mapping urban agriculture

potential in Rotterdam

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Summary

Introduction

Urban agriculture (UA) is an increasingly global trend due to the benefits that it can bring to urban environments. The range of benefits is very diverse, from environmental (stormwater mitigation, air purification, nutrient recycling, urban cooling etc.) or social (food security, education, recreation, physical activity, improvement in healthy eating, improved social cohesion etc.) to economical (income generation, added real estate value, supplying niche markets etc.). In the context of the Netherlands, a highly industrialized country, food security is not currently the main motivation behind the practice, but rather the effort to increase awareness of the importance of local food and its impacts. Rotterdam is a pioneering city in terms of UA, hosting more than 100 active initiatives besides the allotment complexes. However, most of these initiatives are small and do not have significant impacts on a citywide scale.

Aim & Methodology

Because the increasing interest in UA should be encouraged, this research aimed to gather and map data regarding multiple criteria which are relevant to UA in Rotterdam (physical, economical and social). Target groups include government officials, entrepreneurs, various organizations or enthusiasts, all which have an incentive to start new initiatives. The main analysis tool has been GIS (Geographical Information Systems), and very diverse data was gathered, analysed and shown through the aid of digital maps. The data has mostly been gathered from the GIS database of Rotterdam Municipality.

The main output of this research consists of a geodatabase containing all the gathered data. Also, a tool in the form of an interactive PDF file containing the maps presented in this report has been created. The file contains the maps for each relevant criterion, as well as a map of existing initiatives in and around the city and 5 scenario maps (potential maps) presented as guidelines for how the information could be used. The interactive PDF has been created in order to facilitate the visualization of the different maps.

Findings

Rotterdam has a large potential surface that can potentially be converted to UA initiatives. Grasslands and derelict lands without contamination issues amount to 3900 ha and there are 906 ha of suitable flat roofs. Even converting a small percentage of these surfaces would have considerable impacts in the city. Many plots scattered around Rotterdam can benefit from the added functionality brought about by UA.

Next steps

At the moment the interactivity of the PDF file is quite limited, so finding a better alternative for publishing the information (e.g. ArcGIS Online or Google Maps) is advised. Also, more criteria should be researched/gathered that can complement the existing data and, in combination to previously published reports on UA in Rotterdam, a strong knowledge base can be formed that can help push the trend further.

I. Introduction

What is urban agriculture?

Urban agriculture (UA) is, in a nutshell, food production in or around cities. In scientific literature it is defined as "an industry that produces, processes and markets food, fuel and other outputs, largely in response to the daily demand of consumers within a town, city, or metropolis, on many types of privately and publicly held land and water bodies throughout intra-urban and peri-urban areas… [and] applies intensive production methods, frequently using and reusing natural resources and urban wastes, to yield a diverse array of land-, water-, and air-based fauna and flora, contributing to the food security, health, livelihood, and environment of the individual, household, and community"[1].

Note: for this study mainly plant production was considered

UA has been proposed as a solution to current global problems such as food security, land use change, eutrophication of surface waters and greenhouse gas (GHG) emissions emerging from the transport of food that has not been produced locally[1-4].

The concept has been growing in popularity recently, especially in Europe and the US, with enthusiasts having started urban farms for various reasons. The most prevalent are environmental concern, self-sufficiency, food security, education, community building or income generation[1,3]. UA initiatives come in different forms and scales, ranging from backyard gardens or street verges to parks or large scale greenhouses on public or privately owned land/buildings. Whether the farms are commercial or social oriented, there are significant benefits linked to the occurrence of the UA initiatives.

UA can be tailored in order to supply cities with services such as water and air purification, water retention or waste management, whilst maximizing the usage of available urban resources necessary for plant development, such as space, sunlight, water, heat etc. Such services are also instrumental to the increase in social benefits such as education, pollution reduction, improvement in healthy eating, recreation or green space quality[5].

Why Rotterdam?

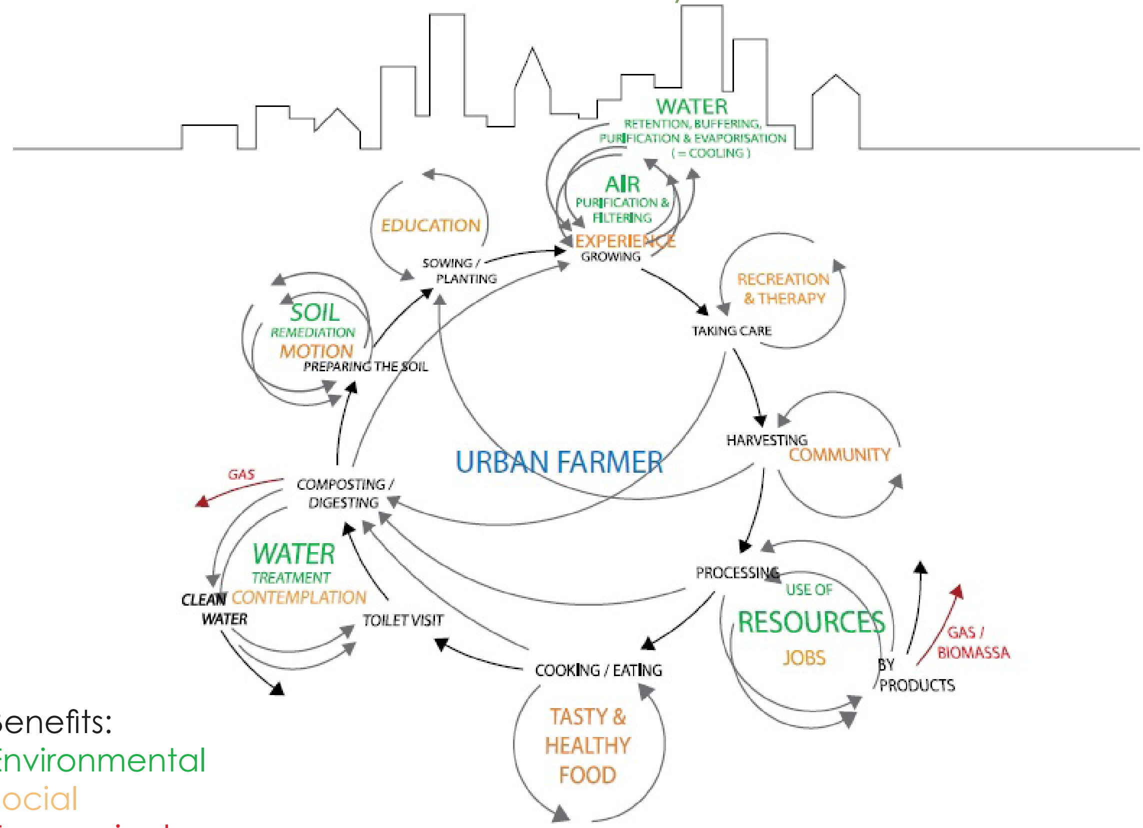
Rotterdam is currently facing social, economical and environmental problems such as a lack of adequate green spaces, recreational facilities, problematic soil and air quality as well as unemployment and health issues related to bad nutrition or lack of exercise[6].

Rotterdam is a hotspot for UA, with more than 100 initiatives present in the city that are currently running. Many types of farms producing mainly vegetables currently supply citizens, local restaurants and shops as well as host training workshops for interested parties and social events for urban citizens.

The UA trend has also been enforced by government officials, researchers and universities from various professional backgrounds.

An expert group on UA, Eetbaar Rotterdam (www.eetbaarrotterdam.nl), has been formed in 2007 in order to promote a network of urban farms in Rotterdam as well as provide guidance for existing

Urban food cycle[5]



Benefits:
Environmental
Social
Economical

Demand	Supply
Agricultural	**Urban**
Sunlight / daylight	Plenty of sun-exposed surface
Nutrition / fertilizer	Waste flows
Irrigation	Microclimate
Soil / substrate	Vacant space
Microclimate / environment	Niche space
Space	Temporary space
Loading capacity (integrated in buildings)	Underused constructive capacity
Labour	Labour force (employees)
Market	Customers
Urban	**Agricultural**
Public green design & management	Aesthetics
Ecosystem services	Relative biodiversity
Education	Experience of seasons
(nature, food production, life skills)	Hands-on learning / work experience
Therapeutic work	Therapeutic work
Appropriate jobs	Skilled and unskilled labour
Water storage	Water intake & evaporation
Climate control (cooling / heating)	Evaporative cooling
Improvement in water, soil and air quality	Purification of water, soil and air
Waste treatment and management	Organic waste treatment

Source: de Graaf (5)

Room for UA in Rotterdam[5]

farmers as well as other interested parties. An organization named Creatief Beheer (www.creatiefbeheer.nl) aids in starting and maintaining community and child friendly gardens since 2002.

Also, several reports on UA in Rotterdam have been published:

Ruimte voor Stadslandbouw in Rotterdam— de Graaf 2011, Eetbaar Rotterdam;

Stimuleren van stadslandbouw in en om Rotterdam—Gemeente Rotterdam 2012;

Stadslandbouw in Rotterdam—Fontein A., la Riviere L., v.d. Broek A., 2013, Groen: vakblad voor ruimte in stad en landschap;

Aim

Existing problems are slowly being tackled to some extent by existing urban farms, but in relation to the scale of the city changes are insignificant. The bottom up approach of UA must be encouraged so that an impressive network of knowledge and resources can be formed that can greatly benefit the city and address these problems.

This research has been aimed at further promoting UA in order to continue increasing the number of initiatives in the city of Rotterdam with the aid of maps.

Through mapping, the inhabitants of Rotterdam (citizens, government officials, entrepreneurs, researchers, enthusiasts etc.) have the opportunity of gaining insight on what is happening in the city in the field of UA, as well as regarding the potential areas for further development. In addition to existing reports on UA in Rotterdam, this study offers a consultancy tool for parties with an interest in starting UA initiatives.

Luckily, the first steps have already been made through the research of Paul de Graaf (see above). Unfortunately, these maps are not georeferenced and cover large areas of the city with a high probability of containing suitable locations for urban farming, lacking detail considerably.

The aim has been to build on the work of Paul de Graaf and previous research by producing maps with greater detail and more embedded criteria. In addition to the physical or environmental factors which are most commonly used in determining which locations are suitable, social and economical factors have also played a very important role.

The finished product is also available in the form of a tool where all the criteria are accessible and can be interpreted depending on the interest of the user.

The work has undergone with supervision from the Urban Planning and Environmental Department of the Municipality of Rotterdam, with close contact with leading researchers in the field of UA in Rotterdam. The maps have been produced using Geographical Information Systems (GIS) as the main analysis tool. Access to the GIS database of Rotterdam Municipality has been granted during this research, meaning that very diverse and recent GIS data has been available.

However, because of the spatial jurisdiction of the Municipality of Rotterdam, which includes the port area and Hoek van Holland, data was not available for towns like Schiedam, Rhoon or Capelle aan den Ijsel, which may have been relevant to this analysis. Therefore, most of the port area and nearby towns were not taken into consideration, focusing mainly on the city of Rotterdam. All data was handled using a specific boundary, as visible in the published maps.

The methodology for producing each map is found in Annex 2.

Wouter Bauman, rooftop farmer on Dakakkers

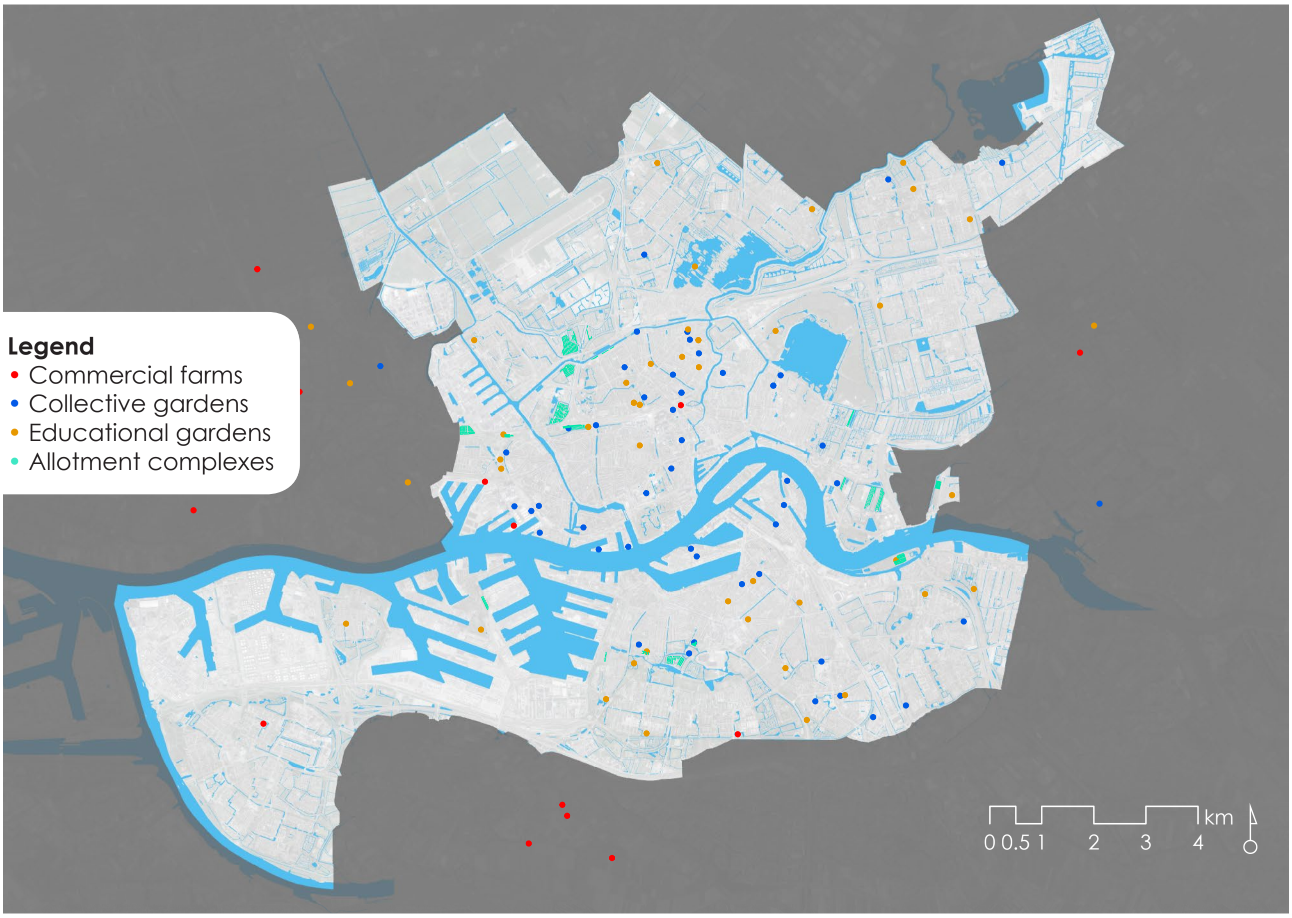
II. Background

UA in Rotterdam

UA has been booming in the Netherlands during the past couple of years, with cities such as Amsterdam, Rotterdam, Utrecht or the Hague developing more and more urban farms for social, educational or commercial purposes. Rotterdam is a hotspot for UA, housing more than 100 initiatives that are currently running.

The majority of these initiatives are small scale community gardens based on volunteers (e.g. Gandhi Tuin, Proefpark de Punt, Spoortuin etc.). Educational/ school gardens (e.g. de Enk, Carnissesingel Tuin, Essenburgsingel Tuin etc.) are also common, having been an important part of Dutch culture and hosting hundreds of children from nearby schools every week. Other notable examples include farms such as Uit je eigen stad (the largest commercial urban farm in Rotterdam, which produces vegetables as well as chicken for its own restaurant and local consumers), de Buytenhof (a traditional peri-urban organic farm in the south of Rotterdam which supplies many shops and restaurants in the city) or the Dakakkers (the city's only rooftop farm initiated by the Rotterdam Environmental Centre and the Zones Urbaines Sensibles—ZUS research centre).

In addition to these initiatives there are also allotment gardens (nutstuinen, volkstuinen), which are rented/leased by citizens who lack private green space. To a large extent such gardens produce food, mainly for the consumption of the producers and their families or friends.



Map A. Urban agriculture initiatives in and around Rotterdam

UA Types

There are many classifications available for urban farms. Based on the agricultural practices the main categories are:

Ground based agriculture

Involves growing plants at ground level in/ without the presence of soil. There are many practices available, the most common for UA being Small Plot INtensive (SPIN) farming (www.spinfarming.com), permaculture (www.permaculture.org) or forest gardening[5]. Such practices are dependent on good quality soil for growing healthy plants for human consumption, and tend to have organic practices such as composting for fertilization as well as biological pest control[5]. However, if over fertilized, soils leach nutrients to groundwater causing algae blooms and anoxic environments in surface waters[7].

Rotterdam has numerous open green spaces, parks, back yards and other areas with access to soil that can be converted to urban farms. In the absence of soil or if soil quality is troublesome, healthy soil can be brought on site. This option has been used on the urban farms like Uit je eigen stad or Spoortuin. However, this solution can prove costly[8].

A very productive alternative to using soil is widely known as hydroponics, which entails the cultivation of vegetables in nutrient solutions using sand/gravel/pumice as substrate. Such methods reuse water and nutrients making them very efficient. The farmer has full control over the content of the nutrient solution, with organic products also being available on the market (for example, nl.eurohydro.com). Also, as opposed to soil based agriculture, no leakages of nutrients to the groundwater can occur with adequate management[9].

Almost all UA initiatives in Rotterdam, including the allotments, are ground based and use soil as substrate for plants.

Rooftop agriculture

In very dense urban areas access to soil can be difficult either due to commercial/industrial activities or lack of green space. In such cases rooftop agriculture is a solution, since it is possible to grow plants on flat rooftops either with or without the presence of soil[10]. If plants are grown in soil on roofs, they generate benefits similar to green roofs: better building insulation, a local cooling effect as well as stormwater retention[11].

In Rotterdam the city centre is a very

De Enk permaculture & educational garden (Rotterdam)

Lufa farm, a large scale rooftop hydroponic greenhouse (Montreal, Canada)

Small scale vertical aquaponics system - Mediamatic Fabriek (Amsterdam)

Dakakkers rooftop SPIN farm (Rotterdam)

Uit je eigen stad, commercial farm and restaurant (Rotterdam) plausible location, having very little green space available but plenty of modern buildings with flat roofs.

However, there are multiple considerations for starting rooftop agriculture: roof strength, wind, solar exposure, height, accessibility, airborne contamination or safety[5,10,11].

Controlled Environment Agriculture

Controlled Environment Agriculture (CEA) is the growth of plants within greenhouses. Such farms are independent on seasonality and can produce food all year round. Also, they are very efficient and require less resource input such as up to 70% less water than conventional farms[8] and pesticides or herbicides are rarely used[9]. They can apply both soil based or soilless practices. Greenhouses can also be placed on roofs, taking advantage of heat radiating from the building as well as helping with insulation[4]. However, large scale farms are required in order for them to be profitable (e.g. Lufa Farms www.lufa.com).

A rather special type of CEA is known as aquaponics. Aquaponics is a mixture between aquaculture and hydroponics. Fish (e.g. tilapia or catfish) are grown in tanks. Their waste is then used by plants that take up the nutrients and clean the water. Excess plants can then be used to feed worm farms which provide food for the fish. It is a cyclical system that produces both fish and vegetables all year round, usually in greenhouses, using 90% less water than traditional agriculture[12].

However, in order to maintain a constant yearly production in the Netherlands, CEA requires energy for heating and/or lighting during winter time or ventilation during summer, which adds to the total costs. Also, initial investments are larger for establishing the systems and more qualified personnel is needed to run the farm[13].

In the case of Rotterdam, which is within 30km of Westland, an area with the highest concentration of greenhouses in the world, CEA can hardly compete with the large scale and efficient production of very cheap vegetables which are also rather local. However, an increased interest in sustainable food production is being noticed in Rotterdam, which might offer the niche market desired by such urban practices. Uit je eigen stad, for example, is starting to run an aquaponic system to provide fish and leafy vegetables to its already large number of customers[14].

Social or commercial?

Urban farms can also be regarded as social-oriented or commercial-oriented. Although many urban farms stand somewhere in between these two categories, a general orientation can be identified.

The social-oriented farms are commonly educational gardens, community gardens or social integration farms. Their activities have a strong motivation towards gaining the social benefits of UA, and the produce is usually distributed amongst volunteers, visitors or to charitable organizations[15].

The commercial-oriented farms are aimed mostly towards selling most of their produce to local consumers or restaurants. However, they also tend to accept volunteering or educational visits. Such farms are usually larger in scale which makes them more economically viable[10,14].

Regardless of the orientation of the urban farms, they all contribute to the increasing awareness of local food and the social and environmental benefits generated from its production.

III. Mapping criteria

As mentioned in the introduction and aim section, multiple criteria with strong connections to UA have been mapped. The general classification includes physical, social and economical criteria.

Physical criteria

Soil based agriculture is mostly dependent on the availability of soil and its quality. Therefore, the permeability (access to soil) of urban areas is very relevant.

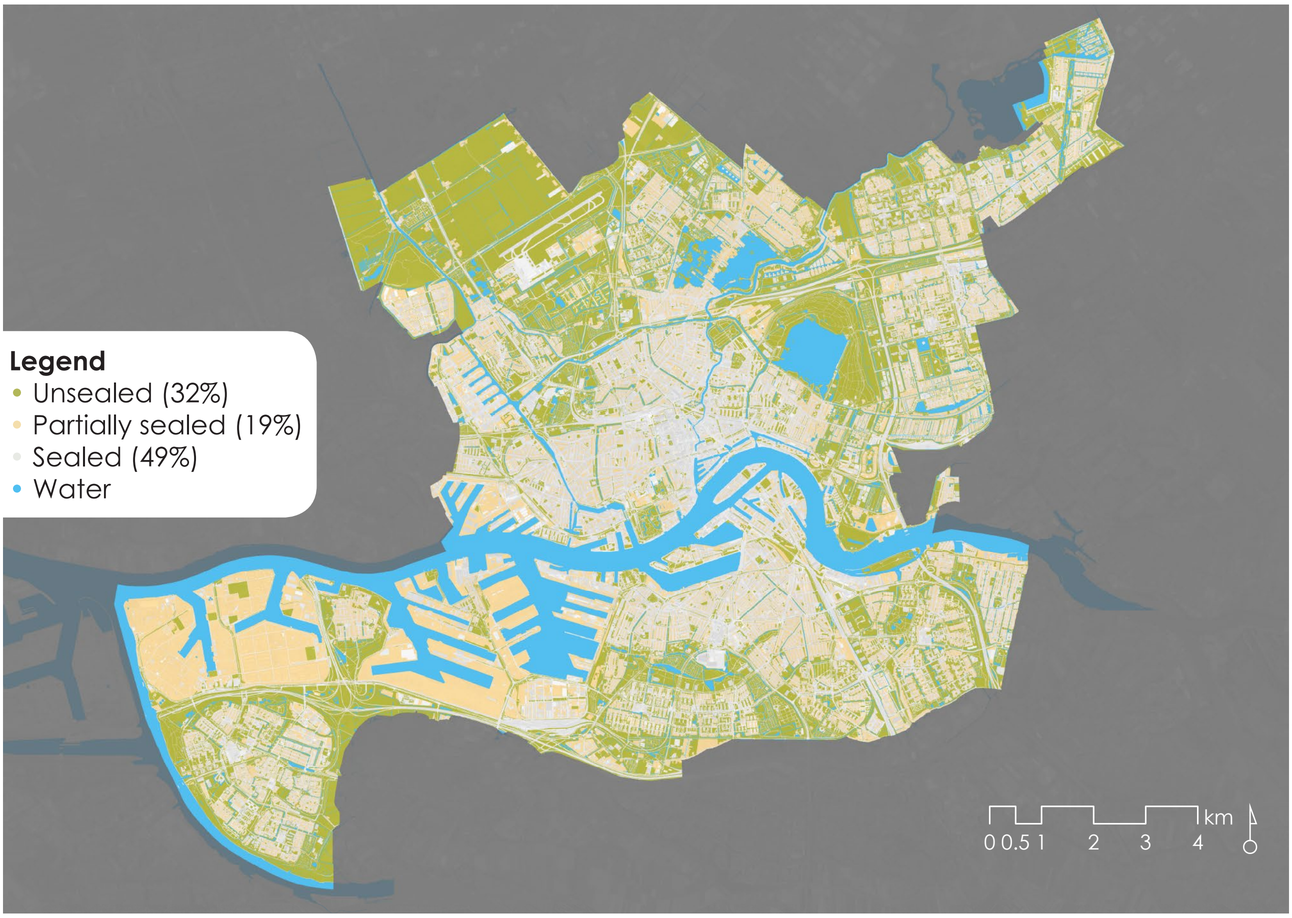
Unsealed areas

Relative to the urban surface considered in this study (142,112,605 m^2 land surface), Rotterdam has 32% uncovered/unsealed land in the forms of parks, lawns, vacant lands or roadside areas. In such areas soil is accessible and possibly usable for UA (map 1).

In map 2, the current use of unsealed lands can be seen. This is an indication towards the most potential areas for developing urban farms.

Grasslands cover the majority of unsealed land in Rotterdam (71%). They can be suited for conversion to UA initiatives, offering an improved and more diverse green space. The highest potential is attributed to the grasslands situated in residential areas with large open spaces. Grasslands from parks might be harder to convert to urban farms due to their strong recreational function, although partly converting them might be accepted.

Sports fields are also covered with grasslands and, although they are unusable, they often have additional space with access to soil nearby, which can be con-



Map 1. Permeability of urban areas

verted into an edible landscape, further promoting the health benefits of sports with healthy eating[16].

Street verges and roadside grasslands are also interesting, as they can easily be converted to orchards[10]. Also, fruit trees or berry bushes can be used to transform green infrastructure into edible produce.

Forests, as presented in map 2, mostly represent areas with trees, which can be used for permaculture or forest gardening. If the tree density is low, SPIN farming might also be possible

The allotment garden complexes are already UA initiatives to some extent which, when combined, produce large quantities of food or other economically interesting products such as flowers or seeds.

Derelict lands are currently unused and might be temporarily available for developing urban farms. Proefpark de Punt is a very good example. It is a community garden started on a set aside land 9 years ago, and it is still running today as an UA initiative (www.proefparkdepunt.nl). This can be the case for many plots in town, as map 2 shows 375 ha of derelict lands available in Rotterdam.

Soil quality

If the soil is accessible, its quality is very important to the development of urban farms. In urban environments soils tend to be very contaminated or unsuitable for agriculture due to their content/structure. Map 3 shows the extent of contamination of the unsealed areas around Rotterdam. Clean or safe for agricultural use soils account for 52% of the unsealed land, with the rest being lightly (33%), medium (11%) or highly (4%) contaminated with various toxic pollutants (heavy metals, asbestos, PCBs etc.)

Many of the existing urban farms in Rotterdam carry out their activities on lightly contaminated soils. In some cases such

Map 2. Unsealed land use (including allotment complexes)

soils have been covered or mixed with clean soil in order to be suitable for plant production[14,16].

Contamination, however, is not an indication towards the suitability of the soil for growing usable plants. The soil type as well as fertility are key issues in this case. A comprehensive map of soil types in Rotterdam does not exist, mainly due to the large amount of work needed to process the data as well as high uncertainty.

Although contaminated sites discourage food production, they have an important incentive towards remediation. An excellent example is the use of energy crops such as maize, willow, rape, elephant grass etc. for the production of biofuels (bioethanol, biomass, biodiesel or biogas). This practice has been proven to clean contaminated soils while generating economically interesting products[17]. A local based company named NNRGY Crops specialises in planting elephant grass on set aside/derelict lands throughout the Netherlands, with several sites around Rotterdam. This perennial crop increases the quality of the soil it grows on making it suitable for agriculture and also generating income as it can be used in sustainable packaging, furniture or burnt as fuel. More information available at www.plantolifantsgras.nl.

However, the cleaning process can take many years before the soil is fit for use in agriculture, which is why physical methods such as removing the soil and treating it somewhere else are preferred, so that the land is quickly available for new developments[18]. But, with energy crops, the economical gain might be sufficient for some land owners for a few years.

Map 3. Soil contamination (0-1m) of unsealed urban areas

Partially sealed areas

Unfortunately, the municipality of Rotterdam only holds limited private data on land use. This means that there is a high degree of uncertainty towards the land use and permeability of private areas such as back yards, industrial areas or other commercial grounds. Such areas have been considered as partially sealed and they cover around 19% of the total land surface of Rotterdam. Although there is no clear indication towards the permeability of these areas, they can still be suitable for agriculture. Possible limitations lack of good quality soil or sunlight. Due to the high degree of uncertainty, these areas have not been taken into account.

Sealed areas

The highest percentage of urban areas in Rotterdam is sealed (49%). This renders a lot of space unusable for UA due to its use in infrastructure (roads, sidewalks, bike paths, foot paths) or real estate (buildings, parking). Paved areas have the potential for developing soilless agriculture in industrial areas, for example, where large paved surfaces are available. Other alternatives include growing produce in and on top of buildings.

Flat roofs

This study only takes into account rooftop agriculture as a solution for sealed areas. Rotterdam has plenty of flat roofs, but not all are suitable for rooftop agriculture. Height is a main concern, since strong winds and sun exposure can limit available crop varieties above certain heights[10]. Since Rotterdam has no particularly high buildings, most suitable roofs shouldn't face such problems. A height limit of 40 m was set for this analysis.

Map 4. Suitable flat roof locations and areas (906 ha total)

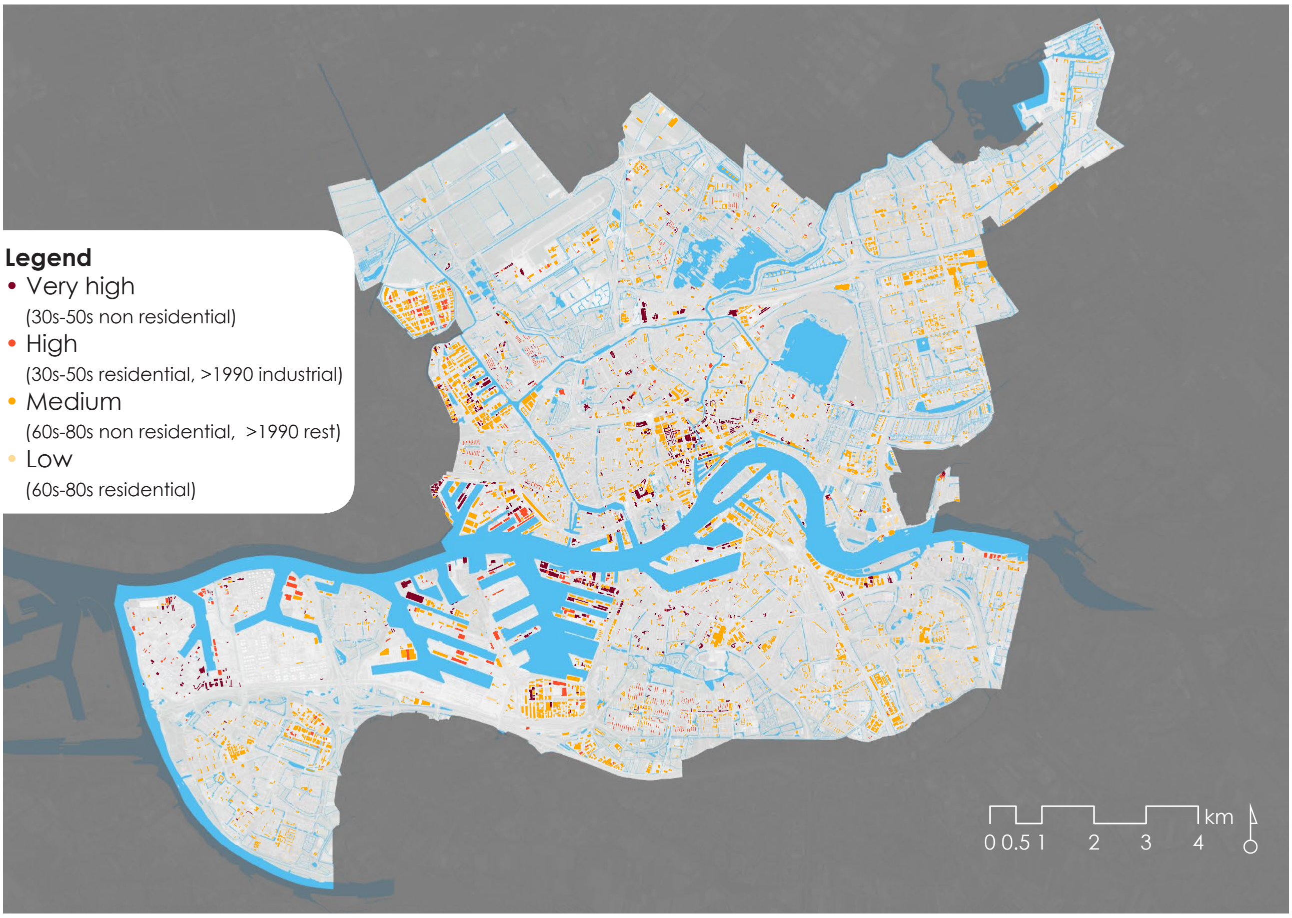
Note: Flat roofs of buildings built after 1950 and with heights lower than 40 m were considered. Also, a minimal surface of 500 m² for adjacent roofs with the same height was applied

The locations of suitable roofs in Rotterdam as well as the available surface are visible in Map 4. For these calculations only adjacent roofs of the same height were considered. Also, the minimum acceptable surface has been chosen as 500 m^2, since smaller roofs might not be economically viable[10]. The total potential flat roof surface in Rotterdam amounts to 906 ha.

Another crucial factor for this type of UA is roof strength, since the extra load can collapse unsuitable roofs. Unfortunately, data on maximum roof loads per buildings is unavailable because of its specificity. However, building age in combination with function can be a rough indication whether buildings are suitable or not for developing rooftop farms (map 5).

The general indication coming from function is that residential buildings, especially row housing tend to have weaker structures than other purpose buildings, as only the minimum requirements by law are met in construction. Industrial or public buildings, for example, are more likely to have stronger structures. The highest roof strength is possibly attributed to buildings built between the 30s and 50s, since high amounts of concrete were used in construction, especially for public or unique buildings (banks, cinemas etc.). Residential houses from that time are also of high potential strength, but as they are usually built with a tighter budget, weaker structures are common for saving costs. Between the 60s and 80s the weakest structures can be found (especially in residential buildings), since a very unreliable concrete composition was used during that time. As for buildings dating after 1990, there is no convincing indication of roof strength, but as newer buildings they should be more sustainable and therefore suitable to some extent[5,19].

The rooftop farm Dakakkers, conducts



Map 5. Suitable flat roof potential strength (based on building age & function)

its activities atop a building constructed in the 50s. It has been assessed as being able to sustaining a maximum load of 180 kg/m^2, which has been proven enough to hold an impressive production of vegetables, herbs and honey after an assessment that identified the stronger and weaker roof areas[20].

This indicates that the weight requirements of a rooftop farm are very similar to extensive green roof requirements (60-150 kg/m^2)[11]. Similar requirements apply to hydroponic roof production in greenhouses, which, due to the lack of soil are rather light weight[5].

The function of the building in question is also very relevant to its possible conversion towards rooftop food production. Industrial buildings are the most likely to support larger scale production, offering vast flat surfaces. Also, depending on the type of industry, residual heat can be available for supporting greenhouse production[10].

Public buildings are also a good example due to the interest of the municipality in improving the liveability of the city. The Erasmus hospital, for example, houses one of the largest green roofs in Rotterdam (1324 m^2) as well as more additional flat roof surface. If converted to an urban farm it could provide leisure for patients as well as supply the local cafeteria.

Residential buildings or building complexes also provide a considerable surface for developing rooftop farms. Such initiatives can start on behalf of tenant associations, large housing corporation owners or individual house owners. The ownership matter is further discussed in the economical criteria section.

Water

As a developed city, Rotterdam has an extensive drinking water infrastructure which supplies the entire city. However, access to the drinking water network can

Map 6. Drinking water network

be very problematic in the case of open spaces. For an UA enthusiast, plots without easy access to water may seem unappealing because of increasing costs. Water access is a crucial issue especially for community gardeners which fund their own farm and are not so willing to invest in irrigation systems. Commercial farmers, on the other hand, aiming towards intensive, for profit crops, will be less sensitive to the issue[16].

Besides the drinking water supply, rainwater collection is a very relevant alternative, significantly decreasing costs for irrigation[15].

A very important issue faced by modern urban environments is linked to the sewage infrastructure and stormwater buffering capacity. Highly sealed areas (such as the city centre of Rotterdam, for example) are vulnerable to floods in high precipitation events, especially due to the lack of permeable areas or water buffers. Without a proper storage capacity, the sewage system can easily be overloaded during strong rainfall. Rooftop farms have been proposed as a solution since they retain water rather than direct it to the sewers[5,10]. These issues are covered in more detail in Paul de Graaf's report (5). Also, the permeability map (map 1) is also a good indication of where groundwater can be stored and where it cannot.

Economical criteria

Valuable information on the economical aspects of UA in the Netherlands is available in a recently published report (see reference entry 8) which covers overviews of existing and successful UA initiatives throughout the Netherlands in terms of their business models, funding, as well as qualitative resource flow charts.

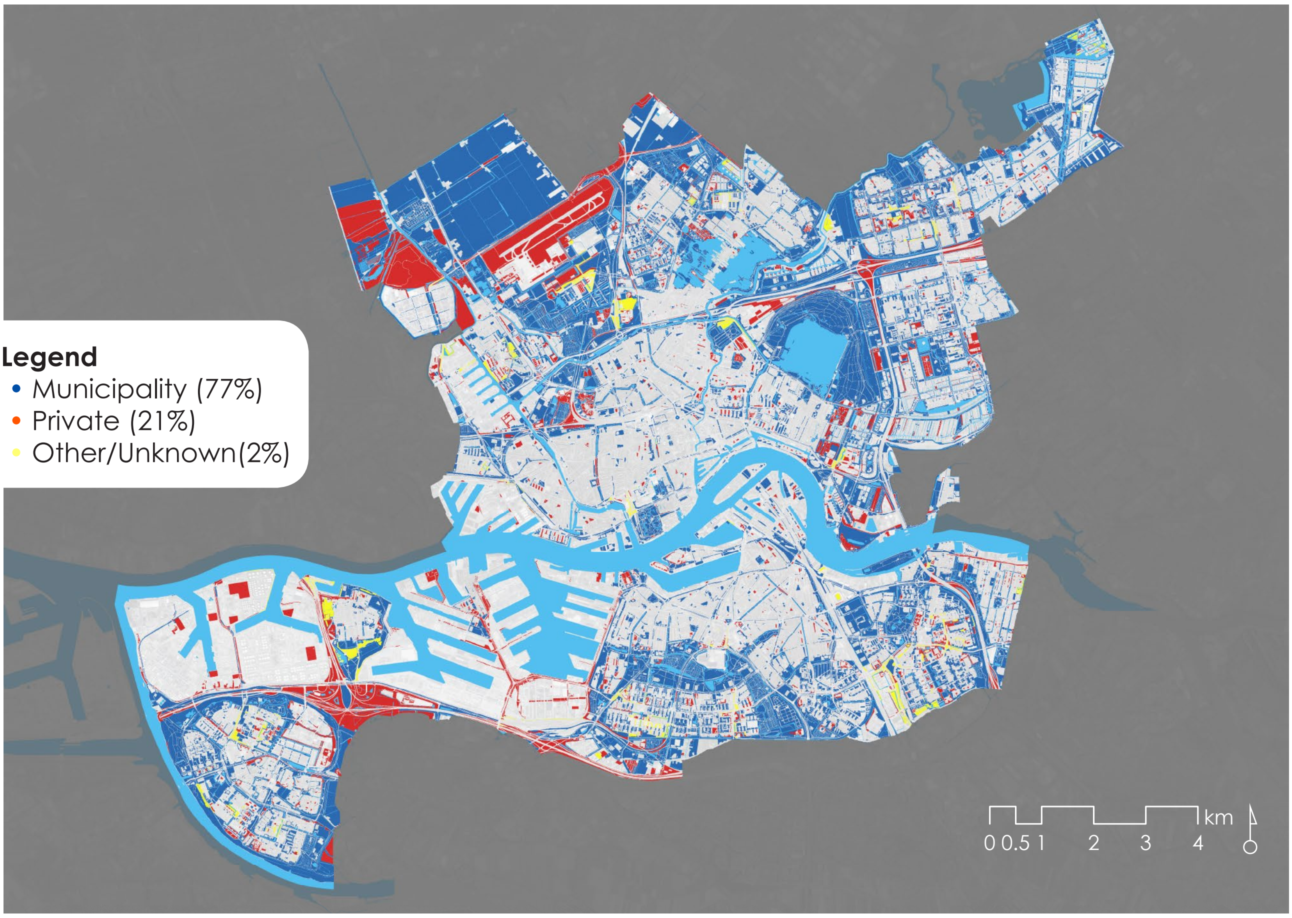
A very delicate issue linked to UA is funding. Funding for UA comes in very different forms, such as investments from family or friends, Non Governmental Organizations (NGOs), research institutes, philanthropic organizations, loans or private investments. In the case of community gardens, funding is mostly coming from the citizens involved in the initiative or interested parties. School gardens are usually funded by the government and commercial farms are privately funded[8,15].

Ownership

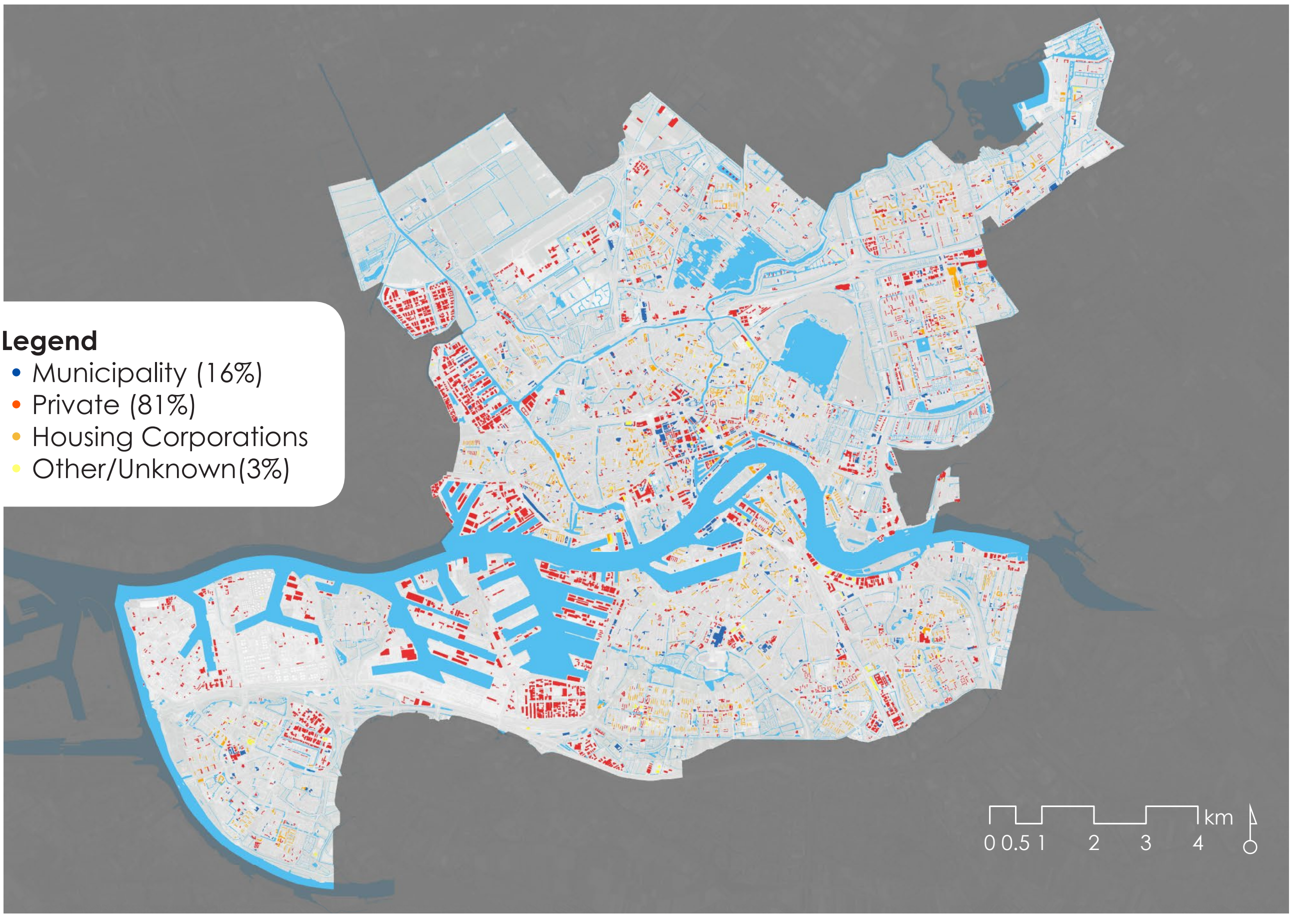
Naturally, the ownership of the land/building suitable for UA is a decisive factor towards the development of new urban farms. Whereas the majority of unsealed lands in Rotterdam are owned by the Municipality (77%) and covering 3540 ha, most suitable flat roofs are privately owned (81%), amounting to a total surface of 736 ha, of which 162 ha belong to housing corporations (maps 6 and 7).

In the existing political climate, urban agriculture is seen as a promising solution for solving many social problems that Rotterdam is currently facing. Alexandra van Huffelen, a city counsellor is fully supporting the growing trend[21]. However, due to the economic situation of the city, support does not come as funding, but only as aid in obtaining permits[22]. This seems to indicate that public buildings are not likely to receive any funding from the government in the near future, thus focusing the attention mostly towards private buildings. Many existing rooftop farms relied on approaching multiple individual owners until willing parties were found[15,20].

Housing corporations may also be willing to support UA initiatives. Hotspot Hutspot, a small scale initiative holding a restaurant and educating children from the neighborhood of Schiebroek has been supported by Havensteder and Vestia, two housing corporations in town (hotspothutspot.tumblr.com). Support in this case comes in the form of funding, but it may also allow residents to convert nearby grounds or rooftops into urban farms.



Map 7. Ownership of unsealed land



Map 8. Ownership of suitable flat roofs

Note: Private also refers to leased and rented properties that are partly owned by the municipality

Also, support might be more easily received from one actor owning an entire row of houses with flat roofs, for example, rather than multiple owners sharing a suitable flat roof surface.

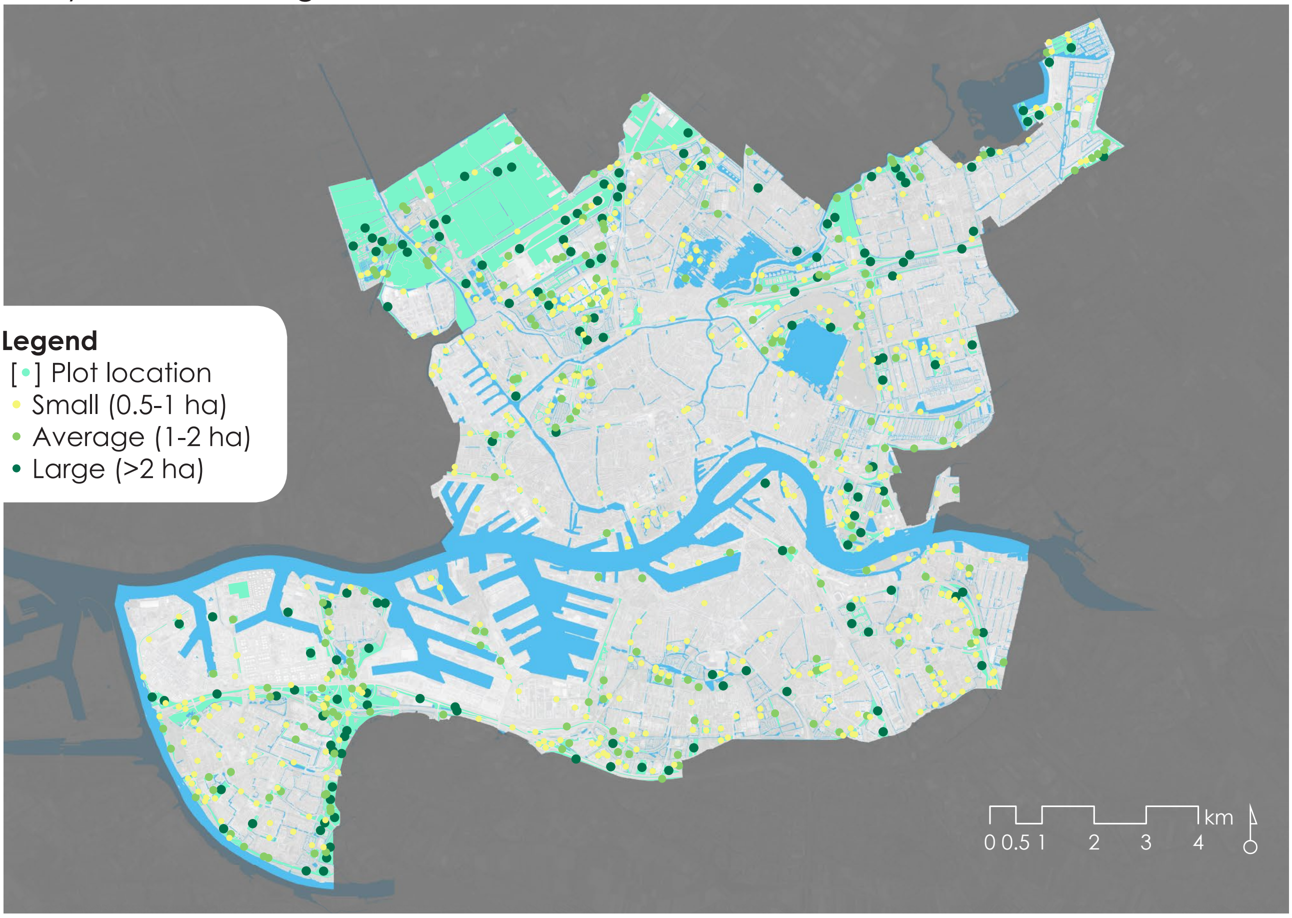
For assist with issues regarding the use of properties and land, Rotterdam municipality offers a universal **call service** accessible by phoning **14010**. For development on buildings the SO-Vastgoedbeheer (Real Estate Management office) must be contacted. Regarding land, the district administration (deelgemeente) is in charge until the 19th of March 2014. After that date, it is uncertain what institution addresses the issue, since the district administration offices will be dissolved[23]. Relevant information is available at: www.stadsmakelaar-rotterdam.nl, www.rotterdam.nl/contactvastgoed.

The extensive bureaucracy might discourage enthusiasts, since receiving authorizations is a lengthy process and the government does not participate financially. Subsidies for green roofs of around 45 euros/m^2 are currently available in Rotterdam, but they only apply to sedum green roofs (www3.rotterdamclimateinitiative.nl). Also, from 2014 these subsidies will cease to exist due to lack of further funding, and chances for UA subsidies to be put in place do not look promising[24].

Farm size

The size of the farm is a decisive factor towards production quantity, making larger initiatives more profitable than smaller ones. Regarding plots, farms smaller than one hectare are mostly socially driven, since commercial farms generally require more space[10,14]. Uit je eigen stad has a surface of 1.5 ha, which allows it to yield enough produce. Map 9 shows plots suitable for larger farms distributed around the city (mostly towards the outskirts). The suitable roofs' distribution and areas are shown in map 4.

Estimating production per ha, for example, is very dependent on the type of crop and local conditions, making it a



Map 9. Commercial farm suitable plot location and size

(grasslands & derelict lands > 0.5 ha)

very uncertain task. But here are some examples.

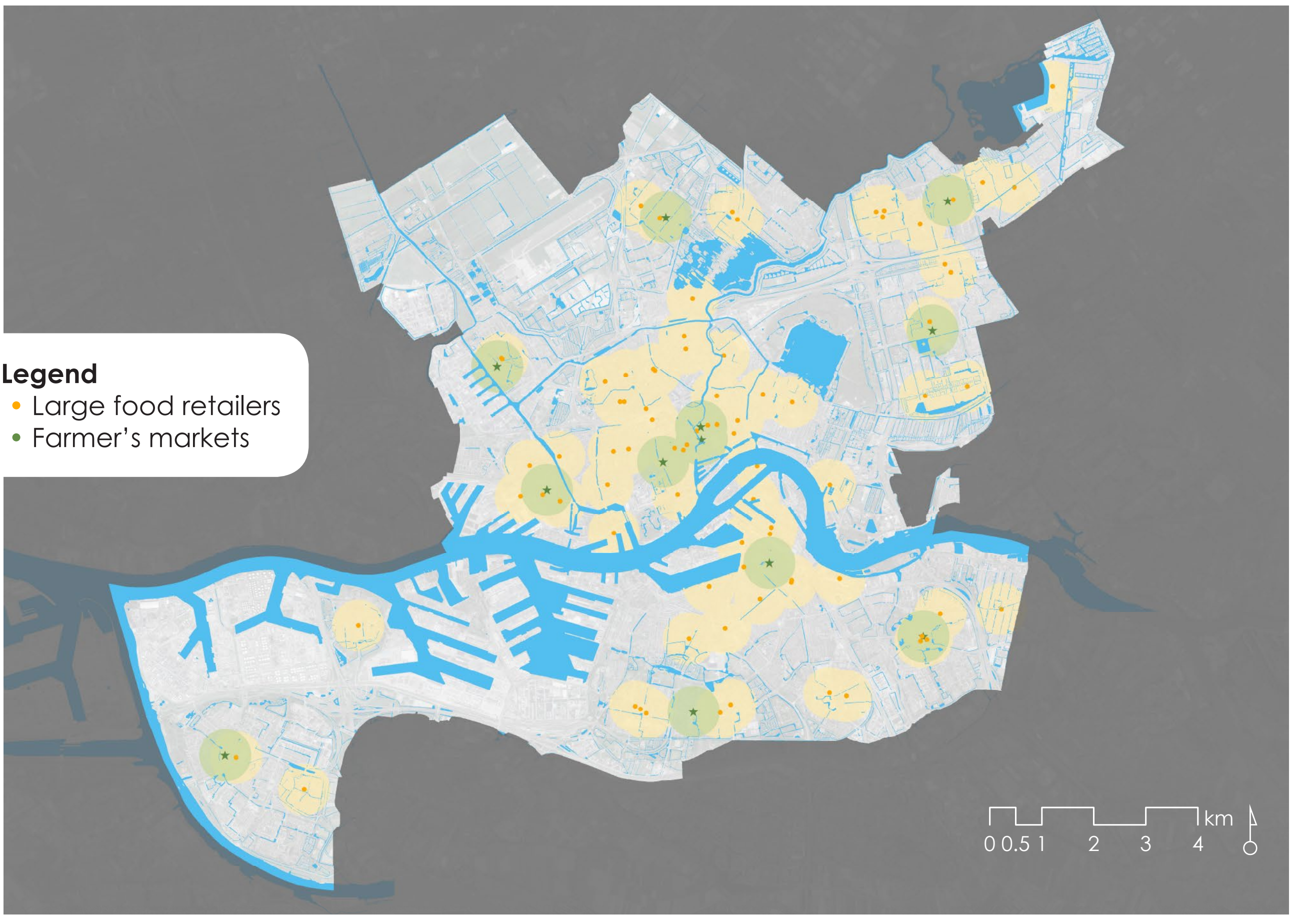
Although urban plots are considerably smaller than those available in rural agriculture, they can still be very productive. An example includes applying polyculture principles in greenhouse production. This implies growing multiple crops in the same space, taking advantage of biological and physical relationships between crops, much like permaculture practices, but with a focus on high value crops such as fruit trees in combination with berries, vegetables, mushrooms and herbs. Such systems take a few years to be fully established (around 4-5), after which they can be very profitable. An example of this design is said to produce 23 tons/ha of produce in the first year 46 tons/ha in the second year, 52 tons/ha in year 3 and from year 4 a stable yearly production of 56 tons/ha. Market values of such produce can amount to 150 000 €/ha (year 1) or 300 000 €/ha (year 4)[13].

SPIN farming initiatives in the US have also been very successful, amounting to profits of up to 150 000 €/ha per year using various crops (www.spinfarming.com).

Besides the large plots, small plots have enormous potential for developing small scale initiatives with a social orientation[15]. This is the case of school gardens, which can be placed either on the roof of the school or on a nearby vacant lot. Also, most neighborhood gardens are based on small plots scattered around the city. Plots suitable for these activities are visible in map 2.

Wholesale

If the main concern is profitability, the placement of a new urban farm is very important. Being in the market of selling food, the most potential locations must then have specific qualities. Although Rotterdam is not facing 'food desert' areas as large cities in the US where UA grew in popularity, there is still a large incentive for local food production[5,16].



Map 10. Locations of large food retailers and markets (including a 500m buffer)

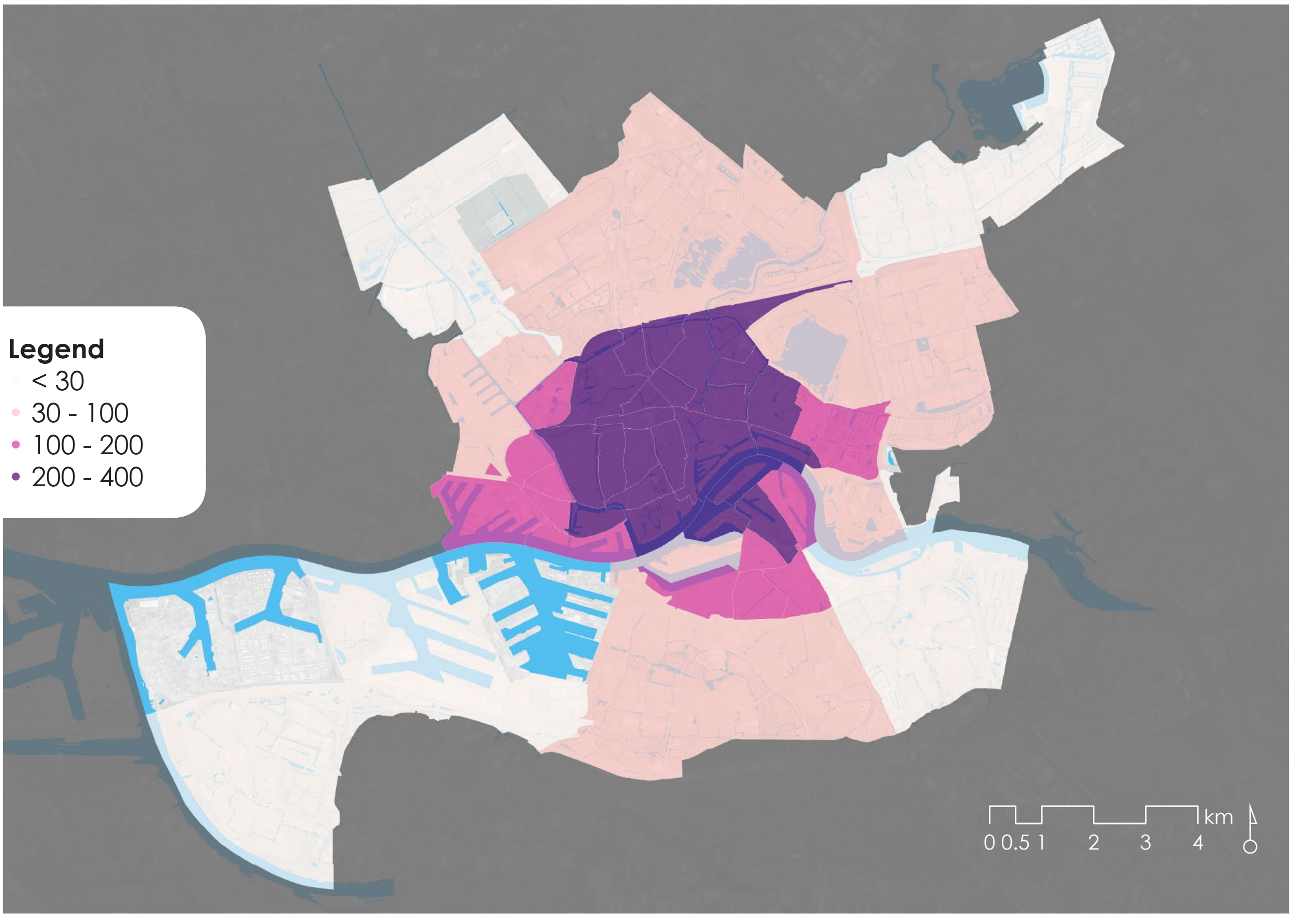
One example consists of areas where there is a shortage of fresh food. These can be roughly identified as areas without a large nearby food retailer or farmer's market. Areas with good access to fresh produce can be seen in map 8. Unfortunately, detailed data on locations of small shops, which are also a big part of delivering fresh produce, is not available.

Although areas without access to fresh food are very interesting for developing urban farms that distribute local produce, well covered areas are also of interest, as there is an emerging market for organic and high quality produce, which can be supplied through UA. Organic food shops are an obvious choice for selling the produce. Specialty products are very good in generating an extra income for the farmers as well as increase the diversity of produce available to the public[13].

Uit je eigen stad restaurant (Rotterdam)

In the case of food retailers, it is up to their willingness to support selling local food. A different alternative is selling it on site, as they do in the shop/restaurant of Uit je eigen stad in Rotterdam (which generates the farm's primary source of profit[14]).

It seems that finding customers for selling the produce of urban farms can be challenging without marketing knowledge. In New York, many community gardeners



Map 11. Number of restaurants within 3 km of neighborhood residents

struggle with selling their produce without the help of people with experience in sales or business[15]. Large scale farms such as the Lufa farm in Montreal or Uit je eigen Stad have well established distribution schemes which allow them to generate enough profit. Supplying restaurants is an important part of this distribution network, since chefs are interested in fresh and high quality products.

In map 11 areas with a good restaurant coverage are shown. There is a large demand for fresh produce, and areas with lower coverage could benefit from a boost coming in the form of UA linked with local restaurants.

In New York, several urban farmers organize markets, which is a very efficient way of getting noticed and selling their produce. Also, it is quite common to employ local residents to help on the market days[15]. Rotterdam could benefit from this approach, since the coverage of the farmer's markets is not so convincing and causes residents to travel larger distances to have access to such produce.

A different approach can be encountered on the Dakakkers in Rotterdam, where due to the existence of the rooftop farm, it is possible to rent out the room and kitchen adjacent to the farm for business meetings or social events, which generates nice profits[20].

Energy

Because farms are more profitable when they extend their growing season and also by producing non-seasonal crops, energy plays an important part, particularly in controlled environment agriculture. Energy requirements in greenhouses imply heating, lighting, ventilation or refrigeration. In greenhouse production, 90% of the energy requirements are linked to heating[25]. In the context of the horticultural region of Westland, heating

Map 12. District heating coverage

Note: The Hoogvliet area receives heat from the plant in Rozenburg, further west is mostly provided using natural gas burners, which is not sustainable and very dependent on the fluctuating prices of natural gas, which will be increasingly problematic[16].

An interesting option for urban greenhouse heating is the existing district heating network which, in Rotterdam, is supplied by three combined heat and power plants as well as residual heat from the port area. Such an option emits 50% less CO_2 compared to traditional gas heating. This comes at the price of about 0.09 €/kWh[26].

Heating a greenhouse using energy saving practices (efficient lighting, good insulation, using electricity meters etc.) and district heat can amount to 34 €/m^2 for intensive crops (peppers, tomatoes, cucumbers etc.) or 11 €/m^2 for extensive crops (lettuce, kale etc.) by using the district heat network available in Rotterdam (table 1, map 12).

An interesting alternative for heating greenhouses is based on heat storage. The principle is that heat gathered in the greenhouse or from the outside environment is stored during the day and released during the night, maintaining an adequate temperature for plants to develop and extend their production year round[27,28].

Heat can be gathered in solar collectors (from low tech painted barrels or metal sheets to highly efficient, specialized collectors) which is then stored in tanks (using water that can heat to up to 26^{0}C) that can be placed above or underground. It can then be distributed in the greenhouse through piping. However, not many commercial installations rely on solar as a primary heat source, as the technology is yet to develop in order to be competitive with fossil fuel heating[29].

Nonetheless, the practice has been proven successful and given the small plots available in today's cities, it is a very promising alternative. By choosing crops

Table 1. Yearly energy requirements for a greenhouse producing edible crops that uses energy saving practices[25]

	heat (kWh/m^2)	electricity (kWh/m^2)	total (kWh/m^2)
intensive	375	10	505
extensive	125	8	173

tolerant to colder weather, production can be extended year round (lettuce, spinach, chard, beet, cabbage, onion, carrot, peas etc.), since the stored heat system manages to maintain adequate conditions for the grown crops[27].

Others argue that with proper design, a greenhouse can be very productive even without heating or lighting inputs[13].

If the heating issue is sorted out, electricity requirements must still be addressed. In greenhouse production ventilation, irrigation and lighting must be addressed.

Earthen Path Organic Farm (Minnesota)[28]

Thermal banking by pumping hot air gathered in the greenhouse into an underground rock bed

Brooklyn Grange Rooftop Farm (NYC)[30]

Compost bins with solar powered ventilation

For soilless practices (hydroponics, aquaponics) electricity is required for pumping nutrient enriched water in the recirculating system.

Such electricity requirements can be fulfilled by solar panels, given the high potential available in Rotterdam. Map 13 only shows the potential available on the suitable roofs for rooftop farms. The data is based on the average potential in kWh per m^2 on each suitable roof.

The electricity requirements of a 1 ha greenhouse farm (according to table 1, of 100 MWh) can be fulfilled by covering most roofs visible in map 13 with solar panels. However, since the crop and panels compete for the same resource, the practices must be combined accordingly. For example, a large suitable roof can accommodate a greenhouse on part of its surface, while still having space for installing solar panels that power a hydroponic production system. Solar panels can be placed on nearby angled roofs (if available), therefore eliminating this issue. Map 13 is open to interpretation towards additional possible solutions for using solar power in urban agriculture.

However, if heat is to be collected, then larger roof surfaces are required. But for less demanding tasks such as ventilation or pumping, even small panels prove useful.

The Earthen Path Organic Farm in Minnesota uses two small solar panels to power a fan which pumps the hot air gathered in the greenhouse into the rock bed dug under the crops, which allows it to grow organic food all year round, and smart crop choices ensures a larger income due to off season produce[28].

The Brooklyn Grange, a rooftop farm in New York uses a small solar panel to pump air into the bottoms of four compost bins, accelerating the decomposition process of 11 m^3 of organic matter[30].

Another interesting fact is that grow-

Map 13. Solar power potential per suitable flat roof

ing plants on a rooftop in combination with solar panels can increase the efficiency of the panel by up to 35% due to the cooling effect generated by the plants. This has been tested using sedum, a common non-edible plant used on green roofs[31]. So this option would only be available for rooftop agriculture using soil and specialized crops which can develop without much sunlight. If a part of a rooftop farm is designed for this purpose, then energy can be generated for irrigation.

Solar power is therefore an interesting option for generating the energy required in UA. However, its price might discourage entrepreneurs and is probably the main reason why it is not widespread.

More information regarding the rooftop solar power potential for the entire city of Rotterdam will soon be available, as the municipality intends to make it publicly available[35].

Social criteria

Social aspects are of crucial importance within UA, since all initiatives are dependent on motivated and interested people for starting initiatives, maintaining them and spreading valuable knowledge. Urban citizens are also the recipients of attributed benefits, such as health improvements due to better food, exercise, water retention, air purification etc. Communities and individuals benefit through participation and increased cohesion, employment and empowerment. Children and young people benefit from education regarding food origins and environmental issues, which, in turn, will benefit future urban environments and future generations[1,8,10,15].

Income

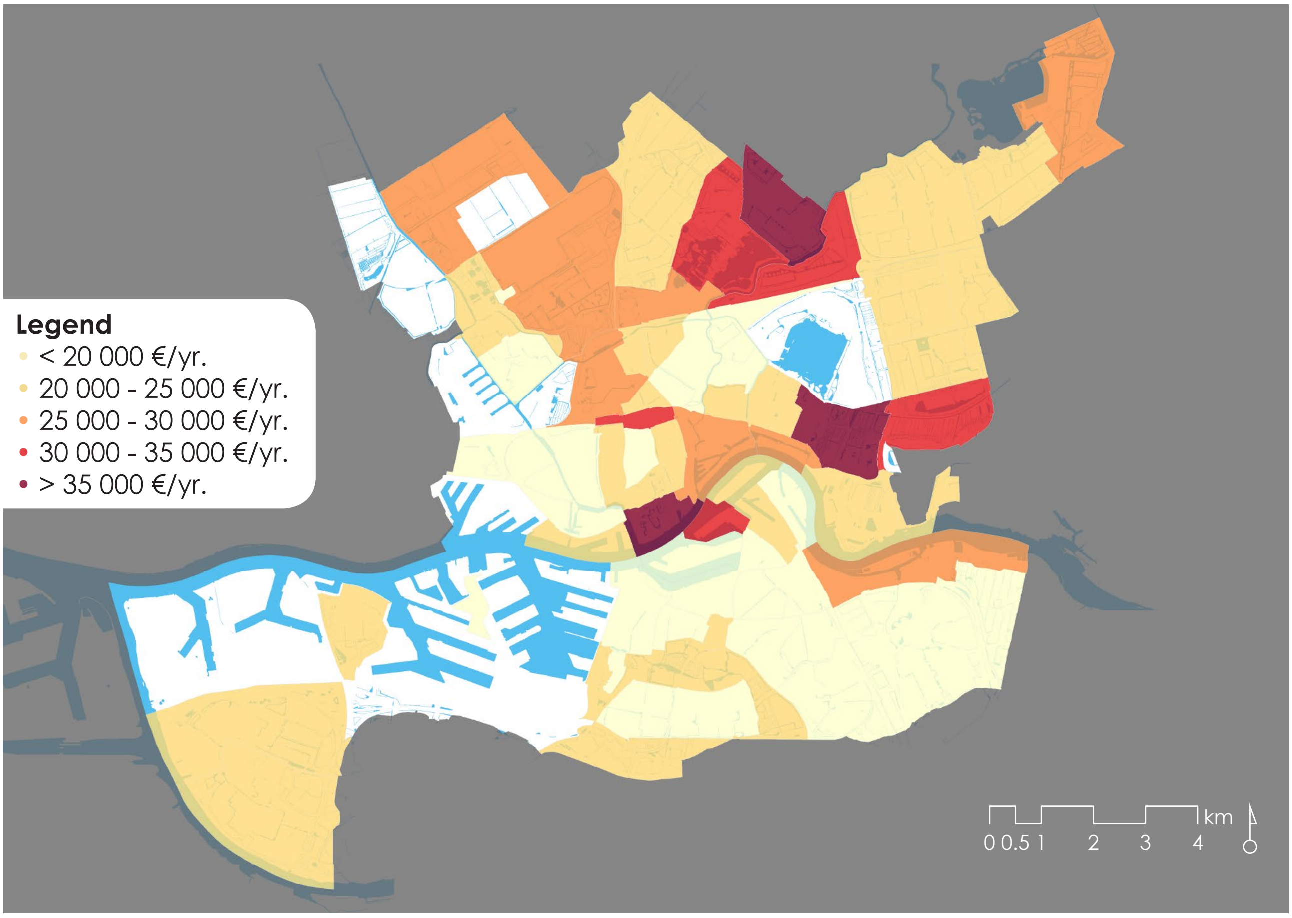
Income offers a first glance at problematic neighborhoods that could benefit from UA. Lower income neighborhoods are of main concern (map 14), since increasing the quality of life in those areas is an important goal within the municipal agenda. By improving the green infrastructure through the establishment of urban farms in neighborhoods such as Charlois, Feijenoord or Oud Crooswijk, communities can grow stronger. Also, the majority of community gardens in Rotterdam are situated in low income neighborhoods.

Proefpark de Punt, situated in Bospolder, another low income neighborhood, is a nice example. For the past 9 years it has provided local residents and their children with a recreational area and the opportunity of being involved and learning about gardening as well as gaining access to local and fresh food[32].

A different approach is that of the Rotterdam Voedseltuin (food garden), a social organization running an urban farm

Proefpark de Punt
community garden (Rotterdam)

Voedseltuin food bank farm (Rotterdam)



Map 14. Average spendable household income per neighborhood (2010)

Map 15. Dominant age group per block (2010)

(situated in Nieuw-Mathenesse) which distributes its produce to the nearby Rotterdam Voedselbank (food bank supplying the needy) as well as conducting reintegration programs for socially excluded individuals[33].

Such initiatives also support minority integration, which also benefits the urban environment. Another proposition would the be aimed towards community centres or other social integration organizations which could use UA as a tool for their practice.

Regarding higher income neighborhoods, they are seen both as initiators of such initiatives due to their better economic situation, as well as potential customers for local and organic food.

Age

Age is an important factor due to several reasons. Firstly, the education aspect concerning young people and food origins and environmental issues. Secondly, the need for recreation, exercise and a healthy lifestyle. Also, children and young people are seen as drivers and participants within the UA movement, which shapes their mindset towards a more sustainable future[10,15].

Seniors can also be important actors, as many of them enjoy gardening and social gatherings, which can be fulfilled through UA. Retirement homes, for example would be potential institutions which could run UA initiatives.

Education

As stated many times in this report, education is one of the strongest social benefits to be gained through UA. School gardens are part of the Dutch culture and have been an effective way of educating children. The public school gardens are slowly being shut down due to lack of funding, but gardens such as the Essenburgsingel educational garden and de Enk educational garden have been active for more than 70 years and will not be shut down.

Map 16 shows the locations of educational institutions with strong incentives to start UA initiatives. Private institutions such as kindergardens and after school centres are more likely to invest in such matters than publicly owned educational institutions, which at the moment seem to be on a tight budget.

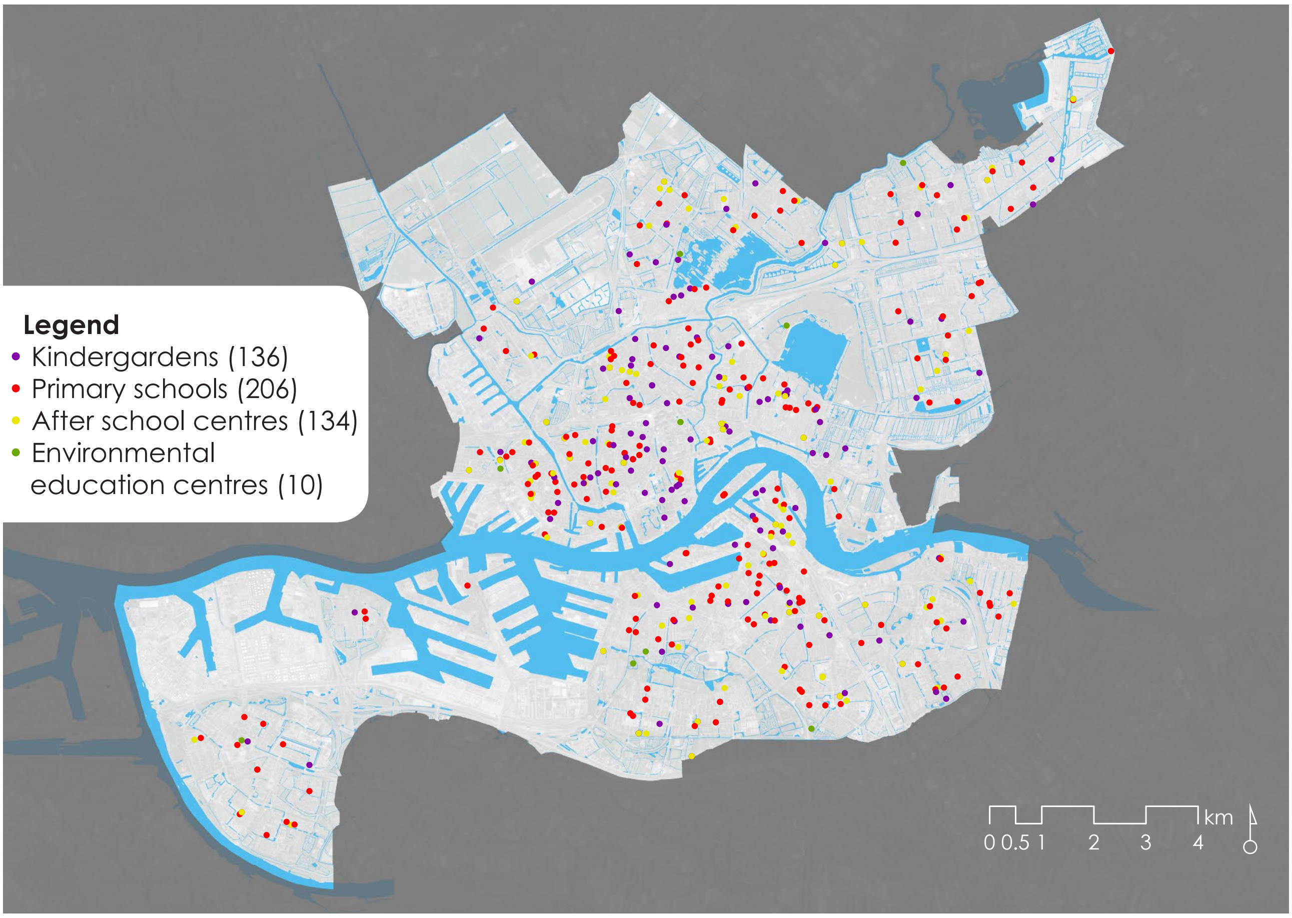
But well designed projects can gather funding nonetheless. Proefpark de Punt, for example, was nominated as the most child friendly project in the Netherlands in 2005[32].

Environmental education centres can easily include edible gardens as part of their curriculum and also engage visiting students in maintaining them.

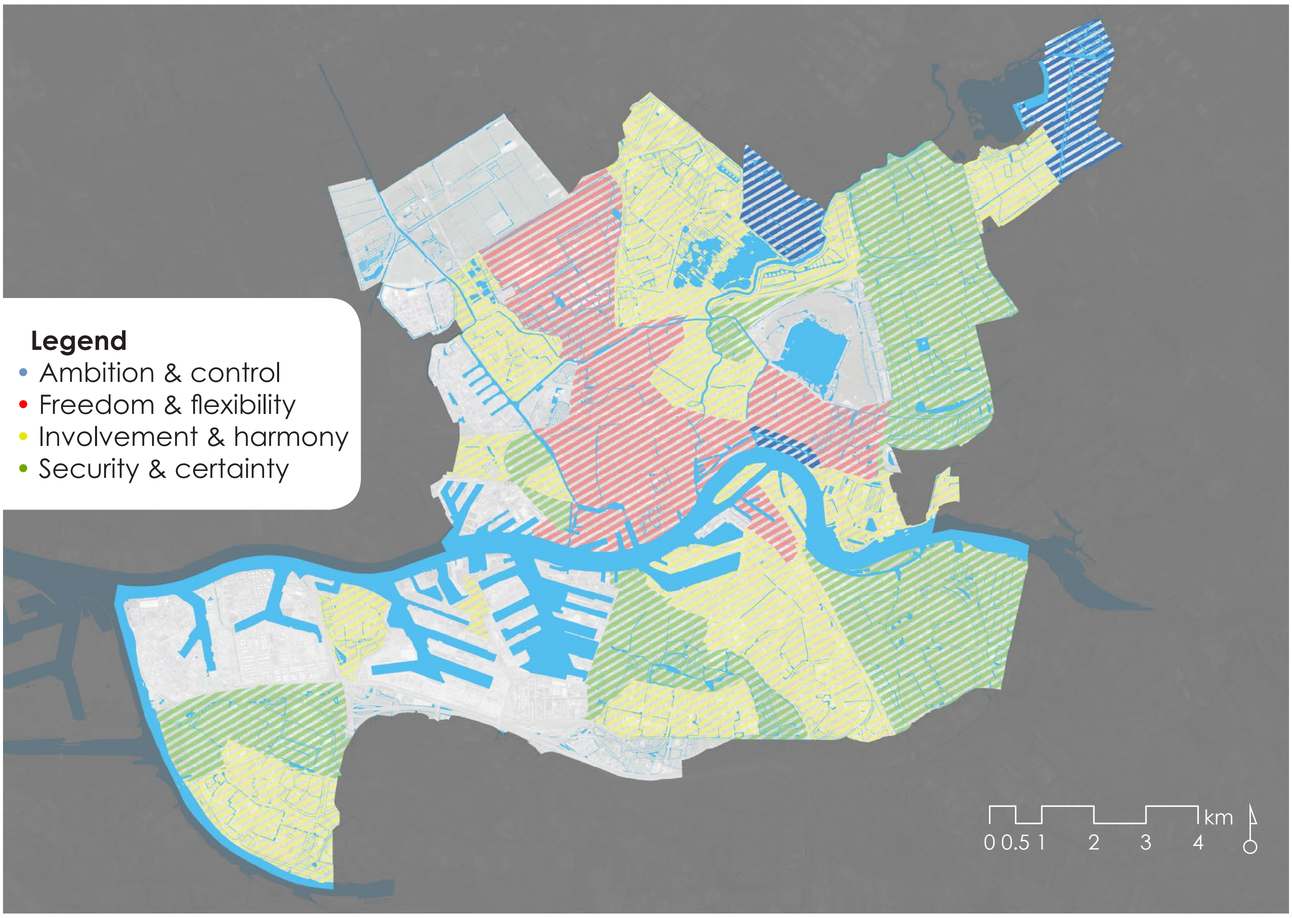
Map 16 is particularly interesting when related to map 15, as an indication of where the target groups for education are placed in relation to the institutions able to provide this service.

Gandhi Tuin community garden (Rotterdam)

Moestuinman community garden (Rotterdam)



Map 16. Institutions with an incentive to start urban farms



Map 17. Dominant lifestyle per neighborhood

Also, some existing farms (Moestuinman in Kralingen-West, Gandhi Tuin in Bergpolder or the Carnissesingel garden, for example) organize gardening and/or permaculture courses for UA enthusiasts as well as children in Rotterdam. So the educational function is not limited to the previously presented institutions, but a result of UA.

Placemaking & Lifestyle

An important concept linked with UA is placemaking. It regards the added value that UA brings to urban environments through community participation and also through generating public interest. UA projects promote activities that, by word of mouth and social media, gain momentum and more and more people get involved. This increases the intrinsic value of the areas containing urban farms, with the potential of also increasing the economic value through commercial activities linked to local food wholesale, restaurants and events[8,34].

Such is the case of Uit je eigen stad, which transformed a derelict land in the port area of Nieuw-Mathenesse into a vibrant farm and restaurant which is visited by many people from Rotterdam and beyond[14]. Also, in combination to the nearby situated Proefpark de Punt, Voedseltuin (which is adjacent to an outdoor art exhibition) and the newly built Dakpark (roof park), a rather dull industrial area is transformed into a more interesting recreational, cultural and food based experience which attracts more people.

An interesting approach to social research that is relevant for this research is linked to lifestyle. Behaviour is a valuable indicator for many purposes, ranging from targeting consumer groups, to policy and urban planning issues. Research on this topic has been conducted for the entire Netherlands, with data available on street level of the most dominating lifestyle type based on psychological and sociological criteria using method called Brand Strategy Research[36]. For producing these lifestyle maps data between 2006 and 2010 was compiled. Four lifestyle categories have been used in Rotterdam[37]:

- blue - ambition and control
- red - freedom and flexibility
- yellow - involvement and harmony
- green - security and certainty

Map 17 shows the dominant lifestyle type for each neighborhood. Such information can prove very helpful in the planning process of new UA initiatives, since these indicators offer insights towards which typology suits a certain lifestyle group.

For example, more high tech solutions such as rooftop hydroponics or aquaponics would suit a blue lifestyle, since they offer very controlled environments and require more skilled labour in order to be ran.

A red lifestyle would be more open to flexible solutions such as SPIN farming on small plots or exciting rooftop projects with strong links to vibrant and culturally driven events.

Neighborhoods with a dominant yellow lifestyle are prone to host successful community gardens with low tech practices such as permaculture and be mainly driven by volunteers.

A green lifestyle would suit urban farmers with an environmentally conscious attitude, relying on practices such as forest gardening or permaculture and spreading the knowledge to other enthusiasts.

Although this data is very vague, it has potential for guiding UA enthusiasts.

Additional considerations

Besides the presented criteria, other subjects should be touched upon. UA initiatives require many resources in order to be initiated. Obtaining physical resources such as soil, compost or setting up infrastructure (fences, tool storage sheds etc.) can be problematic for some enthusiasts[15]. Soil is of concern especially in today's urban environments due to lack of quality (fertility) and/or contamination.

A localized solution is the soil bank of Rottedam (grondbank), which stores and treats soil in various locations around town. They can be contacted at www.rotterdam.nl/contact_grondbank_rotterdam. And, of course, there are many sources for obtaining soil throughout the country.

Obtaining seeds or germinated plants can also be difficult in urban environments. At the moment there is only one shop that does this nearby the town centre (www.stekrotterdam.nl), and many initiatives in town sow their own seeds.

Security is also very important, as theft can be very problematic in UA, especially if the initiative is placed in a low income neighborhood. Many urban farmers in the New York city, for example, cannot produce to the maximum capacity of their plots due to theft[15]. With proper fencing, such problems are addressed, however fencing can prove to be very costly. In the context of community gardens, the largest investment is linked to fencing[15,16].

Nonetheless, smart solutions can be found. The municipality of Rotterdam's public works department (gemeentewerken) often stores old/unused equipment for infrastructure projects (which also includes fences) which could be offered to enthusiasts for free or a small sum. There are 9 public works offices in Rotterdam, and more information can be found at www.rotterdam.nl/gw.

Another cheap alternative would be to use organic waste such as pruned branches or twigs for building fences around the initiative's plot. Proefpark de Punt is using this approach.

Also, community gardens placed next to residential buildings tend to need less security enforcement, since they are very visible[16].

Rooftop initiatives are usually not subject to theft due to the limited access[10].

The public works department also has tree stock locations, which could be interesting for some UA enthusiasts in terms of obtaining organic matter for fencing or other purposes. Parks are interesting in this regard as well.

Sawdust for mulching (covering the soil near the planted crops to prevent weed growth) is another useful resource, from which UA initiatives such as Spoortuin or Proefpark de Punt have benefited already by receiving it free of charge from the municipality.

Many other supplies are required, and inventive solutions can be found in existing UA initiatives. There is a growing community of urban farmers which are sharing their knowledge and experiences. One of the most comprehensive sources is the City Farmer News blog (www.cityfarmer.info). More localized information can be found on the Eetbaar Rotterdam blog (www.eetbaarrotterdam.nl) or on the website of the urban agriculture network of the Netherlands (www.stedennetwerkstadslandbouw.nl).

Stek, local seed & plant shop (Rotterdam)

IV. Interpretation guidelines

Due to the large amount of mapped criteria, combining all relevant factors into potential maps based on the different UA typologies is a large task. Therefore the purpose of this research was to generate a tool that ensures access to the maps presented in this report in a more interactive way, which allows interested parties to access the information they see relevant for the development of different types of projects.

Because of the limited time and funding attributed to this research, the tool in which all maps are accessible more easily is available in the form of an interactive PDF (see Annex 1), as opposed to an online platform linked to Google Maps or similar software. Nonetheless, this is a good starting point and the data that had been gathered and generated is stored in a geodatabase which can be used by people with knowledge of GIS (Geographical Information Systems) and also made available online later on.

In the following section some guidelines towards possible ways of using this information are presented.

Typology driven

A first option would be to analyse the needs of each UA typology presented in the introduction and use the information stored in the relevant maps to identify the best locations for developing each type. Potential maps would then have different embedded criteria depending on the UA type. The number of criteria introduced in a potential map can vary widely, as well as the associated details. There are many ways of combining the data.

The orientation of the initiative, whether social, commercial or somewhere in between can also be hinted through various requirements. 4 examples have been shown in the scenario maps (S1 - S4).

These are extreme examples based only upon the data presented in the mapping criteria section, which still show many potential locations available for the different typology examples. The accuracy of these potential maps will obviously be increased by expert judgement as well as additional data of interest to the particular user. The CBS database (Central Bureau of Statistics), for example, is a very rich source of information which can be used as a valuable tool in combination to the hereby presented data.

Depending on the scope of the initiative, various additional data will be required and used differently in relation to the existing information, with more emphasis on either physical, social or economical criteria.

Spatially driven

Another approach would be to zoom in on an area of interest, say, a neighborhood, and identify which type of initiative would suit the needs or have the capability of improving the specific area.

Katendrecht has been chosen for this purpose due to the following factors (linked to the mapped data): a poor connection to fresh food wholesale on a local level, a low average income, a predominantly yellow lifestyle, mostly unsealed land with no contamination issues, large flat roof areas mostly privately owned, most suitable roofs have a medium potential strength, and there are educational facilities in the area (a primary schools and 2 kindergardens).

Scenario 1

A ground based, low income community garden involving adults and children from the neighborhood. SPIN farming is the main production type.

Requirements

physical

- space: max 5000 m^2
- land use: derelict, grassland
- soil: lightly contaminated at most
- water: easy access (5m)

economical

- ownership: public/private
- relatively low investment

social

- initiator's income: low/medium (< 30 000 €/yr)
- education: within 500 m to education facilities
- targeted age groups: <15, >65 and maybe others
- initiator's lifestyle: yellow, green

S1. Potential locations for community/educational ground based initiatives

Note: Green = all physical criteria, proximity to education facilities, initiator's income. Yellow = green criteria + lifestyle. Orange = green criteria + age group. Red = all criteria

Scenario 2

A rooftop based hydroponic community garden started by residents. Most of the produce is for the farmers, but part of it is sold to restaurants or shops.

Requirements

physical

- roof size: 500 - 1000 m^2
- roof strength requirement: low
- soil: none
- water: provided from the building

social

- initiator's income: medium (20 000 - 30 000 €/yr)
- age groups: 15-24, 24-40
- lifestyle: red, blue

economical

- ownership: private, possibly housing corporation
- electricity for pumping, small solar panel
- wholesale: close proximity to restaurants or other retail options
- medium investment

S2. Potential locations for small scale hydroponic rooftop projects

Note: Green = all physical criteria, proximity to retail and restaurants, initiator's income, age groups. Also, low electricity requirements make all roof suitable. Yellow = green criteria + lifestyle. Orange = green criteria + housing corporation ownership. Red = all criteria.

Scenario 3

Ground based commercial farm with 0.5 ha outdoor intensive production and a 0.5 ha greenhouse. The produce is being sold on site and also through a distribution network in town.

Requirements

physical

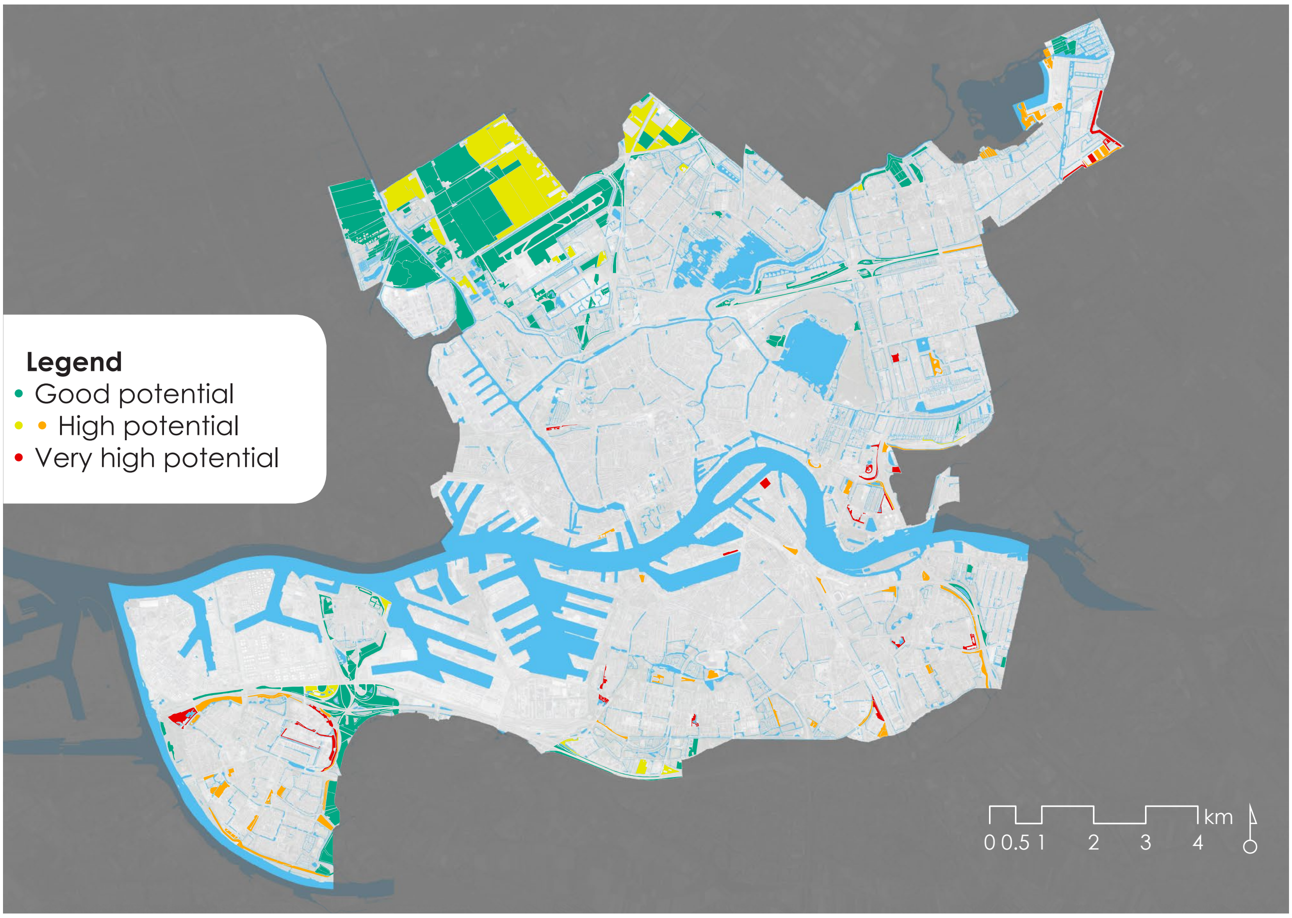
- space: min 1 ha
- land use: derelict, grassland
- soil: lightly contaminated at most
- water: costly access (100m) and/ or rainwater harvesting

social

- targeted income: medium, high (> 20 000 €/yr)
- targeted age groups: any
- targeted lifestyle: any

economical

- ownership: public/private
- district heating access
- access to roof for electricity generation (min 50 MWh potential)
- wholesale: sale on site and distribution network in town
- high investment



S3. Potential locations for ground based commercial farms with partial greenhouse production

Note: Green = all physical criteria, initiator's income. Yellow = green criteria + plots within 10 m of a building whose roof (not necessarily flat) has the potential of producing at least 50 MWh of electricity. Orange = green criteria + district heating access. Red = all criteria

Scenario 4

A commercial rooftop farm growing vegetables in a greenhouse using hydroponics. The produce is distributed to local supermarkets and restaurants.

Requirements

physical

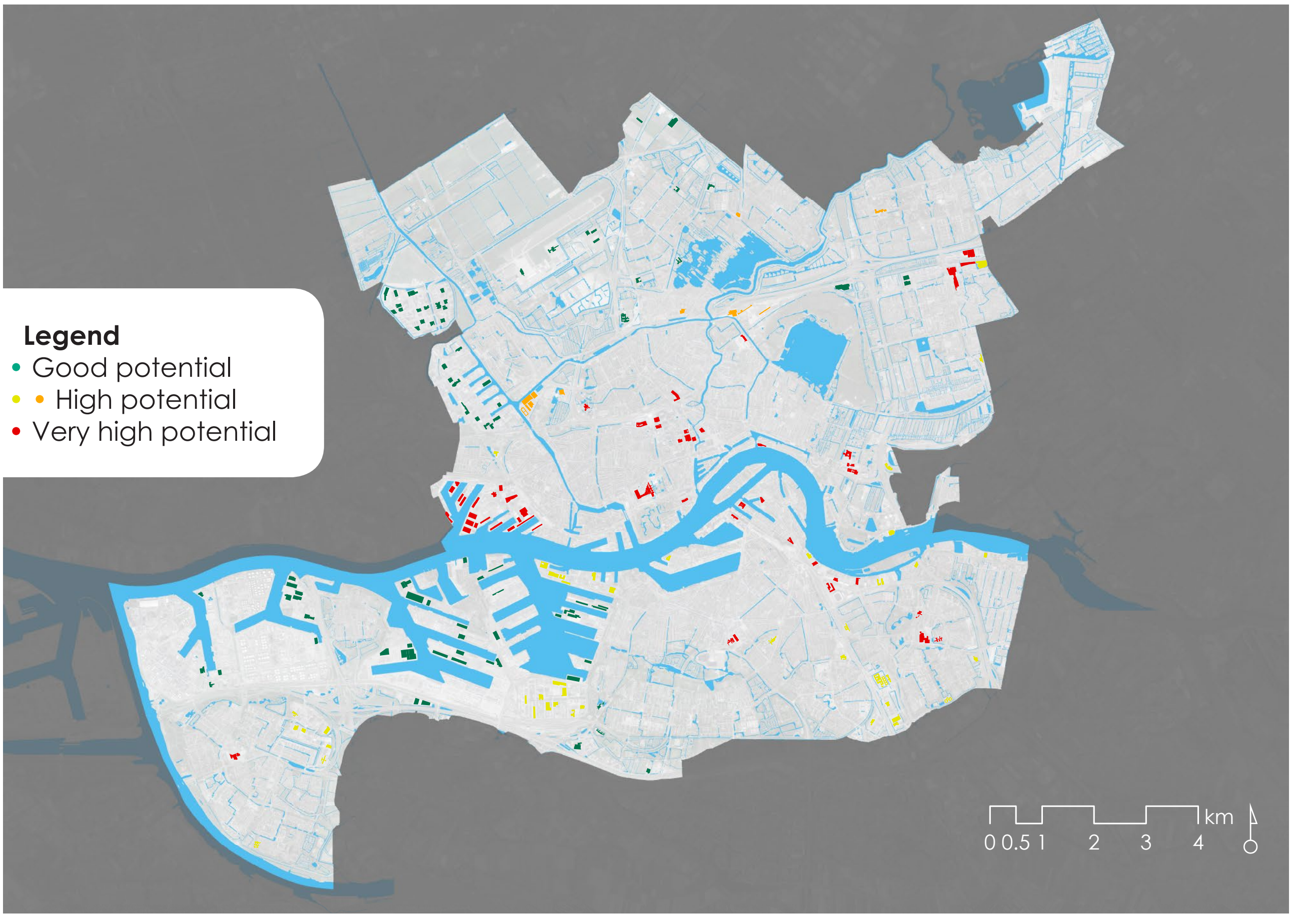
- roof size: min 0.5 ha
- roof strength: at least medium
- soil: none
- water: provided by the building and/or rainwater collection

social

- targeted income: any
- targeted age groups: any
- targeted lifestyle: any

economical

- ownership: private
- district heating access
- wholesale: supplies local supermarkets and restaurants
- high investment

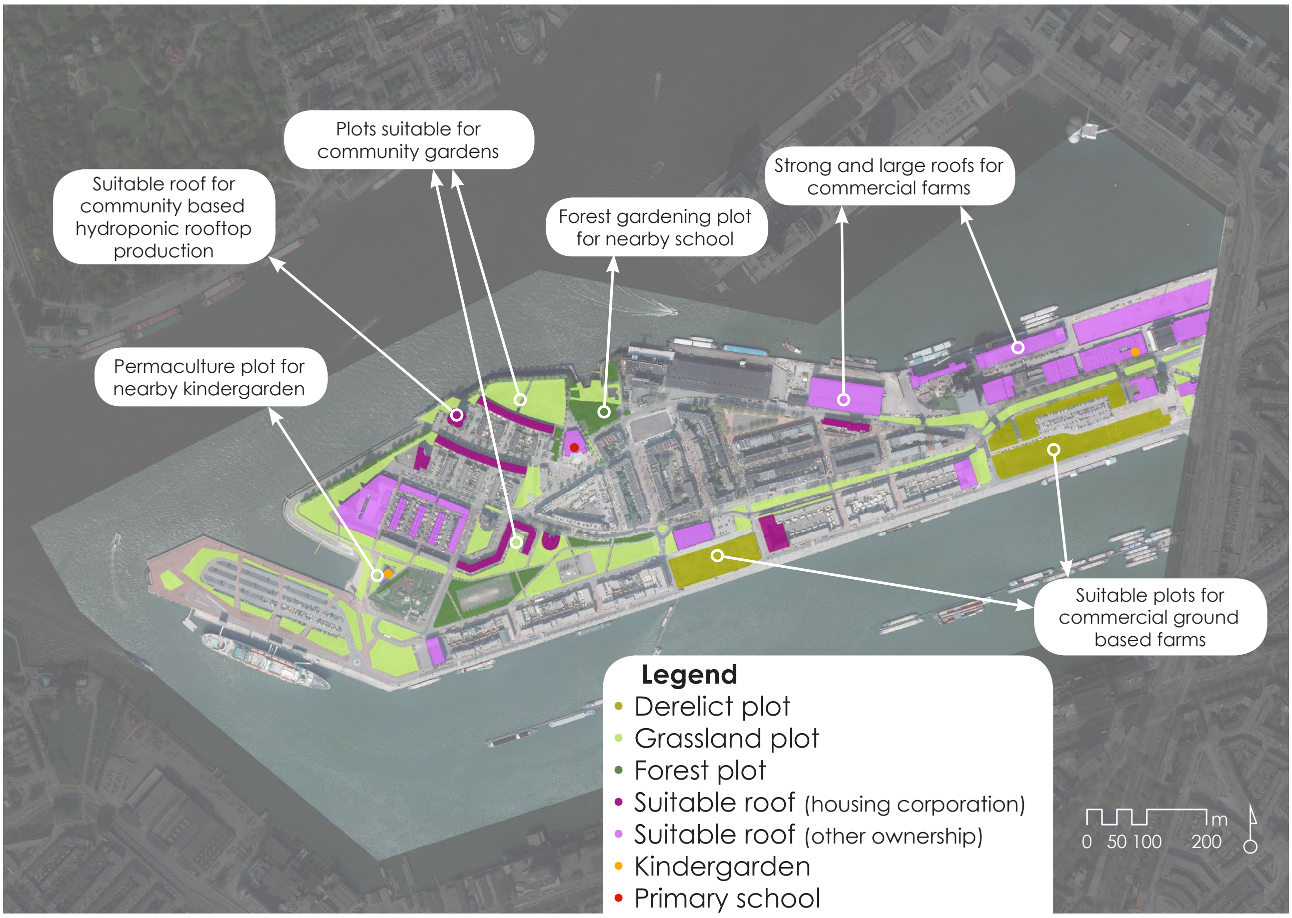


S4. Potential locations for commercial hydroponic rooftop farms in greenhouses

Note: Basic = all physical criteria, private ownership. Yellow = green criteria + district heating. Orange = green criteria + wholesale. Red = all criteria.

Many options are available due to the large number of plots with access to soil and promising roof areas. The yellow lifestyle is interesting for starting projects heavily reliant on participation.

The rather central positioning of Katendrecht is also promising for starting commercial projects that can supply shops and restaurants scattered throughout the entire city. Map S5 shows some examples of these possibilities on several plots available in the neighborhood. There are plenty of combinations possible given the local conditions, such as proximity to schools, available playgrounds, residential buildings etc.



S5. Possible options for Katendrecht

V. Final remarks and recommendations

The created database is a useful tool for parties interested in UA in the city of Rotterdam, as it can be used in many different ways and in combination to very diverse existing data. The information is very usable by entrepreneurs, research organizations, the city council, urban planners or mere citizens in order to further increase the interest in UA through starting more initiatives. An increase in the number of functions of existing green areas or derelict lands is a very important aspect for urban planning. There is a strong incentive for promoting recreation, healthy eating and exercise coupled with environmental awareness and education. Business opportunities arise due to the increasing interest in local food and brave entrepreneurs make the best of them.

As the information in this report requires higher education in order to be usable, an important next step is making it more accessible to people without higher education in order to increase social cohesion and possibly provide employment for sensitive social groups.

Also, a better tool than the interactive PDF should be developed, in order to improve the usability of the information to people without access to or knowledge of GIS (geographical information systems).

According to the gathered data, there is enormous potential for developing plots and rooftops throughout the city into UA initiatives. 3900 ha of areas with soil access and no problematic contamination as well as 906 ha of suitable flat roof structures are very large surfaces. For example, if 1% of this total potential surface (48 ha approximately) were oriented towards local food production, 1920 t of produce (plant based) could be produced yearly (considering a yield 40 t/ha, which can be considered average[13]) in a local and sustainable way. If 30% of the surface were used, 57 000 t could be produced per year, which could cause a serious impact in the city.

In order to build upon this research and increase the accuracy of customized potential maps, more criteria should be found/researched and accounted for. Examples include:

Physical: soil fertility (or content of organic matter, clay etc.), sources of organic matter for composting purposes around town, rainwater availability, heat island effect, areas vulnerable to flooding events etc.;

Economical: networks of local food distribution in Rotterdam, access to fresh food (a more detailed map), solar potential on plots, alternative options for energy generation etc.;

Social: residents without proper access to recreation, the health situation per neighborhood (and a link to physical activity), higher education ratio per neighborhood, environmental awareness etc.

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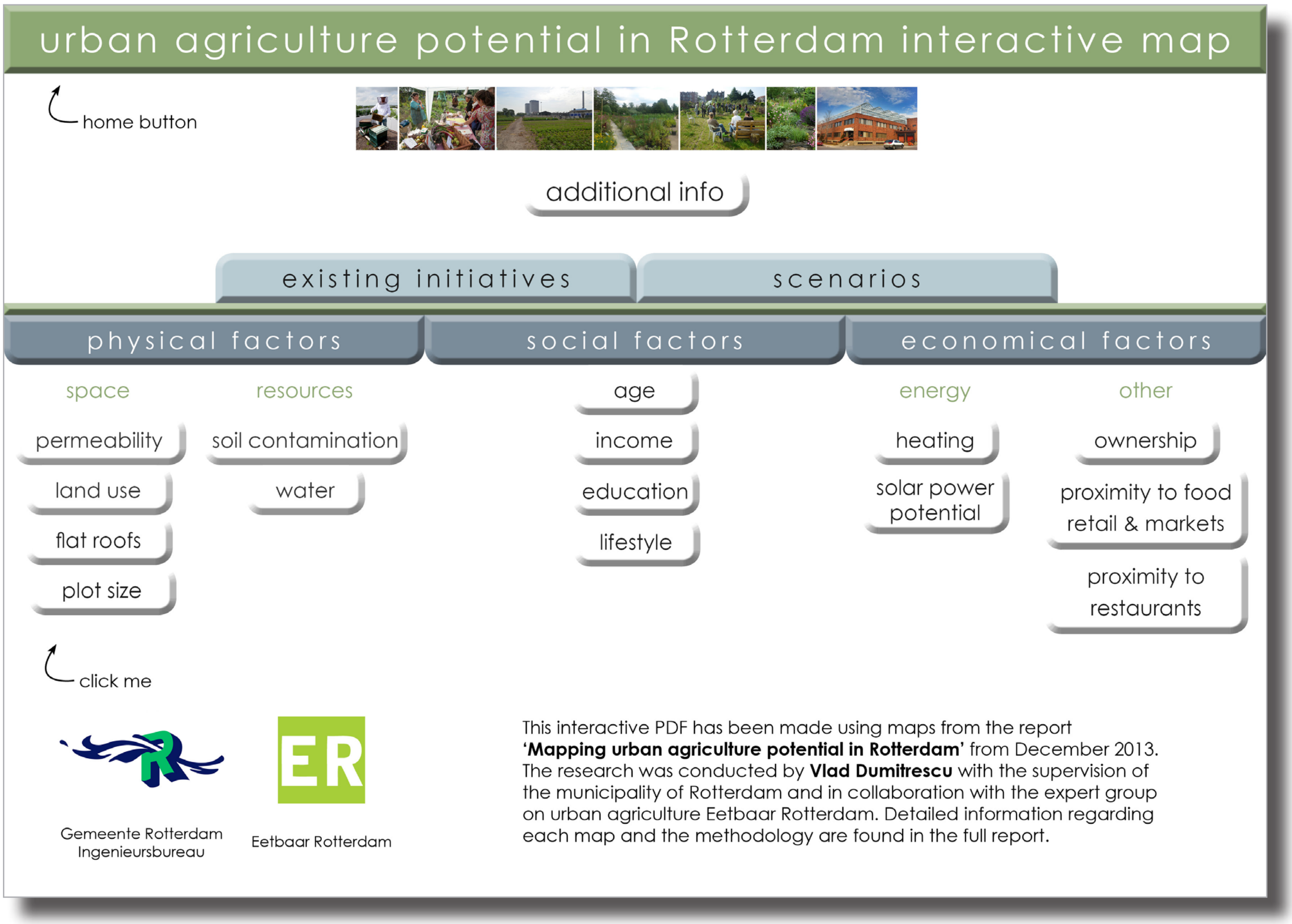
Appendices

Annex 1. Interactive map

An overview (snapshot) of the layout of the interactive PDF.



Annex 2. Methodology

The data used for creating the maps shown in this publication has been obtained from the municipality of Rotterdam (MR), unless mentioned otherwise.

Basemap

For the basemap an aerial photograph covering the South Holland region has been used with a very high transparency. The administrative boundary was cropped from the cadastral boundaries of the MR so that it covers the city with the most western point being the town of Hoogvliet and its attributed port area. A carved square shape has been set to overlap the outskirts of the boundary.

Map A. Urban agriculture initiatives in Rotterdam

A shapefile containing UA initiative locations in point form has been obtained from Arjan Aaftink of DCMR Milieudinenst Rijnmond, with the farm locations and information gathered by Ariane Leliveld and Ans Stolk of Eetbaar Rotterdam. The allotment complexes have been shown from the KBK dataset (explained below) as well as the point locations of the urban farms.

Map 1. Permeability of urban areas

The main file used in this has been the KBK layer from MR. The KBK and 'Klasse_1' fields have been used to determine whether the land was sealed or not. A field named 'Permeability' was created. Grasslands, forests, shrubberies, derelict lands and other similar types have been considered as unsealed. Real estate and industrial areas have been considered partially sealed due to the unavailability of land use indications (MR only holds data on public areas). Sealed areas have been regarded as buildings, roads, paths as well as parking lots. Train or tram lines have also been regarded as sealed due to the lack of access and irrelevance of unsealed area percentage. Values such as 'Unsealed', 'Partially sealed' and 'Sealed' were included in the 'Permeability' field as described. Note, the buildings were not contained in the KBK shapefile, and thus have been removed using the erase tool based on the building footprint file of the BAG (Bevat de Geometrie) dataset.

Map 2. Unsealed area land use

The KBK shapefile was used. A field named 'Land_use' was created in order to narrow down the options available in the 'KBK' and 'Klasse_1' fields. More general criteria such as grasslands, forests, derelict areas and allotment gardens have been used.

Maps 3. Soil contamination (0-1m) of unsealed areas

The map containing the soil contamination of the top metre has been used (IBK_bodemkwaliteit 0 tot 1m-mv_2009). Firstly, the KBK shapefile and the 'BKW_L1' field of the soil contamination shapefile were spatially joined (ArcToolbox spatial analysis tool). For the display of the unsealed area soil contamination a definition query has been set to only display unsealed areas. Further, the 'BKW_L1' field has been shown in the symbology tab of the KBK layer file.

Map 4. Suitable flat roof locations and areas

Firstly, a map containing all the buildings of Rotterdam from the BAG dataset was obtained. This was used as a template that was spatially joined with different datasets in order to contain all the required information (building height, function, age, solar power generation potential per m^2).

The GBKvlak_gebouw_GemHoogteTovMaaiveld.shp file (containing the building shapes plus heights) was used to spatially join the building height relative to the ground level. Buildings higher than 40m have been deleted.

The BAG_functie.shp file of the BAG dataset was used to determine the function of the buildings. A field named 'Function' has been created based on the 'gebruikedo' field, containing the main use of each building, classifying the values as: 'residential', 'industrial', 'office', 'commercial', 'education', 'healthcare', 'recreation' and 'other'. The newly created field has then been spatially joined with the building shapes using the JOIN_TO_ONE function. The value 'other' has been assigned to buildings without available data, and buildings in known industrial or residential areas have been edited manually. This dataset can prove inaccurate, as many buildings have mixed functions.

The building age has been spatially joined from a shapefile of the BAG dataset containing the field 'Bouwjaar'. Further, the field 'Age_POT' (age potential) has been created which categorises buildings built between 1950 and 1969 as having a 'low' potential, between 1970 and 1989 'high'and after 1990 'medium'. Buildings older than 1950 have been deleted.

In order to keep only the flat roofs, the BAG_ZON_RDAM.shp was used. It contains the solar power potential per m^2 as well as the field 'DAKTYPE' (roof type), which characterises roofs as flat or sloped. Sloped roofs have been deleted. The flat roof map has then been spatially joined with the file containing the building shapes as well as all the additional data. Then the Dissolve tool has been used to create singlepart shapes with unsplit lines based on the height field. This has generated a shapefile for which shapes of surfaces smaller than 500 m^2 have been deleted. This shapefile has been used to calculate the roof surfaces in Map 4. A graduated symbols symbology has been chosen to show the various available combined roof surfaces of the same height around town.

Note: the major limitation of this data is the fact that the footprint of the building is being regarded as identical to the roof area, which is in many cases false and makes the height analysis faulty in some cases.

Map 5. Suitable flat roof potential strength by age & function

With the suitable areas available after dissolving the roofs by height, the function and age characteristics had been lost. To regain them, the dissolved roofs were intersected with the undissolved shapefile containing all the required information. The resulting shapefile, named flatroofs_full.shp, contains the correct total area of suitable flat roofs as well as information on age, height, function and solar power potential per m^2. A field named 'Strength' was created, to which the following values were attributed after adequate selections: 'very high' (for shapes built between 1930 and 1959 that had a different function than residential), 'high'(for shapes built between 1930 and 1959 that had a residential function; for shapes built after 1990 with an industrial function), 'medium'(for shapes built between 1960 and 1989 that had a different function than residential or industrial; for shapes built after 1990) and 'low'(for shapes built between 1960 and 1989 that had a residential function). The 'Strength' field has then been shown in the symbology.

Note: This map is only indicative, as in many cases the function is not very accurate. However, due to the strong relation to age, only a small difference in strength potential will be shown (i.e. between low and medium or between high and very high).

Map 6. Drinking water network

A file containing the underground pipe infrastructure named LVZK_NET_BUIS.shp was used. Under the 'Product' field, 'drinkwater' had been shown. To this data a multiple ring buffer proximity analysis was conducted, with one ring of 5m and one of 100m. The buffers were then shown in the symbology.

Map 7. Ownership of unsealed land

For the ownership information, the eigendomkaart.lyr was used, specifically the 'EXPCODOMS' field, from which values were grouped into a more simple classification of 'municipality', 'private' (not municipality or leased/rented) and 'other/unknown' through the creation of a field named 'Own_simple'. This file has then been intersected with the KBK layer with a definition query set to only show unsealed areas. The 'Own_simple' field has been shown in the symbology of the newly generated shape after the intersection.

Map 8. Ownership of suitable roofs

The ownership file was intersected with the suitable flat roof file and the 'Own_simple' field has been shown in the symbology of the newly generated shape after the intersection.

Map 9. Suitable plot location and size

The modified KBK file used in the making of maps 1-3 has been further modified in order to locate more suitable plots. Firstly, a negative buffer of 3 meters was conducted to remove very small and/or narrow areas. Secondly, a positive buffer of

2 meters was done after the negative buffer, thus restoring the shapes to a certain degree and also eliminating 1 metre of the edge of the plots, which are most likely unusable. Sports fields were also deleted using the erase tool and a shapefile containing the locations of sports fields named EDT_ROTTERDAM.shp. Also, plots smaller than 5000 m^2 were deleted. Only plots with 'derelict' or 'grassland' land uses were kept. Then the plot locations and areas were shown according to the intervals visible in the legend. The aim was to locate large enough areas for establishing commercial farms.

Map 10. Locations of large food retailers and markets (including a 500m buffer)

For the locations of markets, the addresses were taken from the website of Rotterdam Municipality. For large food retailer locations, addresses of supermarkets in Rotterdam have been obtained from the following retailers: Albert Heijn, Jumbo, Lidl, Plus and Bas van der Heijden. The addresses have then been introduced in Google maps and saved as point features, which were later exported as a kml file. The kml file was then imported in ArcMap by conversion to a shapefile. Because the data obtained from Google maps was in a different projection than the rest of the data used in this analysis, the Project tool from ArcCatalog was used to project the imported shapefiles in RD_New. After the points have been imported and projected, a 500 m buffer has been applied.

Map 11. Number of restaurants within 3 km of neighborhood residents

The data was obtained from CBS (Central Bureau voor de Statistiek). A shapefile on the neighborhood level was obtained from www.cbs.nl containing data from 2011. Values from the AV3_RESTAU field, containing the number of restaurants within 3 km of all residents in one neighborhood were imported for the neighborhoods suitable for this study and shown.

Map 12. District heating coverage

For this map, the stadsverwarming.shp file was used. The value 'wel' from the 'STATUS' field was shown in the symbology. The points with plant locations were added later on as shapes in the written report.

Map 13. Solar power potential per suitable roof

When the suitable roofs were dissolved by height, a statistics field based on the solar potential in kWh per m^2 was added, calculating the MEAN. This ensured that the resulting shapes retained the information for the solar power potential. In order to obtain the potential for the entire roof, the potential value per m^2 was multiplied by the shape area. The newly generated field, containing kWh potential per dissolved roofs was then shown.

Map 14. Average spendable household income per neighborhood 2010

The data was obtained from CBS via the www.rotterdamincijfers.nl portal. Average income per neighborhood data was exported as an .xls file and then imported and joined with a shapefile containing all the neighborhoods in Rotterdam. The values shown represent standardized spendable income average per year for each neighborhood.

Map 15. Dominant age group per block 2010

The age data was obtained from RM in the form of a shapefile containing the number of inhabitants within a certain age group (intervals viewable in the legend of the map) per block, from which the dominant value was extracted and shown. This data is considered sensitive and only the per block level can be made public.

Map 16. Institutions with an incentive to start urban farms

The file named voorzieningen.shp containing locations of different facilities throughout Rotterdam was used. The values of the field 'TYPE_OMS' containing the locations of kindergardens, primary schools (basisscholen), after school centres and environmental education centres were shown.

Map 17. Dominant lifestyle per neighborhood

Data was obtained as percentages for each lifestyle type (red, blue, yellow, green) per neighborhood in an .xls file from Wim van der Zanden of MR. A new field was created containing the name of the lifestyle type with the highest percentage per neighborhood. This is how the dominant lifestyle per neighborhood was determined. The .xls file was then imported and joined with the shapefile containing neighborhoods and the lifestyle data was shown accordingly.

S1-S4. Typology based scenario maps

For the making of the typology based scenario maps the criteria presented in the text of the report adjacent to the maps have been used. The modified KBK file containing all the mapped information regarding plots has been used for the ground based scenarios (S1 and S3) as the basis for the spatial requirements. Then additional fields have been created based on the social or economical criteria after suitable selections (intersection with coverage areas for factors such as wholesale, income, lifestyle, water coverage and so on). The suitable flat roof file has been used to account for the spatial requirements of the rooftop based scenarios (S2 and S4) and the same approach has been used to identify the roofs with additional characteristics based on the other criteria.

For each scenario a new shapefile was created containing information regarded as basic (which differs for each scenario; details in the notes under each scenario map). Fields have been created for two additional criteria that are not fulfilled in the basic requirements. This is a way of highlighting good, high and very high potential spots for the different typologies attributed to each scenario. A good potential spot only fulfils the basic criteria. A high potential spot has only one additional criteria, and the very high potential spots cover the basic requirements as well as the two remaining criteria.

S5. Possible options for Katendrecht

For the spatially based scenario approach the KBK and suitable roof data were trimmed using the extract tool. The data was extracted using a drawn shape that only covered the surface area of Katendrecht. Then, quite straightforward, the plot land use, a simplified ownership of the suitable roofs (housing corporation owned or other) and the education shapefile (with locations of institutions) were shown. Also, there was one plot which contained contaminated soil. It has been deleted. The other shapes with potential locations for specific initiatives have been added later on in the text editing software.