A methodology to select the best locations for new urban forests using multicriteria analysis

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Summary

In densely populated and sparsely wooded areas, the creation of urban forests has become an important objective of a responsible social policy. This policy framework is based upon the experience gained over recent years from carrying out several feasibility studies for large-scale afforestation projects in Flanders, Belgium. Whilst conducting these studies, a methodology was developed which selected the most suitable and feasible locations for the establishment of large urban forests, with a view to achieving the highest chance of successful implementation. This methodology is a step-by-step multicriteria approach with three stages: (1) the **excluding stage**, which uses excluding criteria leading to a number of locations potentially suitable for afforestation. These are called 'potential locations'; (2) the **suitability stage**, which tests the potential locations on their suitability, leading to the selection of a limited number of (theoretically) 'most suitable locations'. Three groups of criteria are used for this selection, related to the potential for (a) recreational quality, (b) structural strengthening of the landscape, and (c) ecological quality. This is followed by (3) the **feasibility stage**, where the most suitable locations are then tested for their feasibility. Initially, these locations are analysed for possible conflicts with other types of land use; the three main criteria used for this selection being (a) their acceptability by the agricultural sector, (b) their appropriateness for nature conservation and landscape protection and (c) their compatibility with urban planning. Where several 'most suitable locations' have a similar acceptability score, the final choice of the location of the urban forest is determined by opportunity criteria – defined primarily by the potential for the immediate realization of the afforestation project. As a result of the three stages of the multicriteria analysis, the most suitable and feasible location(s) are selected for further political scrutiny prior to implementation.

Introduction

A number of scientific and policy studies carried out over recent years in Flanders, Belgium, have placed emphasis on the importance of creating new urban forests in densely populated and sparsely wooded areas. The Land-use Structure Plan of Flanders[1] and the Long-Term Regional

Forest Plan[2] both include the creation of large (recreational) forests near urbanized areas. Flanders is a region with more than 400 inhabitants km^{-2}, but with very little forest cover (<10 per cent of the land area). It is therefore important that, with respect to the establishment of new forests, major attention should be paid to the creation of urban forests with a significant recreational function.

The Provinces of West and East Flanders are the most sparsely forested provinces of Flanders, with an almost negligible woodland surface area of 2.2 per cent and 4 per cent, respectively. Moreover, only a limited part of this forested area is accessible to the public, which means that the stress caused by outdoor recreation on these accessible forests is unacceptably high. It would seem highly desirable, therefore, to create new, large-scale urban forests in these provinces, so that the recreational impact on the existing forest can be reduced, whilst at the same time maintaining a satisfactory level of forest recreation facilities.

With this in mind, the Regional Government of Flanders, together with the provincial authorities, initiated a number of studies to investigate the potential for afforestation in East and West Flanders, and the feasibility of creating new, recreational urban forests. The ultimate objective was to create a number of urban forests of between 300 and 500 ha for the urban districts of Ghent, Kortrijk and other towns. These studies had a dual task: first, to locate the most suitable sites for the creation of these urban forests through a systematic and scientifically sound approach; and secondly to examine the feasibility of afforesting the selected sites in the near future.

The Government considered these studies to be a pilot project, leading to the formulation of a successful methodology for the realization of similar projects in the neighbourhood of other cities. During these studies, the methodology was progressively improved. This article reports on the most recent approach, which has been followed during the site selection for an urban forest for Ghent, a city of some 250 000 inhabitants. This paper describes a methodology that was developed to select the most suitable locations for the establishment of new large urban forests, a prime consideration being the potential for early successful implementation.

Profile of the urban forest

There is, at the moment, no agreed definition of the term 'urban forest' in Europe. Definitions can include urban parks and green belts or forests of thousands of hectares on the perimeter of big cities. Similarly, there is no agreed and operational definition of an urban forest in Flanders either. Basically, all the forests in the heavily urbanized region of Flanders could be considered to be urban forests[3]. That said, we felt the need to elaborate on a profile of an urban forest, based on the guidelines contained within the Land-use Structure Plan of Flanders, which also includes the design of urban forests on the perimeters of cities in poorly forested areas. This profile turned out to be an essential working document for the development of a methodology for the selection of locations for urban forests. It is of utmost importance to define clearly the type of forest one wants to create.

The urban forest profile formulated in the study for Ghent aims at a forest with a high recreational value, especially for city dwellers, whilst simultaneously offering a significant added value for the urbanized region, both ecologically and environmentally (Anz, 1992; Kremer, 1993). Moreover, green areas in urban regions have to fulfil the important additional role of strengthening the structure of the landscape (Ministerie LNV, 1995). The urban forest should be large enough to fulfil these distinct functions in an optimal way, without the other functions of the forest being compromised by the recreational pressure. It was decided, therefore, to create an urban forest of between two and three hundred hectares. Such an area exceeds the minimal area for new urban forests of 100 ha prescribed by the Long-Term Forestry Plan of Flanders, but takes into account the high population density and the extreme scarcity of forest in the area. Thus the main profile of the new urban forest of Ghent can now be divided into recreational, ecological and structure-strengthening targets.

Recreational targets

An urban forest needs to be located so that it is able to benefit from a high number of visitors, both day visitors who live a short distance from the location, and weekend visitors, who may live

further away. This means that the location of the forest should consider both the day and the weekend recreational requirements of the target groups. Less prosperous population groups and people living in urban areas without gardens are important target groups. The design of the new forest should also take into account different visitor types. The motives of the visitors are different, varying from nature-oriented visitors, people looking for rest and silence, to the main user groups, who consider the forest as an attractive location for spending their active leisure time (Forestry Commission, 1992a, b). Finally, it is important that the location is not unduly disturbed by incompatible infrastructure in the neighbourhood, such as heavy industry.

Structure-strengthening targets

Green areas form an essential part of the urban environment and can contribute to a better structure of the urban landscape, e.g. the role of the urban forest as a natural border of the city area is an important structure-strengthening element. At the same time, the forest can fulfil its environmental function as a visual and acoustic buffer and as a soil, water and air protection area (Lust, 1992, 1994a, b; Van Elegem and Lust, 1996; Van Elegem *et al*., 1997).

All these elements were taken into account during the selection of the locations for an urban forest for Ghent.

Ecological targets

The improvement of the biological quality is an important objective when considering the location of the urban forest. A prime requirement for this is a sufficiently large area, as this makes it possible to plan for one or more quiet zones, suitable for the development of specific nature values. Their location should be based, wherever possible, on existing areas that have a high natural value, as well as exploiting the potential of nature development in and outside the forest environment. Coherence with areas that exhibit high existing nature values should be optimized. A choice of a site with high physio-geographical diversity is preferable, in order to enhance biodiversity (Van Der Werf, 1991) and the presence of adjacent ancient woodlands can favour migration

opportunities for both flora and fauna into the new forest (Peterken, 1981; Muys and Lust, 1993; Opdam, 1993; Bossuyt and Hermy, 2000).

Methodology for the selection of the locations

In order to locate the most appropriate sites for the realization of an urban forest in the conurbation of Ghent, a step-by-step approach, based on a multicriteria analysis (MCA), was used. The selection of the best location(s) took place in three stages: the excluding stage, the suitability stage and the feasibility stage.

The **excluding stage,** through the use of excluding criteria, leads to the initial identification of a number of locations that are potentially suitable for afforestation, called potential locations.

The open landscape that closely surrounds the whole urban agglomeration is considered as a search area. Within this area, the zones that are absolutely not viable as a location for an urban forest are excluded by means of exclusive criteria. In this way, the search area is reduced to a study area (Figure 1), which is then tested with the theoretical profile of the urban forest. The suitable remaining parts are considered as potential locations for the urban forest.

In the next step, the **suitability stage**, the potential locations are assessed on their suitability for the desired afforestation. This process leads to the (theoretically) most suitable locations for the establishment of the urban forest (Figure 1). The locations are selected by means of recreational, structure-strengthening and ecological criteria.

In the third step, the **feasibility stage**, the most suitable locations are submitted to a feasibility test using practical feasibility criteria. First of all, the degree of acceptance of the afforestation is tested against other competing land-use categories (agriculture, nature conservation, landscape protection and urban functions, such as residential development and industry). This analysis leads to the selection of the most 'acceptable location(s)'. In the event that several locations yield an almost identical score, the final choice for the location of the urban forest can be determined by so-called 'opportunity criteria'. This category of criteria is related to the chances for 'immediate realization' of the afforestation project.
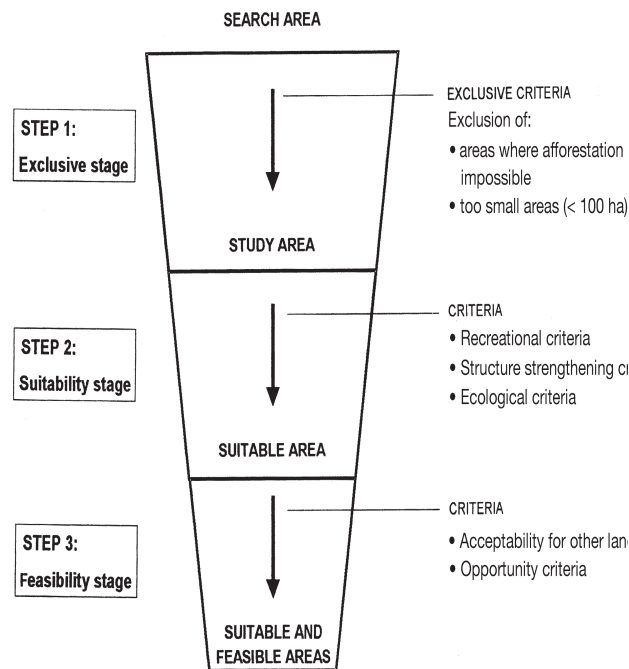
Figure 1. Flowchart of the three-step multicriteria methodology.

The final result is the selection of the most suitable and feasible location(s) for the urban forest.

The funnel in Figure 1 represents the search area, which is progressively reduced by means of the criteria in the different stages, and finally leads to the most suitable and feasible location for the urban forest.

The assessment of the criteria is elaborated upon with the assistance of scientific experts in the relevant disciplines and representatives of the competing land-use sectors. This interdisciplinary and systematic approach means that the project is founded on science and a broad social consensus, significantly increasing the chance of the project succeeding. The sequential stages are now discussed in more detail.

The excluding stage

The main goal of this stage is to delineate potential locations large enough to establish an urban forest and with potential for afforestation. At this stage, four tasks are necessary for the delineation of the potential locations.

First task: definition and delineation of the total search area   The delineation of the total search area is mainly based on the 'morphological agglomeration' of the city, which is defined as follows: 'the whole of the city centre, the adjacent urban areas and the city perimeter'. Within this urbanized agglomeration or adjacent to it, all the non-built up area is considered as the search area.

Second task: exclusion of zones larger than 10 ha not suitable for afforestation due to juridical reasons   The following areas are excluded due to juridical reasons: officially recognized nature reserves, bird protected areas and classified landscapes, where the management plan does not allow large-scale afforestation.

Third task: indication of barriers within the remaining study area   Strong recreational and

ecological barriers, such as highways, main roads, railways or joint ribbon development, are indicated.

Fourth task: indication of potential locations by the delineation of areas of at least 100 ha Within the already selected study area, the unfragmented areas of at least 100 ha are retained. The strong recreational and ecological barriers located in task 3 form the border of the potential locations.

The execution of these four tasks yields several potential locations. These locations are now submitted to the multicriteria analysis of the next stage, in which the suitability for afforestation is examined.

The suitability stage

In this stage, the potential locations, selected in the excluding stage, are submitted to a multicriteria analysis, in which the suitability of the locations for the establishment of an urban forest can be examined. Each location is checked to establish to what extent it meets the selected criteria. For this process, scores on an ordinal scale ranging from 1 (not suitable) to 5 (very suitable) are assigned to the locations.

Table 1: Criteria for the suitability stage

Criteria used
Criteria related to the potential recreational quality
Population density
Number of inhabitants within a radius of 3 km
Number of inhabitants living in areas without gardens within a radius of 3 km
Accessibility
on foot
by bicycle
by public transport
Absence of hindering infrastructure
Absence of heavy industry
Absence of road infrastructure
Absence of soft outdoor recreation facilities in the neighbourhood
Structure-strengthening criteria
Potential of spatial bordering of the urban area by forest
Potential buffer against spatial joining of residential areas
Sub-unit of a city green axis
Sub-unit of the natural structure
Scenic accentuation of cultural-historical elements
Degree of cohesion
Linkage of big open areas (extension facilities)
Degree of fragmentation
Potential protection function
Criteria related to the potential ecological quality
Geographical diversity within the area
Texture classes
Drainage classes
Topographical variation
Presence of forest
Current presence of forest
Presence of ancient woodlands or wood relics
Former presence of forest
Potential cohesion with existing nature values

In all, 14 criteria were selected, spread over the following three categories: (a) criteria related to the potential recreational quality; (b) criteria related to the structural strengthening of the landscape; and (c) criteria related to the potential ecological quality. Table 1 represents the three categories and their distinctive criteria. Some of the criteria are further subdivided into sub-criteria.

As already mentioned, assessment of the criteria is based on the formulated profile of the urban forest, which is further elaborated upon with the assistance of scientific specialists (experts in forestry, nature management and development, landscape design and land-use planning). It is evident that the guidelines and criteria of this methodology can be used for other, non-urban afforestation projects. In those cases, some of the criteria or sub-criteria should be adapted to the specific character of the project. For instance, in an afforestation project with a mainly ecological objective, some other more specific ecological criteria should be added.

In order to give more importance to certain criteria, weights are attributed to them. However, the assigning of weights to criteria might unduly influence the final result of the multicriteria analysis. The terms of reference, upon which the assigning of weights is based, are therefore made thoroughly explicit and informed by the clearly specified profile and target type of the urban forest.

In order to check the possible influence of the assigned weights, a sensitivity analysis was done in which the effect of varying criteria weights on the final result was evaluated and compared with the result of a scenario without attributed weights.

The following example for the criterion 'accessibility by public transport' shows how a criterion is made operational by defining scores:

(1) A score of 5 is given to locations which can be reached easily by public transport with a high frequency (direct connection with the location and more than one connection per hour, including during the weekends).
(2) A score of 3 is given to locations which can be reached easily by public transport but with a lower frequency (direct connection but only one connection per hour, including during the weekends).
(3) A score of 1 is given to locations which cannot be reached directly by public transport or where the frequency is low (no direct connection or less than one direct connection per hour).[4]

These scores cannot be considered as absolute values and are adapted to the local situation. The main goal here is to classify the different locations based on their accessibility.

The next example illustrates how weights are attributed to the ecological criteria (Table 2).

In the **zero scenario**, the three criteria are considered of equal importance and are hence attributed the same weight. Since two of the three

Table 2: Weights attributed to the ecological criteria for different afforestation scenarios

| Criteria | Weights | | | |
	Scenario 0 (equal weights)	Scenario 1 (basic scenario)	Scenario 2 (defragmentation scenario)	Scenario 3 (conservation scenario)
Geographical diversity	3	3	3	3
Texture classes	1	1	1	1
Drainage classes	1	1	1	1
Topographical variation	1	1	1	1
Presence of forest	3	6	6	6
Current presence of forest	1	2	2	2
Presence of ancient woodlands	1	2	2	2
Former presence of forest	1	2	2	2
Potential cohesion with existing nature values	3	6	3	9

criteria contain three aspects, the criteria weights are set to 3 (Table 2).

In the basic stakeholders' scenario (**scenario 1**), the 'potential coherence with the existing nature values' and the 'presence of forest' are considered the most essential criteria and therefore they get a double weighting. This is based upon a wide consensus among stakeholders from forestry and nature conservation sectors (both NGOs and government agencies). In this scenario, the double weighting factor for the criterion 'potential coherence with the existing nature values' expresses a strong willingness to avoid the loss of existing nature values due to afforestation and to make afforestation the most appropriate way of encouraging nature development in the selected location. The double weighting factor for 'presence of forest' refers to the importance given to the dispersal of forest flora and fauna elements from existing forest fragments into the new forest areas.

As well as the zero scenario and the basic stakeholders' scenario, we built two other scenarios testing different viewpoints: a defragmentation and a conservation scenario (scenarios 2 and 3).

In the defragmentation scenario (**scenario 2**) the presence of forest in or adjacent to the new forest location is considered essential for optimizing the ecological potential of the new forest and receives a double weighting.

In the conservation scenario (**scenario 3**) a prioritization is made between the criteria. The criterion 'potential coherence with the existing nature values' is considered crucial and receives a triple weighting. The criterion 'presence of forest' is considered important and receives a double weighting. The criterion 'geographical diversity' is considered of lowest priority in our context and is therefore attributed a single weight.

A separate multicriteria analysis is applied for the three categories of evaluation criteria (recreational, structure-strengthening and ecological). For each of these three categories, a score is calculated, and the suitability is expressed as a percentage of the maximum score.

Finally, in the overall multicriteria analysis of the suitability stage, the results of the different categories are added together, after weighting the three categories. On the one hand, the recreational aspect of an urban forest is an obvious priority, but on the other hand the other aspects are

deemed to be essential too. It was therefore agreed by the planners to give the recreational criteria a slightly higher weighting than the two other groups of criteria (recreational criteria – weight 1.5, structure-strengthening criteria – weight 1.0, ecological criteria – weight 1.0).

Finally, this stage has to lead to the selection of the theoretically most suitable locations. Obviously the most suitable locations must achieve an overall score which is considered to be high enough. However, because of the multifunctional principle of a forest, it is also important that these suitable locations have a high enough potential in each of the three categories: recreational, ecological and structure-strengthening. Thus this dual target was achieved by only selecting locations with an overall score higher than 60 per cent and with no score lower than 50 per cent for the recreational, ecological or structure-strengthening analyses.

Thus the suitability stage results in a selection of the most suitable locations for the establishment of a recreational urban forest, which are then subjected to a feasibility investigation.

Feasibility stage

This stage consists of testing the most suitable locations for their feasibility. The feasibility stage can be divided into two parts: possible conflicts with other land-use claims and the opportunity stage. The same methodology of the multicriteria analysis of the previous stage is followed, in which different weights are assigned to the criteria. Again the assessment of the specific criteria in the analysis is elaborated upon with the assistance of scientific experts in the relevant disciplines and representatives of the sectors involved.

Possible conflicts with other land-uses The acceptability of afforestation is investigated by submitting the locations to criteria that indicate possible conflicts with other land uses, namely agriculture, nature conservation, landscape protection and urban functions (Table 3).

Acceptability by the agricultural sector is investigated by looking at its claims on the agricultural land in the area. In Flanders, the Decree on Farmland Fertilization of 1991 put serious restrictions on manure disposal in several zones, including areas with high natural values and drinking-water

Table 3: Overview of feasibility criteria

Criterion
Acceptability for the agricultural sector
Economic importance of the agricultural sector
Existing environmental restrictions for manure disposal on farmland
Presence of marginal agricultural land
Acceptability for nature and landscape values
Acceptability for nature conservation
Acceptability for landscape protection
Acceptability for urban planning
Planned extension of enterprises
Planned recreational development
Planned residential development

supply areas. Such areas have lost their agricultural value since then. As a consequence, we could use 'restrictions for manure disposal on farmland' as an important criterion to assess the acceptability for afforestation by the agricultural sector. Another criterion was 'the economic importance of the local agricultural sector', measured by the 'gross standard balance per hectare', i.e. an indicator for the intensity of land use. The last criterion was 'the presence of marginal agricultural land', determined by the soil texture and drainage classes[5] as well as the marginal location[6] of the sites.

Acceptability for the nature conservation and landscape functions was determined by the presence of important nature and landscape values or potential values. These values were identified by using several information sources, such as the Biological Valuation Map of Belgium, i.e. a digital vector map with a 1 : 25 000 scale indicating the vegetation type and the biological value of each landscape element. The biological value is an ordinal variable with three classes: low, medium and high biological value, based on the degree of rareness, threat of extinction, sensitivity to disturbance, etc. of the landscape unit. The compatibility with afforestation and its area within the afforestation zone is assessed.

Acceptability regarding the urban functions was determined in an analogous way. Investigations were carried out to determine which claims should be included in the potential afforestation zone by using existing recreational urban and industrial extension plans.

Taking into account the local situation, in which agriculture is by far the most important land user, the highest weight is attributed to the acceptability of the agricultural sector, although the two other groups also play a determining role in the application of the multicriteria analysis. Therefore, it was decided that the difference in weights allocated to the three main criteria should not be too large. As in the suitability stage, different scenarios were used to check the possible influence of the weights assigned to the criteria.

As a result of this analysis, the most suitable and acceptable locations for the establishment of an urban forest are selected.

Opportunity criteria If it appears that the most suitable and acceptable locations gained almost equal scores, the final choice for the location of an urban forest can be determined by so called opportunity criteria. This category of criterion is related mainly to the degree of 'immediate realization possibility' for the afforestation project (the acquisition and afforestation possibilities of lands in the short term). Within this category, the local opportunities for afforestation are examined at a high-resolution scale, preferably based on information at the parcel level.

Moreover, the application of these criteria leads to a better understanding of the problems faced in realizing the urban forest in the 'most suitable' location, because it provides the planning team with detailed data.

Examples of opportunity criteria for the establishment of new urban forests are:

(1) a green designation of the selected site according to the regional land-use zoning scheme;
(2) the presence of existing afforestation projects;
(3) the possibility of the acquisition of land in the short term;
(4) the presence of publicly owned land;
(5) the presence of fallow land in the area;
(6) the presence of non-professional agriculture;
(7) the presence of farmers without direct succession.

As a result of the three selection stages, the most suitable and feasible location for the realization of the urban forest is finally selected.

Results

Figure 2 shows the results of the different selection stages. In the excluding stage, 11 sites adjacent to or lying in the urbanized area of Ghent were selected as potential locations. All these locations were submitted to the next stage, the suitability stage.[7] During the suitability stage, four locations were selected and were submitted to the feasibility stage. Here, the two most feasible and suitable locations were selected for the realization of an urban forest for Ghent.

Discussion

In this study an analytical and straightforward methodology is proposed to delineate the most suitable and appropriate locations for an urban forest. This methodology has proved to be a reliable and useful tool throughout the entire selection process of an urban forest for the city of Ghent. The search area, where the possibilities for afforestation were investigated, was gradually reduced through the three stages and finally led to the selection of the best locations for the successful establishment of an urban forest:

(1) As a result of the excluding stage 11 potential locations were selected.
(2) As a result of the suitability stage four suitable potential locations were selected.

(3) Finally the two optimum locations for the aimed afforestation were selected as the result of the feasibility stage.

In this way the locations 'Kastelensite-Scheldevelde-Rosdam' (locations 5, 6 and 7 in Figure 2) and 'Vinderhoutse Bossen' (location 9 in Figure 2) were finally selected for the creation of an urban forest. Both locations appear to be suitable for large-scale afforestation and seem to be acceptable to the other (potential) users of the land in these locations (agriculture, nature conservation, industry, urban development). Moreover, in both locations there are clear opportunities for the acquisition of the land on a short-term basis. Thus it was possible to select a 'suitable' and 'feasible' location by means of the proposed methodology.

An essential aspect of this integrated and systematic methodology is the elaboration process, where scientists from appropriate disciplines and representatives of the stakeholder groups involved, guide and influence the project. As a consequence, not only does the scientific foundation of the project improve, but the project gains support and acceptance by a broader social platform drawn from the different sectors involved.

Such an approach found favour when the results of the project for Ghent were presented to the local authorities involved. The project was very well received and endorsed by the local authorities. This positive response stemmed particularly from the integrated systematic approach of the project: from the early stages of the project, representatives from the distinct stakeholder groups and authorities were consulted and involved in the research. Because of this procedure, such projects can be more readily accepted by the local authorities, in which the particular sectors are based.

In conclusion, the methodology used proved to be a reliable tool to select the best locations for new urban forests. Its approach ensures the generation of project proposals that can expect full support by the local authorities. This methodology can also be applied successfully to other afforestation and nature development projects. The three stages and the mean groups of criteria could be used unchanged, while the specific criteria and the weightings could be changed or
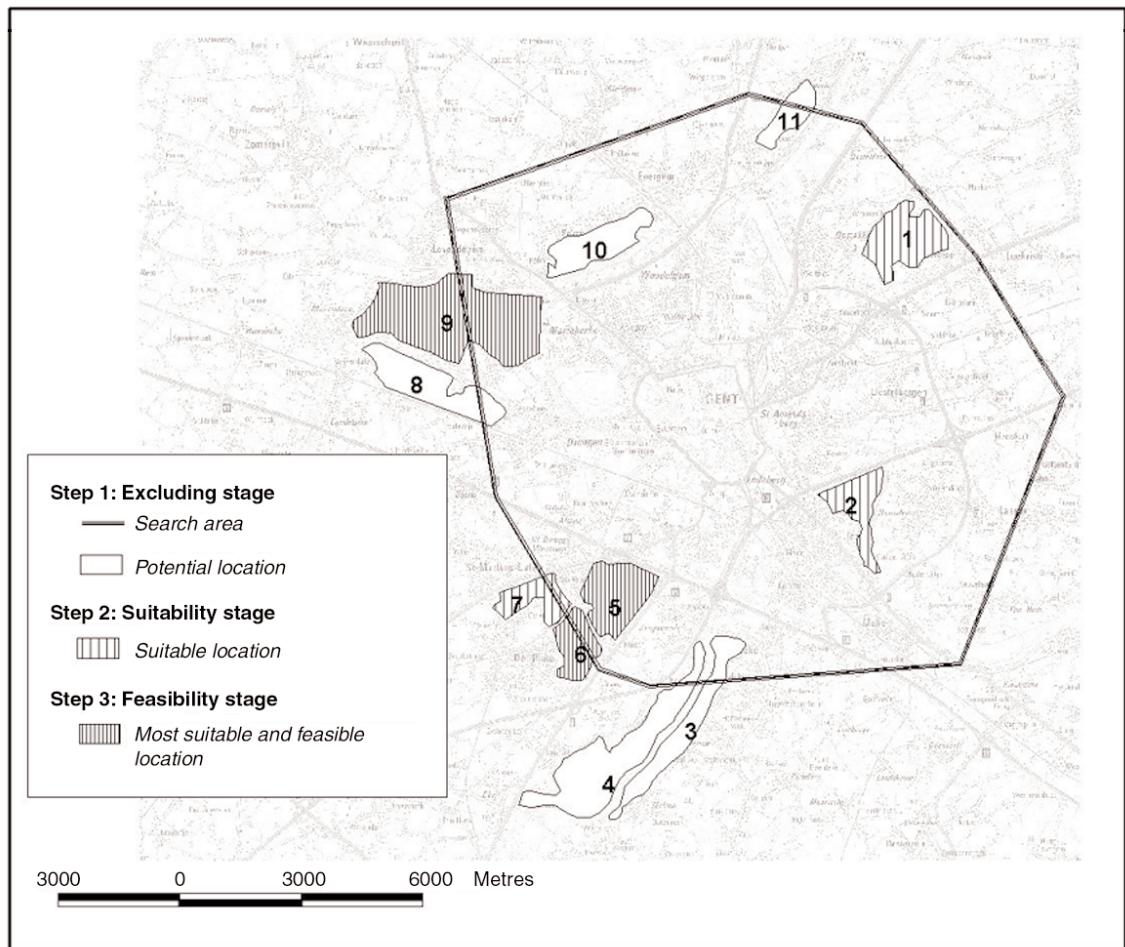
Figure 2. Selection of the most suitable and feasible locations of an urban forest for Ghent.

adjusted according to the specific circumstances and objectives of the project through a participatory approach with all stakeholders and local authorities.

Notes

1 The Land-use Structure Plan of Flanders is a new instrument of the Flemish Government for sustainable land-use planning. The main goal of the plan is to improve the general quality of life in urbanized areas and to strengthen the open space structures. This plan will influence land-use planning for the next 10 years.

2 The Long-Term Regional Forestry Plan is a sectorial plan, in which the basic framework of the regional forest policy is identified for the future.

3 In the EU Cost-action E12 'Urban Forests and Trees'

an overview of the definitions used in the participating countries is made. So far it seems that many countries, such as the UK, France, Austria and Czechia, include 'peri-urban' or 'urban fringe' forests such as the Forest of Jaegersborg near Copenhagen in their definition of urban forests. These forests often lie at a distance of 20 km or more from the city centre. Because Flanders is a very densely populated area where most cities lie almost adjacent to one another, all forests lying in between these cities can be considered to be urban forests.

4 Although the routes and frequencies of public transport could be adapted once the forest had been created, it is considered an advantage to choose a location that is already easily accessible.

5 Extremely wet soils and soils with a very high sand fraction were considered marginal for the agricultural sector.

6 For example, a small patch of agricultural land adjacent to a forest or surrounded by industrial activities can be considered as marginal due to its location.

7 The three locations, 5, 6 and 7, that belong to the most suitable locations were considered as one location in the suitability stage. Because of the highly residential character (many gardens with trees) of ribbon building which forms the border between locations 5 and 6, both are considered as one location. Thanks to several bridges over the railway, which forms the border between locations 6 and 7, location 7 can also be considered as part of a bigger location called 'Kastelensite-Scheldevelde-Rosdam'.

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