Urban agroforestry

For developing ecosystem services in urban forests

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Susanne Tellström
Palleråsen, 25th of June 2014
Abstract
As urbanisation increases choices in how to use green areas within cities grow in importance, determining how several urban sustainability issues will play out. In urban environment the role for forest, both inside and at the city borders, is most important for the well-being of city inhabitants from several species, as well as provider of numerous ecosystem services necessary for anthropogenic development. Despite this, urban green areas are often given a lower priority in city developing processes compared to new structures, meaning them being transformed into built environments. This makes a higher awareness of what urban forests provides, and can provide, evident.

Thus, this bachelor thesis presents the idea of urban agroforestry. The focus is towards agroforestry systems as they can be adapted and applied in a Swedish context.

Firstly, literature review is used for investigating the concepts of urban forest, ecosystem services and agroforestry, defining and connecting them. Some of the critique towards the ecosystem services concept is lifted, as well as some specific ecosystem services directly connected to urban forest. Also, recent Swedish development in the agroforestry field is mapped and briefly described.

Further, knowledge from this is adapted to the settings in Östersund, developing suggestions for construction of actual urban agroforestry systems. This part describes the local possibilities for urban agroforestry, as well as suitable urban forest areas, species and things to take into consideration in terms of risk assessment.

Finally, the thesis also presents some suggestions for how to account for the change in ecosystem services in a more mathematical way. This is followed by discussion of both general findings and the local agroforestry potential, as well as some suggestions for focus points in further studies.

This study shows that despite the cold climate in Sweden, urban agroforestry provides an interesting potential for preservation of ecosystem services as well as reconstruction of historical landscapes. It further suggests that urban agroforestry systems within Östersund should be focused on cultural services rather than high yields, by this aiming to connect to numerous local interests seen as defining for the region.

Keywords: urban forest, ecosystem services, agroforestry, local food production, city planning, environmental science.
Introduction

Use of forest has been the habit of mankind since the very beginning, from the hunting and gathering cultures into the timber production of modern forestry. During the same period of time people have moved from settlements in the forest to cities, where availability of both trees and natural habitats grow more sparse. This have made the main values connected to urban forest less depending on wood prices, more relying on soft terms such as recreation, presenting more direct interests for people living close by. Urban forests are also crucial part in how city inhabitants relate to the natural world, raising awareness of sustainability issues on several levels.

Still, forests growing at the borders of society are often marginalized, transferred into built environments for housing or industry as cities grow. Thus, the need for a better understanding of ecosystem services connected to urban forests is apparent to have decision makers and city planners prioritise their existence. If these values can be further accounted for, and even increased, these important green areas might have a more fair chance for preservation.

Purpose

The basic idea behind this thesis is that agroforestry can increase ecosystem services from urban forests, by connecting such areas to local food production, enhancing their biodiversity and value as living habitats. Further, having urban forests include cultivation would make them interesting from more points of view in terms of recreation. As such, agroforestry would make visitors more aware of what the forest provides, as well as advance the intent to preserve such areas from other land uses.

This will be investigated to determine possibilities for actual agroforestry implementation in Östersund, a city situated in the middle of Sweden, being known for gastronomy as well as a rich surrounding landscape in terms of recreation.

The work here conducted describes possibilities to increase the value of forest with otherwise low output, such as urban forests represent, to raise and preserve interest in such areas from ecological, economical and social points of view. Also, it may illustrate how agroforestry can connect to and enhance cultural and historical values found in Swedish forest landscapes.

To set some limits to the scope, this study will focus on:

I. Forest ecosystems found in the Northern hemisphere.
II. Urban forests, as such not having their main values connected to timber production.
III. Agroforestry as a possible solution to increase ecosystem services values in such areas.
IV. Determining what ecosystem services would benefit from such application.
Goals
The work here aims to generally increase knowledge in ecosystem services connected to urban forests, but more specifically to:

- Determine if agroforestry is a reasonable way to increase the values from ecosystem services, and what services would benefit from such application.
- Investigate agroforestry development in Sweden, and possibilities for applications in Jämtland.
- Present local potential in Östersund, with suggestions for suitable areas, agroforestry systems and species.

Method
The first part of this thesis is based on literature review, spanning over several sources and kinds of publications to best describe the concepts; urban forest, ecosystem services, and agroforestry. It also connects these to illustrate how they relate and depend on each other.

The second part may be seen as a less academical investigation, based upon information from local authorities and general knowledge from living in Östersund for several years. This is suitable since it aims to describe the settings for a local urban agroforestry system, and the possibilities of developing such a project, which must be based on local knowledge to be sufficient. As such, this part also includes further analysis of the starting concepts and how they can be applied into something suitable for a specific area.

From this suggestions for actual urban agroforestry are developed, based upon analysis of the previously presented facts, general biology and logical reasoning from the author. To develop ideas for local agroforestry systems excursions to several urban forest areas in Östersund have been made, as well as evaluation of the possibilities these areas present in terms of system construction. This is partly presented as a SWOT-analysis, to make comparison possible, even if no specific area is singled out as most suitable within the frames of this study. Further, suggestions for important points in terms of risk assessment is pointed out.

Lastly, a formula for how to account for ecosystem services in urban agroforestry systems compared to regular urban forest use is presented. This is very general in character, but hints at some important points in such calculations as well as things that must be taken into account in the planning process for any urban agroforestry system.
Urban forests

In Sweden forest exist in abundance, the 23,1 million hectare productive forest land representing more than half of the total land area, compared to a mere 1,2 million hectares of urban land totally (Swedish Forest Agency, 2013). This means many Swedish cities in truth are surrounded by forest, growing as specks of civilisation in the wilderness. Parts of this wilderness is maintained within urban limits as urban forest, a term that lacks clear definition but none the less is widely spread and used.

According to the Swedish Forest Agency and their statistical yearbook of forestry, from the classification for forest presenting other land uses than timber production, urban forest is:

“Productive forest land within or adjacent to urban areas, and in areas of intense outdoor recreational activity that clearly influences timber production.”

And further, in a more general description of urban forest (Swedish Forest Agency’s web-page, 2014):

“... the forest that is near and within an urban area and whose main feature is that it is used by the agglomeration population. This means that the limit of an urban forest is determined more from the number of people using the forest than how far away the forest is located.”

Some more parameters are presented by Naturskyddsföreningen [Swedish Society for Nature Conservation]:

“...wooded land with a natural field layer wholly or mainly located within or not more than three kilometres outside an urban area (from the urban limit).”

Naturskyddsföreningen also points out how the lack of definition and boundaries towards other forest makes it hard to keep track of presence and development of urban forests. In extension this means it is hard to plan and manage such forest on both local and regional levels, even though management requires regional awareness if biodiversity is to be maintained.

Urban forest is thus mainly defined by how it is used, and by how many, rather than some typical ecosystem. The presence of humans is the most significant feature. As more people move into cities the importance of urban forest is increasing, but at the same time expanding cities means that more people have less access to green areas. This means urban forests have a need for preservation, both as providers of recreational values and for the maintenance of human interest in the natural world.

(Berg, 2010)
<table>
<thead>
<tr>
<th>County/region</th>
<th>Inhabitants</th>
<th>Amount of urban forest land (ha)</th>
<th>Urban forest land/inhabitant (m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stockholm</td>
<td>2 091 473</td>
<td>83 687</td>
<td>400</td>
</tr>
<tr>
<td>Västra Götaland</td>
<td>1 590 604</td>
<td>156 157</td>
<td>982</td>
</tr>
<tr>
<td>Skåne</td>
<td>1 252 933</td>
<td>56 220</td>
<td>449</td>
</tr>
<tr>
<td>Dalarna</td>
<td>276 565</td>
<td>88 956</td>
<td>3 216</td>
</tr>
<tr>
<td>Jämtland</td>
<td>126 299</td>
<td>29 707</td>
<td>2 352</td>
</tr>
<tr>
<td>Norrbotten</td>
<td>248 545</td>
<td>43 620</td>
<td>1 755</td>
</tr>
</tbody>
</table>

Table 1: Presence of urban forest in some, chosen parts of Sweden (from table 5.15 in Swedish Statistical Yearbook 2013).

The actual quantity of urban forest in Sweden is a bit tricky to determine. According to SLU the 100 largest cities in Sweden has in average 20% of their area covered in forest fragments, but variations between individual cities are big. If measured by the definition from Lantmäteriet [GSD Landuse], urban forest representing the forest within 1 km radius of an urban area, the total area is about 1,1 million hectare or 1 100 square meters per inhabitant. The local variations are big also in this respect, as illustrated in table 1. The three urban regions Stockholm, Västra Götaland and Skåne, quite naturally have less urban forest per inhabitant. But, the county of Västra Götaland has the greatest total area of urban forest land within the country. This shows how abundance of forest, as is general in the northern regions, is not the determining factor for the amount of forest defined as urban. Jämtland has among the highest amount of urban forest per inhabitant in Sweden, but this connects to low population and city density more than the actual area of urban forest. The urban forest accounts for just 0,6 % of the total land area in Jämtland, compared to 4,6 % on national level. (Swedish Forest Agency, 2013)

Urban forest is a major part of what is often described as green infrastructure, in short the green landscape within city boundaries. This includes green space planning in a large scale, planning for interconnection of habitats and future needs, as well as restoration of degraded ecosystems where such is possible. Such planning also aims for multi functionality in green areas, and as such provision of a wider range of ecosystem services from such areas. (Grant, 2011)

Managing urban forests is a question about operating different expectations and needs, fulfilling the requirements from some visitors without removing the factors attracting others. Some want the untouched nature, while some require special accessibility to be able to get out in nature in the first hand. This means no single urban forest design or method can please all users. Variation is key, as planning and management must take into account knowledge about both humans and other species. (Berg, 2010)
An important factor determining the amount of use of an urban forest is where it is situated, affecting travel distance. A forest closer to the urban space where people live and work will be seen as more accessible than a forest situated further away. This generates more visitors, increasing the use of the area. Further on, the perceived quality of the forest and its historical uses influence its local importance, as does availability of outdoor recreation facilities and other conveniences. (Swedish Forest Agency, 2014)

Most people in Sweden want access to recreational forest within 1 km from where they live, this distance representing a comfortable walking distance. In general, people are more attracted to forest with more tree species and with trees in different ages. Big, old trees are often seen as landmarks and older forest is in general more appreciated. Urban forests thus must be allowed to grow older than common forest. At the same time, forest developing freely is often perceived as untidy and less attractive for recreation. The visual impression is most important, especially forest edges must be tended to with special care since they often are what people see from inside their windows. Compared to other forests, urban forests are often more varied. In both north and south of Sweden they include more species of deciduous trees, bushes, herbs and grasses. (Berg, 2010)

Urban forests are connect to two of the sixteen Swedish environmental goals;

- **A Good Built Environment**, aiming for built environments contributing to health as well as regional and global environment, including buildings as well as connected green areas, and the nature and cultural values of such areas.
- **Sustainable Forests**, set to preserve both biodiversity and forest production, as well as cultural and social values connected to forest.

So, on a national level urban forests are given great importance both to people living in cities and nature existing within such realms. They are crucial part of the total amount of forest in Sweden, as areas available for recreation and experiences of wilderness, even though they in some terms can be described as commodified.

Further, as the communique from the Copenhagen Climate Change Summit 2009 states:

*“We the mayors and governors of the world’s leading cities... ask you to recognize that the future of our globe will be won or lost in the cities of the world.”*

An enormous part of future welfare will thus be affected and controlled by urban nature, in terms of direct environmental effects and other factors whereupon civilisation as we know it rests. Urban forests will be essential to this, providing both biodiverse habitats and numerous ecosystem services for growing cities all over the world.
Ecosystem services
The term ecosystem services has been widely spread since the Millennium Ecosystem Assessment, released in 2005, called for by United Nations. This extensive report summarise the work of over 1 000 international scientist, mapping human impact on Earth. The focus of the study is to link human welfare to ecosystems, the services these ecosystems provide, and how the ecosystems enable human development.

Ecosystem services can be described as functions found in an ecosystem, supporting and sustaining species and other parts present within it. Humans is the specie mainly taken into account when reporting these services, but the presence of services beneficial for anthropogenic use is often beneficial for other organisms as well, as long as the resources the ecosystem services provide are not exhausted.

Ecosystem services are further divided into four categories:
- Supporting; having values tied to primary production, nutrient cycling and soil formation.
- Provisioning; values from fuel, food, fresh water, wood and fibre.
- Regulating; connected to climate regulation, water purification, disease and flood regulation.
- Cultural; concerning aesthetic, spiritual, educational and recreational values.

A lot of the ecosystem services are not directly connected to an economical output, even though provisional services to a great extent can be used to build trade, industry and economic wealth. This creates a situation where most ecosystem services are offered completely free of charge, over time affecting the availability of services as the ecosystem is used and adapted to anthropogenic needs.

As an ecosystem is used for various or one single activity the presence of resources and services is affected, be it by relocation of species, use of materials or from chemical pollution. This means the system over time may degrade, presenting less services, especially those less visible and not easily measured and controlled. If spiralling downwards the ecosystem will soon be seen as less valuable than it may actually be, and as such less worthy to preserve or restore. Such development will keep the ecosystem services at the very same low point, or diminish them even further.

In attempts to avoid this kind of development ecosystems services are often connected to monetary values, to better account for the benefits and necessities they bring. This involves economists thinking of the support an ecosystem provides as well as the value from the extracted goods, which is a major change from most of industrial human history. (Grant, 2011)
In the often quoted *The value of the world’s ecosystem services and natural capital* (Costanza et al. 1997), seventeen ecosystem services are evaluated on a global scale to 16-54 trillion US dollars. This study sets the average value of global ecosystem services to 33 trillion dollars, representing 1.8 times the total global GNP, and a value being estimated as too low also within the variation span. As further concluded:

“Because ecosystem services are largely outside the market and uncertain, they are too often ignored or undervalued. [...] As natural capital and ecosystem services become more stressed and more scarce in the future, we can only expect their value to increase. If significant, irreversible thresholds are passed for irreplaceable ecosystem services, their value may quickly jump to infinity. Given the huge uncertainties involved, we may never have a very precise estimate of the value of ecosystem services.”

The valuation and economical thinking behind ecosystem services also have its critics, both among people feeling spiritual reluctance to further connecting the natural world to economical settings, as well as economists and other scholars seeing clear limitations to the concept.

Arguments include the impossibility of placing values on intangible things such as life and nature, as well as the notion that we should be able protect ecosystems for purely moral and aesthetic reasons. But such moral thinking presents clear issues, since moral to a high extent include goals prioritising human needs, often putting very high demands on both ecosystems and economical systems. This makes both the valuation process for ecosystem services and choices coming from it more difficult and and less obvious. (Costanza, et al. 1997)

Valuation of ecosystem services as such also means valuation of ecosystems as a whole, and comparison between them in terms of value. Some or many ecosystems may not provide enough value to justify their protection based on their services alone, which could be devastating for local environments and present great risks for regional biodiversity. This weak link in connection to biodiversity is most relevant, since more biodiverse ecosystem not always provide better services in terms of human use. This could over time undermine the amount of present ecosystems and drastically change current landscapes, replacing them with more effective ecosystems as demand for certain services increase. (Marris, 2011)

Aldo Leopold’s argument from 1949 is most valid in this discussion:

“One basic weakness in a conservation system based wholly on economic motives is that most members of the land community have no economic value. Wild-flowers and songbirds are examples. Of the 22,000 higher plants and animals native to Wisconsin, it is doubtful whether more than 5 per cent can be sold, fed, eaten or otherwise put to economic use.”
To illustrate some of the difficulties of incorporation ecosystem services in economic settings with an example: it can be applied by paying landowners for providing the services. This is meant to affect the landowner to not diminish or eliminate ecosystem services, by affecting their choices of land use. In Costa Rica this has been part of policies to prevent deforestation since 1997. The payments are now up to 15-18 million US dollars per year, ‘protecting’ 8 % of the country, having among the lowest deforestation rates in the world.

But this kind of application may not be as effective as wished for, as expressed by legal scholar John Echeverria (Marris, 2011):

“Paying landowners for not to damage the environment sets up an expectation of reward for refraining from bad behaviour and a financial obligation for future taxpayers.. [...] Landowners should be expected to do the right thing and punished when they don’t. [...] The implicit message of agreeing to pay is that they should be entitled to destroy nature.”

This means landowners may choose to maintain ecosystem services as long as they provide sufficient income compared to extraction of resources. It may also be economically impossible over time, as ecosystem services increase in value and more landowners are included within such a reward system.

Ecosystem services in urban forests
Ecosystem services in urban forest can be described as a combination of general services provided by forest and services connected to urban green environments. Part of this connects to that the use of urban forest is relying on direct human use and experiences rather than resource extraction.

The most highlighted ecosystem services in urban forests come from the regulating and cultural categories. Supporting services, such as primary production providing oxygen, are of course important, but of less interest in the specific urban setting. The same goes for provisioning services even though they can overlap with recreational value creation, from e. g. picking of berries and mushrooms, but then presenting values existing in all forest where such activities occur, not bound directly to city landscapes.

Regulating ecosystem services have effects both connected to the properties of trees and the needs of city inhabitants. On a local scale urban forests are important for levelling of climate, taking away extremes in temperature, run-off and air movement. They increase air quality within the city, as mixed deciduous forest absorb up to 15 tons of particulate matter per hectare and coniferous trees are even more efficient (spruces absorbing 2-3 times as much). The cleaning process takes place when dust and other particular matter sticks to leaves and needles, before being washed into the ground by rainwater. Urban forests also provides cleaner air streams through the urban areas, as the temperature within a city is higher than that in the surrounding landscape, meaning
air rising from the city being exchanged by air from the surroundings. This means that the quality of the landscape around a city also affects the air quality within it. Other directly physical impacts on the surroundings are protection against wind and sunlight, which can lower energy consumption in nearby buildings. Forest also means an actual reduction of noise as well as being psychologically important to how noise is perceived by humans, and as such the stress levels it causes. (Berg, 2010)

Further, trees presents great value as carbon sinks, binding carbon dioxide to the soil solely by their growing existence and keeping it until incinerated or otherwise decomposed. As such, planting trees or having trees growing within close distance to the sources of emissions, such as cities and dense population presents, could mean a more effective way of practising carbon capture to handle global warming.

The regulating services also includes control of storm water, as trees and vegetation absorbs water and binds it to the ground. Water quality is affected in general, and areas of urban forest can be used for removal of nitrogen as well as heavy metals. (Grant, 2011)

Cultural ecosystem services is the ecosystem service category hardest to account for in terms of monetary gain, yet representing a lot of value since they are so directly appreciated by humans. This becomes most obvious in urban forest, existing more for leisure than provision of goods.

In Sweden one out of three Swedes visits the forest every week, and more than half of these visits occur in urban forests, as such representing huge recreational values. In a summary of several national and international studies the average value of a forest visit in Sweden is set to 200 SEK. Local variations are most present in such an estimation, relating to the amount of forest available for visits. As an example: in Skåne, which is sparse of forest, the forests have been estimated to have a recreational value of 44-97 millions per year, compared to 7,2-14 millions per year in timber value. (Berg, 2010)

This figure seems kind of typical in cases with urban forest, providing much higher values in terms of recreation than in harvest of actual goods. In a case study performed by Rebecka Axellie on an urban forest area in Dalarna, which is rich in forested land in general, the recreational value was estimated to more than 750 000 SEK per year, compared to just above 7 000 SEK per year in timber value.

The recreational value is affected by factors such as number of visitors, number of visits and number of visit hours, related to the size of the visited area (Søndergaard Jensen, 1995). In urban forests these numbers and perceptions are easier to find out than in rural forests, since an urban forest overall have a greater level of control and awareness surrounding it. Also, urban forests are more often visited in organised forms, making actual measurements possible, as well as investigations from surveys and similar.
Presence of nature and cultural values are in general often tightly tied together, since landscapes are formed by human activity. Spending time in urban forest can thus increase the understanding of historical settings in the area as well as development of the present society. Nature represents part of history itself by containing species present in older days, but also surrounds and enhances its monuments. Further, inspiration from the natural world are a foundation for mythology, folklore, literature and art. (Berg, 2010)

Historically, preservation of nature has mainly been focused towards ecosystems found in the countryside, which people have visited for recreation. Despite this, green areas in cities are often found to be biodiversity hotspots. They are thus important in linking ecosystems together within and outside the city, for preserving biodiversity. Some of these areas are old ecosystems, protected from competition when the city has encapsulated them over time. (Grant, 2011)

Scientists means that since the costs for recreation of urban forest are high it is most important to preserve those present today. This is reflected in the Swedish Environmental Code, stating that areas important for nature, culture and recreation as far as possible are to be protected, with special significance given to areas in urban settings. (Berg, 2010)

The need of ecosystem services inside cities, of all kinds, is probable to grow over decades to come, as expressed by Gary Grant:

"Cities rely on ecosystem services in the wider world, but it is important to remember that ecosystem services can be provided within the city by creating multi-functional, biodiverse, green infrastructure. [...] This approach will make cities more resilient and better able to cope with climate change and the stresses that will emerge as civilisation makes the transition to the post-oil era."

This suggests we have undervalued the urban ecosystem services this far, as well as the opportunities of development they present. Since urban forests are what many think of when talking about urban nature, they represent a possible leading role in further greening of cities. Investigations on how the ecosystem services they provide can be preserved, increased and better used is thus something much needed for a more sustainable future.
Agroforestry

According to the World Agroforestry Centre, agroforestry is:

“A dynamic, ecologically based, natural resource management system that, through integration of trees on farms and in the agricultural landscape, diversifies and sustains production and builds social institutions.”

Agroforestry is applicable to both farm and forest land, giving benefits connected to intercropping; the growing of two or more crops in interaction with each other. This kind of land use presents several advantages over sole cropping, including more effective use of natural resources (sunlight, land and water), decreased risks for infections from pests and diseases, and as such can lead to higher yields. (Nair, 1993)

Cultivation through large monocultures have been applied in both forestry and agriculture for about a hundred years, something possible only by the powers and chemicals of industrialisation. Loss of biodiversity in forests as well as fields has been one of the effects, even though a higher amount of one single good per acre or hectare has been produced. From ecological point of view this has created a lot of issues as natural ecosystems have been exchanged for industrial ones.

As models for output oriented land use are developing and spreading across the globe, it stands clear that also from an economical interest and in connection to social issues this may not be the most beneficial way of cultivating either wood or food. To maintain the productivity of monocultures artificial fertilisers are often needed to keep the soil fertility at sufficient levels, as well as pesticides and herbicides to avoid intrusion from other species. The huge amounts of land needed for profitability means increased need of machines, and as such less working force in terms of human labour. All of these parts represents great expenses for farmers and foresters, making cultivation at business level overall more demanding and risky. In a social level, both modern forestry and agriculture have the capability to dissolves cultural, historical land uses and taking over old settlements and livelihoods. This happens in most direct ways, e.g. by companies acquiring land from private or communal properties, as well as in indirect ways by beating competition from smaller producers and putting them off the market.

One topic in particular is of great importance for the adaptation of agroforestry into modern times. Tropical deforestation has been high on the environmental agenda since the 1970’s, as it causes great damage in irreplaceable ecosystems. The products from logging of precious woods presents great profit, which mostly has been enjoyed in the Western world, not in the countries harbouring the forests they come from. Shifting cultivation, using temporary plots for agriculture and then leaving them bared to erosion has provided further to the thinning in stocks of tropical forest. These areas are thus affected by both unsustainable forestry and agriculture, especially in relation to local conditions in terms of soil quality. As this become apparent it created a need to
investigate and if possible slow down the processes eroding both tropical ecosystems and the possibilities for a decent living for its human inhabitants. In 1975 Canadian John Bene started the study that institutionalised agroforestry, two years later establishing World Agroforestry Centre. Agroforestry was presented as a solution to both ecological and social issues, combining concerns from various fields into possibilities of rediscovering traditions as well as providing goods for the future. (Nair, 1993)

There are three common attributes which agroforestry systems possess and can be evaluated from:

1) Productivity; by maintaining or increasing production of goods and the productivity of the used land, as such enhancing outputs of wood and yields, reducing cropping system inputs and having a better efficiency in terms of labour.
2) Sustainability; through conserving production potential by beneficial effects from woody perennials on soils, maintaining the resource base in terms of nutrients, water etc. and as such preserving fertility within the ecosystem.
3) Adoptability; connecting to the acceptance level from the farming community, which is high when the system is based on traditional and historical practices, as such taking into account local ecological heritage.

Some general properties of agroforestry systems can also be identified. They involve two or more species of plants, or plants and animals, whereof at least one is a woody perennial. Thus, agroforestry always has two or more outputs in terms of resources available for harvest. Also, the production cycle of an agroforestry system is always more than a year. Further, this means even the simplest agroforestry system is more complex ecologically, both structurally and functionally, as well as economically than a system based on monoculture. (Nair, 1993)

Agroforestry requires more long term planning than conventional agriculture, but presents output faster than regular forestry, something that can be used for creation of a more steady cash flow than sole cropping of trees. The longer time frame also provides a more stable ecosystem for longer periods, which means an increased value as habitat also for species not directly included in the agroforestry system. This offers more chances for establishment and adaptation, which is most important for biodiversity.

P. K. R. Nair uses four criteria for categorisation and description of agroforestry systems, being as follows:

- Structural basis, looking at composition of components and how they are arranged.
- Functional basis, defining the major function or role of the system, usually related to the trees or other woody components.
- Socio-economic basis, presenting the level of input, management, intensity and if there exists commercial goals.
- Ecological basis, connecting to environmental conditions and ecological suitability of the system within the area where it exists.
Structural classification of agroforestry systems defines what kind of agroforestry is applied; agrisilviculture consisting of crops and trees, silvopastoral including animals and trees, or agrosilvopastoral containing crops, animals and trees. The system structure is further outlined through arrangement approaches, describing density, vertical stratification of components and potentially temporal arrangements as shifting cultivation and fallow cycles.

The functional classification describes what output comes from the system and what roles different components have, placing agroforestry systems in varying degrees of productive and protective settings. This include the services provided by trees towards other vegetation and animals as something necessary for their growth and cultivation. Sustainability thinking is built into this functionality, P. K. R. Nair clearly stating that output alone should not be used to evaluate an agroforestry system:

“Although production is a very important consideration in agroforestry, it is the sustainability attribute that makes it different from other approaches to land use.”

Making a socio-economical classification is often based on the following groups:
- Commercial agroforestry, being output oriented, conducted by paid labour, often in connection to plantations of trees providing a resource such as palm oil or rubber, grown together with crops providing food or other commodities.
- Intermediate agroforestry, growing income generating crops and/or trees as well as providing sustenance for the farmer.
- Subsistence agroforestry, meaning cultivation that wholly or partly fills the food needs of a household, directed towards personal private use as in home gardening, but may include sales of surplus crops, etc.

These groups relate to the purpose of cultivation rather than size of land or amount of crops or timber harvested. Purpose is also the major factor affecting the amount of management and the intensity used within the agroforestry system. The local setting will also have some effect to where a specific system end up in the scale, compared to similar surrounding activities.

In planning of an agroforestry system, all four categories must be addressed and taken into account sufficiently to create a system sustainable on all levels.
Agroforestry development in Sweden

In historical context agriculture and forestry in Sweden have been much more interlinked than today, when they have been separated into two different industries and types of land use (as further described in Appendix 1).

During the beginning of the 21\textsuperscript{th} century it has become clear that the functions and demands on both agriculture and forestry in the Nordic countries are changing:

- In relation to other industries and sectors the economical significance of timber products as well as the paper and pulp industry is decreasing (Fritzbøger & Søndergaard, 1995).
- In all Nordic nations and most European countries future annual forests growth is expected to be higher than annual forest cut (Hytönen & Blöndal, 1995).
- Outright and numerous departures from conventional forestry and farming due to environmental concern.
- Increasing use of environmental labels, such as FSC for wood products and numerous labels for organic food (such as KRAV in Sweden).
- Increasing wilderness tourism in rural areas.
- Growing interest in urban farming and greenimg of cities, to benefit both human inhabitants and ecology.

At the same time bioregionalism is increasing, focusing on a sustainable lifestyle through consumption of local materials and food, as this reduces production of greenhouse gases. (Grant, 2012)

Further, there is a growing awareness of the importance of trees on a global scale, as providers of ecosystem services, biodiversity and carbon capture. Recently a lot of companies are adopting carbon offset, paying for plantation of trees to make up for the carbon footprint from their products. Trees thus have become important symbols in the battle against global warming, reaching the public eye in most direct ways.

Agroforestry is still mainly carried out in areas around the equator, with systematic research and practice concentrated to tropical ecosystems, due to the radical environmental and social effects tropical deforestation has in these countries. But the above stated facts may widen the scope, as new approaches to land use are both needed and much wanted on local as well as international levels.

The traditionally most common applications of agroforestry in temperate zones are intercropping in fruit and nut plantations, or using such lands as pastures when the trees are large enough to not be damaged by the animals. This use has shown to be more economically viable than sole tree cultivation, both when growing black walnut and pecan trees in the US and in European poplar plantations. In some areas in the US cattle graze industrial pine plantations, functioning as biological control of vegetation, as the animals are moved between different altitudes over the course of the year to divide pastoral pressure. From such silvopastoral systems a problem with pastures in
production forest has been noted, as the possible meat production decreases as the forest develop into denser stands. Many foresters argue against management for thinner plantations including trees of various ages, as well as plant damages caused by grazing and animal owners not being willing to pay adequate fee for forage, hindering development in large scale. Further, it is established that Northern agroforestry systems can present directly functional protective roles in agricultural settings, as trees in open landscapes form wind breaks covering fields, homesteads and animals from the weather, creating microclimate effects most positive for yields. (Nair, 1993)

This illustrates how ecosystem services provided in tropical forests can be found in temperate forests, providing similar support and functions adapted to colder climate. The trees provide shelter from cold instead of heat, their roots preserving soil from erosion in high latitudes with thin soil layer. Also in Northern latitudes agroforestry can be implemented for cultivation in areas not accessible for conventional farming, presenting a more effective land use.

In 1987 a Swedish governmental investigation pointed at agroforestry as a solution to then existing overproduction and environmental issues in agriculture. Despite this, in Sweden application of agroforestry is still uncommon and mainly carried out by special interest groups. Swedish agroforestry systems thus have small business values, but are more focused towards garden interests and as such recreation.

One of the places important for Swedish agroforestry is Holma Forest Garden, situated in Skåne. It was started as a project in 2004 from funds provided by the Swedish Board of Agriculture. From 2009 the garden is managed by the non-profit association Skogsträdgårdens vänner [Friends of the Forest Garden], maintained by membership fees. The main part of the cultivation here is divided into six different groves, built around apple, pear and plum trees, in combination with various berry bushes, hazel and herbs, including aromatic herbs like mint and chervil. These groves demonstrate cultivation techniques as well as new species. Four focus points have been chosen for research; vegetation structures (trees, bushes and herbs), soil management enabling self-seeding, biodiversity for prevention of pests, and establishing ecological niches filled with desirable plants. The largest problems within the forest garden are connected to wild animals eating from the crops; roe deer, hare, bunnies and water vole. To decrease this fences and blood meal has been used. Late occurrences of frost have also affected the output from the systems, damaging apple flowers and other vegetation having early buds. (Skogsträdgårdens vänner, 2014)

In 2010 Holma Forest Garden started the project Agroforestry i MittSkåne [Agroforestry in MidScania] with the purpose for participating farms to enhance their ecological and sustainable thinking in cultivation and pasturage. The goal was to involve five farms for creation of their own development plans, but in the end eleven farms contributed, representing a much greater interest than expected. Out of these most of the farms were small, implying that larger farmers are still cautious towards the agroforestry
concept. One of the weaknesses is suggested to be the long time frame for implementation of an agroforestry systems, since including cultivation of trees makes it a slow method compared to conventional agriculture. (Leader MittSkåne, 2013)

In Västra Götaland, *Agroforestry Väst* [Agroforestry West] is a main contributor to the development of agroforestry in the region. This far not much has been presented in terms of results, but in 2014 begins the construction of an experimental forest garden in *Lärjeåns Trädgårdar*, Gothenburg. The association also works to start a nursery garden and provide courses in agroforestry and permaculture (cultivation performed to achieve self-sustainability). As a vision behind the activity stands to be a catalyst to make people relate to their food and each other in the local area, as well as creating long-term ecosystems providing for human needs and show how they can have a positive effect on the environment. (Agroforestry Väst, 2014)

Within *Utveckling Nordost*, the biggest EU funded city development project within Sweden, agroforestry and urban farming is given a lead role in the progress towards a sustainable city, in terms of environment as well as entrepreneurship and social development. The pre-study for this project, running from 2011-2013 involve the city districts Angered and Östra Göteborg. Some of the suggestions coming from it are to start pilot projects in agroforestry connected to local food production, selective forestry and local animal husbandry. This includes the wish for creation of an academy for West Swedish Agroforestry, as well as conducting courses for holiday working adolescents in agroforestry cultivation techniques. The project further aims for cooperation with local animal keepers to benefit local meat production, as well as development of bee-keeping plans. Sheep and cows are suggested for a pilot project, as are wishes for introduction of summer pastures. Another proposal, also lifted in the region Dalarna, is the possibility for city dwellers to own animals and outsource them to local keepers. (Utveckling Nordost, 2013)

In a more academic level Örebro University hosts a project for evaluation of agroforestry, looking into economy, resource need, climate effects, contribution to biodiversity and generation of ecosystem services. This project is run as as collaboration between scientists and farmers and will identify perennial edible plants that are suitable for agrisilviculture systems within Sweden. (Björklund, 2013)

This project includes 13 farms, whereof two agricultural colleges. Since the start in 2012 it has focused on two main areas; use of forest gardens, and intercropping of trees and bushes in pastoral animal husbandry. A common design for forest gardens has been developed and installed in 12 of the participating farms, including e.g. apple trees, alder, hazel, sea-buckthorn, blackberries, beans and kiwi. Over the coming years these forest gardens will be used to determine possible gain per area unit, energy relation between input and output and positive environmental effects. Other issues discussed are how a positive interaction between species can be evaluated, as well as the culinary value from the production. The study of silvopastoral systems investigates methods for tree
establishment in existing pastures, system optimising, potential for carbon capture compared to regular pastures and forest, and what ecosystem services are created from such a system. (Engvall, 2013)

Further, in a system study for a environmentally adapted and sustainable agriculture from the Swedish Environmental Protection Agency, agroforestry is pointed at in several ways as an option for the future. It is stated that it can contribute to a rich cultivated landscape, biodiversity and carbon capture, mainly focusing towards silvopastoral systems. In such, climate benefits per land unit and paid environmental support would increase due to the rising amount of trees in open fields, as well as providing higher environmental support per animal. This would also compensate climate effects from the grazing animals, especially if the tree components could be used for bioenergy. One of the greatest obstacles for development of silvopastoral systems within already existing animal husbandry is the need for plant protection, which mainly is applied to individual plants. The study thus suggests plantation in groves, which are easier to protect from grazing until they come of age, but also can make wood cutting easier. (Kumm, 2013)

Lastly, on the World Congress on Agroforestry in Delhi as of February this year, the most renowned researcher P. K. R. Nair said:

“We’ve heard how agroforestry can do this, can do that. That agroforestry has so much potential, many advantages, offers many opportunities... and so on and on... But how much of what is being said is new?”

This is a most worrisome question in any setting, but especially when dealing with a concept still unfolding its possibilities, in a world fast changing and in much need for the multiple implementations it suggests. Perhaps this implies how the scope of agroforestry applications and research on a global scale must grow wider if the full potential of the concept is to be discovered. Even though it connects much to historical land uses it can fill a role in the future, given that models and systems for it are adapted to modern settings, and as here suggested, moving into urban areas to provide both food and recreational shelter for city inhabitants.
Urban agroforestry potential in Östersund

Östersund represents an urban area in a rural region, as such presenting numerous challenges and possibilities tied to both categories. Part of the regional development is slowed down by distances to the main Swedish city regions, while others flourishes in close connection to the wild landscape. As in many cities more jobs, homes and inhabitants are needed for growth, which creates a need for being distinguished from others. In the work directed towards gaining a more environmental profile, conducted by the municipality, starting a project in urban agroforestry would be interesting on national level as well as connecting to values most important within Jämtland.

About 50 % of the total area in Jämtland is used for agriculture and forestry systems, as such important part of economy both on regional and national scale. In 2009 forestry turnover was approximately 4,8 milliard SEK, while agriculture turnover was around 1 milliard SEK, representing a year when the value from agricultural products was relatively low (LRF, 2012). Both sectors represent important job opportunities in the region, agriculture alone permanently employing among 4 300 people, or over 5 % of the inhabitants. (Jämtland County Council, 2014)

The municipality in Östersund owns about 6 100 hectares of forest, whereof 1 100 hectare is classed as urban forest. Boundaries towards other categories of forest are somewhat unclear, except those forming nature reserves. Only 3 100 hectare is labelled production forest. The area used for recreation may be considered bigger, since it probably also takes place on privately owned land. In 2012 a revision report on the forest management within the municipality asked for clarification in terms of ownership, cooperation and organisation around the urban forests, as well as development of the management plan according to current conditions. The urban forests are a shared responsibility between the culture and recreational board and the environment and community board, as such needing effective cooperation between different departments. (Deloitte, 2012)

Jämtland has a great interest in locally produced food, providing a developing market for such products. Östersund has been named Creative city of Gastronomy by UNESCO, the Creative Cities Network being an initiative to stimulate cultural development and exchange in several categories. The title is a confirmation for Östersund as well as the region Jämtland as providers of high quality gastronomy and artisan food. (Municipality of Östersund, 2014)

Östersund has also been named Matlandethuvudstad in 2011, in a competition announced by the Swedish Department of Agriculture, the purpose being to show possibilities for job creation and growth in connection to food production. Östersund was named due to a strong entrepreneurship with creative companies and a great commitment to good food within the municipality. Since 2012 Östersund is also holding
a diploma as Fairtrade City, striving towards fair trade and ethical consumption. These are trademarks that could be further developed and lifted by agroforestry, both in urban and rural forests. If placed within the city borders a high availability for visitors also from outside the region could be gained, strengthening tourist interests as well as possibilities to showcase alternative food production in an area famous for it.

Due to the old practices of agriculture within Jämtland, agroforestry also presents an interesting relation to cultural ecosystem services, since the similarity to historical customs. Use of summer pastures has been most important in the region, and as such making use of the birch forest south of tundra like landscapes. Such areas could be restored to older ecosystems, rare on a national level, if silvopastoral systems were developed for such a purpose. Animal husbandry as such contributes to tillage and fertilisation in a most natural way, keeping the landscape more open and biodiverse. In Jämtland this provides extra biological values, since a lot of the regional forest is dense and coniferous.

Compared to other Swedish agroforestry systems earlier presented, one in Östersund would exist in a colder climate. Still, the climate close to lake Storsjön is more beneficent than in other places in Jämtland. One property of extra importance in such a Northern setting is the frost resistance of the system and the species planted within it. This would mean possibilities for innovation in terms of system components, and possibly also experimental cultivation including some sort of supporting structures for preserving of heat or protection against wind (e.g. attempts to create greenhouse like conditions without loosing the outdoor feeling which is important for recreational values).

In a larger scope, food production on a global level is one of the main challenges for the future. Numerous scenarios point in the direction that we both need to increase the amount of food stocks produced and redistribute at least parts of how it is produced to gain better environmental and social sustainability. This implies other cultivations methods, such as agroforestry, as a most important tool to reach a more effective land use.

Suggestions for urban agroforestry systems

Urban agroforestry as here intended aims to increase provisional and cultural ecosystem services, but is expected to provide further benefits to supporting and regulating services, at least by strengthening the interest in the ecosystems providing them. A lot of this connects to the fact that these urban agroforestry systems is meant to be implemented in already present forests, as such already providing services to the urban area. The process would thus not require extensive plantation of new trees, but rather focus on other crops providing food and other resources to the neighbouring society.
Such a system would to great extent emphasise the social levels of agroforestry, rather than the monetary gain, which usually is more connected to the trees themselves. Some production of timber is still possible within an urban agroforestry system, but the main output is produced in a faster pace. This design depends on the apparent needs of the city inhabitants, more directed towards food products than wood. Still, timber may be a good complement to finance other cultivation, or as a resource within the system providing recreational values (for handicraft, etc.) or biological (e.g. as dead wood habitats).

Urban agroforestry also means adapting older models of forest use to urban forests, combining them with modern knowledge, management and planning tools. This can provide more attractive output and ecosystem services from such a system, in extension developing the present use of urban forests to fill future urban needs.

Including more recreational interests in the same area makes it more efficient in terms of land use, but also gives an opportunity for people to connect on a social level. Urban agroforestry thus provides higher recreational values for the urban forest, making it more worthwhile to preserve based on cultural ecosystem values.

There are two ways of applying urban agroforestry; low intensity agroforestry system mainly offering cultural ecosystem, or models with higher intensity more directed towards providing provisional services. As such they may span from subsistence systems, being a almost completely recreational activity, to intermediate systems having a greater output more in line to the food needs of the city. The reason commercial agroforestry is left out from this is that the interest to produce within more agricultural settings probably is low among the city population, as well as harder to implement on communal grounds such as urban forest most often resides in.

Regarding city development, agroforestry with a higher intensity can provide job opportunities, to handle plants as well as animals, and further managing the higher outputs. In such a system a lot of the harvest is probably not handled by the end-user before it ends up in a home kitchen. On one hand this means a better controlled system making sure of productivity levels, but on the other it may easily turn out to be expensive, needing more maintenance as well as a higher level of knowledge to be balanced towards nature.

A low intensity urban agroforestry system demands less planning and economical input in the start, as well as less interference in the already present natural ecosystems. But this also limits the output, in a worst case scenario not being capable of providing the resources asked for. A system with lower amount of plants also makes the risk of misuse, as in over-harvest by one or very few users, extensively higher.
Concerning suitable species

An agroforestry system can be based on species naturally occurring within the forest ecosystem, by clearance enhancing further spreading or sparse plantation for support of the already existing population. It can also consist of garden like species and animals, present in the region but not naturally within the forest ecosystem. Further species can be implanted from other regions, seen as foreign, but perceived as suitable for the forest ecosystem and climate.

Many agroforestry systems aims for producing output with a high economical value, but at the same time having low input in terms of maintenance needs and including self-seeding species. What is most beneficial depends on local prerequisites in demand and expectations on what is to be produced, both to use directly as raw material and products for refinement into artisan food and similar.

Some species that might be suitable for urban agroforestry in Östersund is presented in table 2, based upon species common within the region and as such providing resources already of interest to local food production and artisan food in particular. They are also to some degree proven productive in the cold climate, as well as viable in connection to other naturally occurring species. Some of them may be planted further in connection to urban forests, while other presents possibilities for unattained harvests (e.g. rowan berries for jelly) or have habitats that can be further enhanced to provide better output (keeping clear areas for raspberries, etc.) and higher biodiversity. Many of the species above are found in gardens around Jämtland, as such providing garden like cultivation to apartment inhabitants.

Another factor connected to these species being suggested is significance for the person picking them, as in bringing a resource even if not harvested in great amounts. Plants working as spice is easier to provide to more people in comparison to vegetables or other things filling a more staple commodity role.

Proper species should also be chosen in connection to seed prices, maintenance need and possibilities for perennial growth. Further, such choices and the overall planning process may include the intended users of the output to best fit their needs and wishes.

<table>
<thead>
<tr>
<th>Trees</th>
<th>Bushes</th>
<th>Ground cover</th>
<th>Vines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td>Black currant</td>
<td>Strawberries</td>
<td>Hops</td>
</tr>
<tr>
<td>Cherry</td>
<td>Red currant</td>
<td>Rhubarb</td>
<td>Peas</td>
</tr>
<tr>
<td>Rowan</td>
<td>Sea-buckthorn</td>
<td>Blueberries</td>
<td>Beans</td>
</tr>
<tr>
<td>Juniper</td>
<td>Raspberry</td>
<td>Culinary herbs</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Species suitable for agrisilviculture in Jämtland.
Further ideas in development of urban agrisilviculture is:

- Plantation of fruit trees rather than ornamental species.
- Using alley cropping for plantation of trees or berry bushes along walking trails.
- Using forest edges for plantation, providing shelter from trees as well as high accessibility for harvest, also providing higher aesthetic value for such areas if so planned for.
- Having vines growing on fences and other structures used within urban forest, both to enhance aesthetic values from those and provide sunlight for the plants.
- Creating better conditions for berries and mushroom already present in the area, increasing the original productivity of the ecosystem.

If urban agroforestry steers towards silvopastoral systems many more requirements must be fulfilled, both in terms of management and planning for a safe setting for both animals and humans. This requires planning for temporal or permanent pastures, including fences as well as access to water and other necessities. In comparison to mechanical clearing of vegetation presence of animals is probably more preferable to most urban forest visitors, given the settings are perceived as secure.

Some animals that would fit in joint to other production in Jämtland are:

- Bees for honey production, providing pollination and as such directly enhancing ecosystem services.
- Sheep and goats for cheese, meat and wool production.
- Cows for cheese and meat production.

Another interesting concept for the region may be provided by *aqua-forestry*, combining aquaculture with fish production. This means plantation of trees or bushes lining the ponds, providing nutrient uptake from the water as well as forage for herbivorous fishes.

**Suggested areas in Östersund**

Östersund can be described as a most wild city, residing in forest and agricultural landscapes, the city itself filled with parks and other green areas. Also, the oblong shape of the city means forest and other natural ecosystems are never far off, either in connection to the lake or towards the bordering forest in the east. This presents a lot of land that can be defined as urban forest when defining it by type of use, and as such many possibilities to develop agroforestry systems in such areas both in municipally and privately owned land.

In this section a few of these areas are briefly described, provided with SWOT:s to give more insight to how urban agroforestry could be applied in their specific settings. Some further areas are accounted for in *Appendix 2.*
**Lillsjöskogen**

Lake Lillsjön resides close to living areas in Odensala as well as the industrial area Odenskog and shopping malls in Lillånge. The area includes ecosystems from open meadows to mixed forest and swampy lake shores. It also presents connections to old summer pastures as well as a cleared passage adjacent to power lines. Lillsjön is well developed for urban forest use, including beach, 700 meter of wooden paths accessible for disabled visitors, barbecue place and free fishing (Municipality of Östersund, 2014).

Lillsjöskogen has an educational focus, numerous signs providing information about the area and characteristics of the landscape. The bedrock is rich in lime and the herb flora is rich in species common in central Jämtland. Plans for further development of the educational values have been presented, but not implemented due to lack of funding. They include exhibition possibilities indoors, audio information along the wooden paths, and schools classes taking care of part of the maintenance in the area. (Rignér, 2003)

A most discussed feature in connection to Lillsjöskogen is the snow dump, its melt water reaching the lake by rivers and sedimentation ponds. Investigations show that this does not risk the water quality in the lake, and plans to move the dump is not really apparent, even though it may be desirable from an aesthetic point of view if the area is to be a nature reserve. (Ljungmark, 2013)

In the plan for Östersund 2040 Lillsjön is among the areas that the municipality want to protect by establishing a nature reserve or similar, to preserve wetlands as well as urban forest. It is stated that this would raise the status of the area, as well as generate more visitors. Further, the closeness between Lillsjön and areas where a lot of people work provides high recreational values tied to work places by being available at the end of the work day.

**Distance from city centre:** 4 km

**Strengths:** Big area with varied vegetation and many ecosystems suitable for agroforestry attempts. Number of visitors, possibly increasing due to the expansion of Lillånge. Connection to historical values through the summer pastures.

**Weaknesses:** The road E14 working as a biological barrier. Very strongly defined as forest, meaning plantations must blend in to not disturb aesthetic values. Possible risks for red-listed species present in the area due to changes of species composition by planting.

**Opportunities:** Aquaculture or rain-gardens in connection to the existing ponds for better water treatment and possible output of biofuels. Providing educational information about agroforestry systems in joint with already existing signs. Fencing meadows or part of the power line passage for pastures.

**Threats:** Air pollution from traffic, including noise affecting the recreational values. The expansion of Lillånge. A lot of people living nearby already have gardens to apply their cultivation interests.
Minnesgärde

Along the shore to lake Storsjön lies the park Minnesgärde, on grounds earlier being a residential area. Part of the garden vegetation still remains as a characteristic feature, creating a room like feeling. Recreational activities are provided by a volley ball field, walking trails and the beach including a handicapped accessible fishing pier. The municipality plans for further recreational development. (Municipality of Östersund, 2014)

A lot of pines grow in the park, and it dissolves into stands of mixed forest, further spreading out into meadows and cottage like housing areas towards Odensala. The historical use of the area is apparent also in the more forested part, as many of the birches show signs from bark extraction. Further, the railway bank cuts off the area from the city above, which creates a somewhat secluded elongated green passage between the railway and the lake. The railway bank itself represents an ecosystem often highly productive. Both Mittnordenleden and St: Olovsleden leads through the area, being major walking trails passing through Östersund.

Minnesgärde is of special interest to the municipality since the fresh water intake in lake Storsjön is situated close by. This requires safe use of the area to provide for future water needs, as the extraction is expected to increase as the city grows. Thus a proposal for making Minnesgärde a national interest for water supply has been presented. (Jämtland County Council, 2013)

Another factor that may affect the status for Minnesgärde, giving it a higher recreational value, is the planned construction of a new city district called Storsjöstrand. These apartments would be situated by the lake, between Minnesgärde and the city centre. Minnesgärde would then represents a most accessible green area for people living there.

**Distance from city centre:** 2,3 km

**Strengths:** Situated on a south slope. Area connected to protection of watershed, as such less attractive for urban development. Little or no motor driven traffic in the area.

**Weaknesses:** Isolated from other forest ecosystems. Exposed to wind. Erosion in connection to the shore line.

**Opportunities:** Development in joint to Storsjöstrand. Cooperation with the allotment gardens in Odensala. Using the old garden lots for more garden like cultivation of vegetables and similar.

**Threats:** Railway accidents.
** Lövbergaparken**

This park in the eastern parts of Östersund cover both regular parkland and more forested areas. Similar to Lillsjöskogen it is connected to the forests east of the city, crossed by E14. The area is originally grounds from two properties, Lövberga and Björkbacka, which has been used for recreation since 1912 when a soccer field was built by volunteers. The park is accessible by bus lines as well as bicycle lanes, being most accessible from the city centre. It presents boule lanes and tennis courses, as well as a café, providing lawns as well as more forested parts within the park boundaries.

**Distance from city centre:** 1,3 km

**Strengths:** Easy to get to from the city centre. In extension connected to both forest and open landscape. 

**Weaknesses:** E14 being a biological barrier. More park like setting, meaning more strict landscape architecture. Small area compared to other alternatives, probably limiting the system to agrisilviculture. 

**Opportunities:** Cultivation of vegetables, berries and other crops suitable to use in the café. Communal cultivation for apartment dwellers from several, neighbouring city districts. Plantation of fruit trees when other trees are felled, to not cram the lawns with plantations and still get valuable output. 

**Threats:** Connected to recreational activities less connected to forests use such as gathering of berries.

**Risk assessment**

The construction of urban agroforestry systems must include investigations on local level on how to relate to and prevent certain risks, such as:

- General pollution risks connected to cultivation in urban areas. Airborne emissions are to some degree countered by the presence and protective properties of trees, but soil properties and water quality must be accounted for to make sure the harvest is safe for food uses.
- What would be considered as an invasive specie, something that may vary depending on the conservation status of the ecosystems in the chosen area.

- Possible risks and effects from wild animals eating from the plantations, in some terms steering what and how much is economically viable to plant, but also what area is wisest to choose for agroforestry from how it relates to other green areas.

It should also be planned for how misuse of the agroforestry system is to be prevented and dealt with if such incidents should occur, be they true vandalism or too excessive harvesting of certain plants.
Some notes on evaluation of ecosystem services in urban agroforestry

To be able to present the values of created or enhanced ecosystem services coming from urban agroforestry in an economic setting some calculations are needed. Here, these will not be presented in detail since no such agroforestry system is fully developed within the study and can account for actual costs, etc. Thus, rather than giving wide estimations this section aims to point at some general thoughts on how this can be conducted when such a system is available.

Based upon the facts here presented, one formula to estimate the change in ecosystem services value from an urban agroforestry system compared to regular urban forest use could be:

\[
\text{Value of urban agroforestry} = \text{change in cultural ecosystem services value} + \text{change in other ecosystem services value} + \text{harvest value} - \text{maintenance costs}
\]

A change in cultural ecosystem services value is reached by the adding of interests and possible visitors in the urban forest area. This is probable to increase both when measured from the contingent valuation method (by asking people what they would be willing to pay) and from the travel cost method (how much is spent for actual travel to the area). It is important to be able to compare values from when the agroforestry system is first presented to values from before it was installed, as well as comparison to values from when it can be considered a common feature in the area. This would make it possible to trace how the interest in the area develops over time and to what degree the agroforestry system contributes to its recreational value.

Changes to values from other ecosystem services must also be accounted for as far as possible to keep track on how the ecosystem develops when the agroforestry system is present. This connects to values from carbon capture, soil properties, biodiversity, decomposer availability, etc. whereof some are hard to account for in monetary terms. Still, this is something that must be tracked in some way to make sure the agroforestry is sustainable, not deteriorating the system rather than invigorating it.

The harvest value will depend on what crops are grown and if trees are felled for timber sales. This can be measured in SEK/kg or similar, representing somewhat different values connected to how the harvest is distributed (sold for profit or provided for free, or a mixture of both). One can argue that this should be included in the factor here presented as change in other ecosystem services, but it is singled out since this value is of special importance for any urban agroforestry system as one of the main factors that can be used as for determining its validity.
Maintenance costs in an urban agroforestry area is probable to increase compared to the costs before agroforestry implementation. This is due to the fact that plantation will increase, at least in the starting process, and that the area will require more management both in terms of direct maintenance and planning. As (or if) the number of visitors to the area increase, increased wear to pathways, facilities and similar is expected, meaning the level of upkeep will rise. This will add to both material costs and wages for labour, a development that can be partly countered for by parts of the harvest value or other value creation such as parking fees, etc.

There are some things to be aware of in economic evaluations of urban agroforestry, since it may result in misleading numbers to how effective or appreciated the system is. To start with, the contingent value method generally generates higher values for green areas in connection to where people live in apartments. Also, the travel cost method will present lower values to a central area, since the travel distance is shorter for most of the visitors or may not even represent any cost at all if they can walk there. Thus, the formula above will not suffice for comparisons between different areas, but rather focuses on determining changes to values from the same system.

The most important numbers to account for may be as simple as changes to numbers of visitors per week and maintenance cost per year, figures already accounted for in urban forests tended by municipalities. From them it is fully possible to establish how much effort is reasonable to put into urban agroforestry systems if they are to be economically sustainable.
Discussion

Above all else this thesis indicates how urban forests provides numerous possibilities for development, along with continuous and improved provisioning of ecosystem services in the urban environment. The lack of clear definition for the urban forest concept comes across as a strength in this setting, as it suggests this kind of forest in truth can be many things. This could make it easier to include agroforestry in such areas, since the uses are already clearly stated as multiple.

Another interesting notion is how easily urban forests are seen as secondary in terms of need for ecological preservation, even though their ecosystem services value may be far more useful than for any rarely visited ‘wild’ forest with red-listed species and so on. This study also points at how ecosystem services in urban forests often are presented as focused on the cultural values, other more fundamental services put aside for discussions on vague estimations rather than the more obvious facts connected to climate regulation and similar services.

Further, this thesis illustrates a common problem in planning of urban forest: recreational accessibility and maintenance requirements often collide with nature and biodiversity conservation. These different needs are more easily managed if the urban forest area is large enough to fit for several activities, and by applying management plans taking into account both recreation and preservation. This issue is often aggravated by how responsibility for urban forests usually is shared between several municipal administrations, that not necessarily work together in other areas. Still, the bottom line is that loss of biodiversity also means deteriorating conditions for outdoor activities and cultural ecosystem services in general.

On another note, ecosystem services as here presented, including critique against the concept, seems to be a somewhat rare occurrence in many settings, despite it being a major buzz word in many present environmental discussions. Using ecosystem services valuation is indeed one way of addressing the gap between environmentalists and business people, presenting environmental issues from another perspective. But, it is not the only or the best way in every case, since adaptations are often necessary to grasp specific situations. Nonetheless, it does to some degree relate environmental interests to economical, creating common ground for better decision making and increasing environmental awareness.

The high level of uncertainty seems to be a most common attribute of ecosystem services calculations, in one sense implying a weakness to the concept since lack of certainty makes it hard to really compare ecosystem services to other services created and already existing within the economical system. Thus, the reliability of what such calculations suggest can be discussed, and should be in specific cases to ensure the result is interpreted the right way in the local economical settings. Still, it stands clear
that even vague attempts to appraise the value of ecosystems can brings old issues to the tables of decisions makers on a new level, over time affecting policies etc. towards a more sustainable use of natural resources including other services than just provisional.

In a way similar to previously mentioned concepts, agroforestry provides a most direct way of linking subjects together (both in tropical and Nordic climate). But it also works to connect countries from different parts of the world, having similar interests but for different purposes. When agroforestry is addressed from a more Northern latitude it stands clear that social aspects will be most important in terms of effect and generated values, but providing this more from a cultural and recreational point of view than the socio-economic benefits created in tropical forests. Agroforestry is bound to be more attractive as environmental awareness, bioregionalism and general interest in farming increases. In this setting agroforestry can present culturing as a more social activity providing local, natural alternatives, both when applied in urban and rural areas. The development of recreational cultivation in industrial countries thus grow closer to an important factor making agroforestry so favourable in tropical climate: the benefits from communal farming.

Most of the agroforestry systems here studied are sprung from the agricultural part of the scale, with systems built on farmland rather than in forestry settings, which nu doubt raises some issues. When working from open land the agroforestry implementation process requires a very long time frame, since trees grow slowly and the whole system has to be constructed from scratch. No doubt systems built within forest as it already exists can provide a more decent output earlier on, even though the ecosystem within it from some aspects are more sensitive. A forest more often already present some level of biodiversity, which of course is not to be obstructed, meaning another kind of planning process taking this into account is necessary.

The urban agroforestry here presented is less focused on the timber output from the trees, since urban forests defined by use not mainly represent timber resources but recreational areas. Thus, in opposite to systems based on production forest, the timber values are somewhat marginalised. Though, one can argue that to represent true agroforestry it must be accounted for in some way. A thought on this in a more recreational agroforestry model is that it perhaps would be a better idea to keep the output from timber production within the system, providing dead wood to the ecosystem and for recreational uses such as fuel for barbecue, wind shelters, benches, litter for pathways or as material for carving craft.

It is easy to diminish the possible uses and values of urban agroforestry to something less than what they really present, due to low productivity or similar. Thus, it must be emphasised how the recreational opportunities created within such a system connects to two sources of imminent well-being; gardening, and spending time in the forest. Both activities are practised by many Swedes, living in rural as well as urban areas, on a regular basis, provided appropriate sites for such activities exist.
Other advantages most important to take into account when considering Swedish agroforestry are the possibilities for ecological restoration, boosting range and quantum of available ecosystem services while repairing ecosystems and restoring biodiversity. No doubt it can be used to reconstruct historical ecosystems and landscapes, both in rural and urban areas, since so much of Swedish history presents forestry and farming as connected activities. Also, agroforestry can assists to raise awareness of the versatility of ecosystem services in forest, not being only provisional, as most often taken into consideration. In a grander scope agroforestry presents systems built from a deeper understanding of what a more balanced anthropogenic out-take from nature could look like, which is something a nature rich country such as Sweden should indeed strive for.

This thesis suggests urban agroforestry attempts in Östersund, which may raises some questions on how relevant urban agroforestry would be in a rural area compared to in a larger city. Östersund has been considered within this study due to the already high availability of locally produced food, but also since there is a lack of development in agroforestry systems on such a northern latitude. This means a lot of knowing and practice in regional land-use is available for adaptation into agroforestry systems, if an interest can be stimulated, but also a possibility for some ground-breaking research in the agroforestry field.

Just from the very brief system proposals here presented some things can be learned, for other cities as well. While planning an urban agroforestry project the local settings must be the foundation, even though inspiration from other locations may be used. A suitable area must be chosen in terms of many aspects, from how many people are living close by to possible harvest gain and plantation possibilities. Generally a larger area is better, meaning smaller intervention per hectare is possible and as such leading to less competition with other recreational uses, as well as smaller effects to existing ecosystems.

The purpose of the agroforestry system is the determining factor, both for choice of site and many other issues. Situations where productivity potential compete with recreational needs should be expected, but can be handled by including those intended to use the urban forest for leisure in the planning process. The latter is also important to create a socially sustainable use of the system and biological properties of the area where it resides. To not risk the ecological gain or biodiversity local factors relating to this must be taken into account, and steered towards proper system goals.

Overall, a major benefit on municipal level from the urban agroforestry concept is that it requires an increased cooperation in planning of urban forests in general, to not risk certain activities or overuse of the chosen areas, as such better providing for preservation of these important green areas. It makes it more important to determine what these areas really represents in terms of value creation, and what ecosystem services they can provide.
Concluding remarks

After this study it can be concluded that agroforestry represents an interesting way for development of urban forests, as it can mean a more versatile use of present ecosystem services, while better preserving them by raising awareness of their existence. Urban agroforestry as here intended thus suggests a version of multiple land use that takes into account cultural, Besides provisional and regulating services, sating several needs from an increasing urban population. This implies a way towards more efficient land use in urban areas, having much need for greening as well as a higher degree of self-sufficiency.

From the work here conducted, it stands clear that all versions of agroforestry must be adapted to local preferences to be as effective, desirable and environmentally viable as possible. In urban settings this is of still greater importance, since different cities and city districts present variations in preferences such as lifestyle and marketing trademarks, affecting local choices for recreation and other activities. The need for cultural services from the ecosystems within an urban forest thus can vary greatly, depending on population density, access to green areas in general, and other social factors.

The potential for any urban agroforestry system relies on a balance between economical input and gaining an output without compromising other recreational activities, or biodiversity. How to achieve this must be determined within the city where such a system is planned, based on existing local prerequisites.

From this knowledge, it is here proposed that an urban agroforestry project in Östersund should be focused on the social, recreational potential to be most successful, as such increasing the values from cultural ecosystem services in local urban forest. Such an adaptation could also mean a raising awareness of the ecosystem services concept and the opportunities agroforestry represent in urban settings. A sound way to approach such a project would be by connecting the regional common interests in outdoor recreation and local landscapes to the municipal environmental work as well as the local commitment in artisan food, as such enhancing some of the hallmarks of Östersund.

To further pursue this many details around an actual system construction must be accounted for, as well as some relations to Swedish law (primarily regulation for safe food production, the Forestry Act, the Environmental Code and Allemansrätten [The Right of Public Access]). Furthermore, social and economical planning of who will grow the crops and have the right to harvest them must be determined. Preferably this can be achieved by case studies tied to specific areas of urban forest, looking into present ecological as well as social and economical requirements.

In a grander scope, comparisons in terms of value creation from ecosystem services in urban agroforestry in Östersund and similar projects in the main Swedish cities would be a wish for the future.
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Appendix 1: Nordic agroforestry in historical context

Looking back in history, agriculture and forestry resembling agroforestry have been widely applied. In the Nordic countries, including Sweden, this have been most necessary means to provide sufficient supplies from sparse resources and cold climate.

The plant and animal resources found in forest is the basis for the Nordic settlements, starting with the hunting and gathering cultures, continuing to the present day. As agriculture developed the forest was still an important incorporated factor, affecting both construction of agricultural systems and providing them with extra food resources and raw materials needed for construction of farms and fields. These systems were built around alternating cultivation of crops with animal grazing and periods of fallow when the fields could recover to provide new harvests in the coming years. An ordinary field was made from a patch of suitable forest land, where the trees where stripped from bark and died, before fire was used for clearing the area. Then crops, often rye, were sown in the ash and providing 1-4 good harvests. After this the field was often used as pasture, allowing reversion of the ecosystem back to forest, before the loop could be started anew. This kind of swiddening presented long term effects, opening up coniferous forest for pioneer species of leaf trees, and as such made the agricultural landscape more diverse. (Fritzbøger & Søndergaard, 1995)

In many ways this was a more careful use of forest ecosystem than in modern times, only diminishing them in certain areas and then having them return towards their original state. Use of fire and slash-and-burn may sound brutal, but it left the soil layer more intact, as well as the capability of forest to grow back from seed sowing from the surroundings. Cycles of fallow, sometimes with plantation of legumes to restore the soil fertility by their ability to bind nitrogen, could further enhance the time span a field was fruitful by adapting natural processes towards providing more gain. This can also be seen as enhancing ecosystem services to better fit human needs in historical settings.

Due to the low amount of available arable land animal husbandry has been a major part of agriculture in the Nordic countries. This provided fresh food during long winters when no cultivation was possible, from milk and meat. For pastoral uses deciduous forest was more important than coniferous forest, since it provided more grass and herbs, and as such formed better pastures. In southern Scandinavia the trees were protecting the pastures from sunlight and drought, making them more productive than the open fields. Settlements were often situated as villages having infields with deciduous forest and outfields with coniferous forest, a pattern created by anthropogenic land use and animal grazing. The by animals preferred trees were elm, birch and ash, which was cut and used for leaf fodder in the winters, especially in more northern settlements. Leaves were also used as fertilizers in vegetable gardens, a custom still common the 18th and 19th century. (Fritzbøger & Søndergaard, 1995)
Historical use of forest was tied to numerous other provisional ecosystem services creating economical value than those just coming from sheer agricultural activities. A lot of trade was based on hunting of rare furs, which also was used as tax payment in periods. Wood for ships was another commodity used both for national interests and international trade. Pine tar and pot ash was extracted from wood, the latter leading to major local reductions of deciduous forest in southern Sweden. Another product coming from wood is charcoal, most important in development of industry. To connect back to the sustenance level of forest use, bark was used as substitute for flour and coffee in times of need as late as during the first half of the 20th century.

Silvopastoral systems with forest pastures for animal husbandry was effective and still in use even in the late 1800’s, when technical inventions and economical reasons resulted in more specified forestry and agricultural industries. On the agricultural side, the iron plow made it possible to grow crops in areas that had earlier been vegetated with trees, and adoption of artificial fertilizers took the trees role in nutrient supply chains. At the same time timber prices for coniferous wood was rising, due to advances in the forestry sector, meaning that more dense forest was created in areas not cultivated in agricultural sense. (Kumm, 1990)

As local wood demand increased the forestry production was differentiated and organised to provide more output, along with new technology affecting the balance of traditional peasant forestry. From early 20th century selective cutting was replaced by natural regeneration cutting, and from the 1950’s with clear cutting and plantation. This meant more trees were cut per hectare, having larger effects on the ecosystems. At the same time agriculture developed to be more up-scaled, using more machines, requiring larger and more open fields, pushing aside trees and forest in the agricultural landscape. As urbanisation and industrialisation increased, the forest was turned into a source for raw materials and field of action for specialists, parting the larger part of the population from it in in crucial ways. This represents a major demographic shift in Nordic history, as in most of it the majority of people have lived within the forest itself. More modern times have also invented an antagonism between arable fields and woodlands to symbolise man’s struggle against nature. Within this the wilderness it put against society and civilisation, opening up for alienation from nature, in a way that completely overlooks the original connection between farming and forests. (Fritzboger & Søndergaard, 1995)

All of this make forests most important in connection to Nordic cultural landscapes, due to the historical multiple uses and many regional variations. Values from cultural ecosystem services have thus increased over the last hundred years, as experiences of forest for the average person has grown more sparse, but also since recreation as an organised activity has been introduced.
Appendix 2: Additional areas for urban agroforestry in Östersund

Andersön
This nature reserve residing on one of the largest islands in lake Storsjön is in terms of distance from the city centre less of an urban forest, but in terms of recreational use it fits the description well. Archaeological remains such as cairns and terraces used for cultivation can be found within the area, tracing agricultural practices in the area back to the iron age. Further, Andersön has harboured one of the most well-managed farms in Jämtland. On the estate 70 linden trees, 600 maples and lots of chestnut trees were planted. Apple and pear trees was also growing on the farm lands, along with strawberries and arctic raspberries. (Jämtland County Council, 2014)

Distance from city centre: 15 km

Strengths: Less affected by human use and city dwelling than the other areas here presented. Provides more natural ecosystems to work with. Large available area, naturally foreclosed into a system.

Weaknesses: Distance to the city requiring a most active choice to get there. Limitations connected to nature preservation within a reserve. Great risk for animals eating from plantations.

Opportunities: Reconstruction of historical environments and ecosystems, increasing the cultural ecosystem services. Harvest events, inviting people to take part and bring a part of the harvest home. Showcasing educational material and information on historical agriculture by practice.

Threats: A less controlled system than in connection to inhabited areas. Risks for misuse since the possible great output may lead to theft. More visitors to the area, and as such harder pressure on the nature resources meant for preservation.
Frösön

Across the lake from Östersund are the settlements of Frösön, the ones on the city side more urban in character and the island further unfolding into agricultural areas. Overall, the settlements are more scattered, providing patches of forest and numerous areas that could be defined as urban forest due to the kind of human use. Since the distance across the lake is short, many of these areas are also within walking distance from the city itself and as such most accessible. Bike lanes and walking trails are present on most of the island, as well as bus connections. The close relation to actual agriculture presents interesting possibilities to spread it towards or into the urban forest areas for recreational purposes.

Distance from city centre: 1,5 km to the island, then further depending on forest area

- Many accessible groves for agroforestry.
- Direct connections to both forest and agricultural ecosystems.
- Presence of local farmers who can contribute with skills and knowledge.
- Cooperation with local farmers.
- Project in developing agroforestry for a self-sustainable Frösön.

Torvalla

As the most southern city district of Östersund, Torvalla borders to both forest and agricultural settlements similar to Frösön. In this area a main part of the city population resides, meaning great needs for recreation. The central part of the city district consist of apartment blocks, as such having no access to garden like recreation. Since the surrounding forest is abundant, cultivation in such a setting may bring great interest. In other parts separate houses make up the residential areas and here the agroforestry potential is probably lower, but since a lot of the residents within those are families with children an interest in healthy food production can be expected.

Distance from city centre: 7 km

- Lots of forested areas situated between housing blocks, which could be used for communal agroforestry.
- Presence of local farmers who can contribute with skills and knowledge.
- Need for recreation in Torvalla, rather than in central Östersund.
- Projects tied to Djur & Kul-gården, using the horses for grazing in larger areas, cultivation of forage, or beating of hay in traditional manner.
- Forest gardens in connection to schools in the area.
- Sales of locally agroforestry produced crops at the local food store.