involve citizens in the design, share knowledge and organise the maintenance system**: create the management plan for invasive species, green waste and paths between the plots, meet with decision-makers, involve schools. For the agroforestry corridor there is a need to overcome administrative boundaries and political limits, to plan at the watershed scale and bioregional scale and have a participative planning and design process to create local communities and agro-districts or agroforestry neighbourhoods in the frames of the eco-neighbourhoods of Montreal.
4. Involve citizens at the **neighbourhood** scale and create agro-neighborhoods or agro-districts with accessible tools and materials such as sketching and painting materials with tinctorial plants. This will encourage the creation of socio-ecological networks for resources and management for agricultural cultural landscapes such as hay, manure, plants and seeds. Based on experience, there needs to be a definition of the leader of the community urban agroforestry garden and to define his/her role.
5. Design from the **scale of the soil** and existing ecosystems and vegetation.
6. Exchange of knowledge and research in plant species and monitoring between researchers, engineers and volunteers with on-site practice and experiences. The landscape architect collects the information and transfers the information through his/her designs.

Landscape architects need to plan and design from the existing ecosystems and prioritise enclaved spaces and neighbourhoods with high heat stress rates.

Some species are recommended for cities. The *Sorbus domestica* and *Sorbus aucuparia* can be good multipurpose trees for cities because they are useful for stabilising slopes, they are resistant to drought and air pollution and are also useful for attracting birds in the case of

Sorbus aucuparia or as a fruit tree in the case of the *Sorbus domestica*. The wood is also useful for woodworking. They can be planted in hedgerows. Tilia species are good to plant in urban hedgerows. Vitiforestry needs to be planted at a far distance from high traffic and urban heat islands. It is best located in peri-urban areas. Tinctorial plants should also be included in urban agroforestry gardens and peri-urban agroforestry farms. The Landscape Architect needs to prioritise species which are not toxic or with high allergy risks.

The landscape architect has several roles to play in urban and peri-urban agroforestry.

He/she:

- Makes a diagnosis of the landscape in the city to choose the species and the systems.
- Assesses the soil and the landscape of opportunity spaces for agroforestry gardens with participation of citizens and transfer of knowledge in design.
- Makes concepts, sketches and designs with research in species and companion planting and according to the land use, the watershed scale, the location of the plot and local context of the climate and soil.
- Works with local garden animators.
- Teaches and transfers knowledge through participative designs and plantations.
- Builds inclusive cities with agroecological principles through transfer of knowledge in the designs and participation of citizens and connects urban agroforestry gardens through green networks and hedgerows.
- Makes connections between technical and scientific research and arts in the designs.

He/she is limited by the fact that agroforestry and urban agroforestry are not a land use. There is the need to reflect on this to design permanent agroecological spaces in the cities. The watering management regulations need to be made and authorised by decision-makers. The emergency and challenge for the landscape architect is to find adaptive watering systems and species adapted to heat and drought and also mitigate desertification when it is present. The PPGIS is a good tool for cooperating between cities and creating an agroforestry corridor. It needs to include decision makers and experts. Another tool such as a platform could be created for this purpose. The landscape architect can make suggestions to manage invasive species with experts. The plot needs to provide space for free plantations with some restrictions such as no poisonous and non-invasive species.

The landscape architect is a mediator between decision-makers and citizens. Decision-makers and city planners cooperate with researchers, agronomists and naturalists and with citizens, community gardeners and schools. The PPGIS and participative designs are used to involve citizens in the planning and design of agroforestry systems with waste management, water management, creation of paths and networks for resources. Citizens also take part in participative planting and the maintenance of the plots. There needs to be an animator of the plots and a landscape architect for teaching and transfer of knowledge. The city provides public land for cultivating with agroforestry systems.

The production from agroforestry gardens can be marketed to restaurants and school canteens and also to different infrastructures: medical, educational, cultural. Peri-urban agroforestry

can generate a new diversity of production for cities with an economy of water and the management of nutrients in the soil. There can also be a new artistic development with natural products and mediums from agroforestry plantations.