ISPRA
Istituto Superiore per la Protezione
e la Ricerca Ambientale

ROMA

SEVENTH FRAMEWORK PROGRAMME

TURAS

Guidelines of sustainable urban forestry for the Municipality of Rome

MANUALI E LINEE GUIDA

129/bis 2015

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PRESENTATION

In Europe more than two thirds of the population lives in urban areas and is therefore at local scale that policies for adaptation and mitigation of complex environmental changes taking place should be encouraged and implemented.
These Guidelines for sustainable urban forestry, prepared by ISPRA with Roma Capitale, are an important opportunity to emphasize that between the tasks of the Institute, which I chair, there are, in addition to monitoring and environmental control, to provide scientific and technical support to the decisions, so as to bridge the gap between science and policy that often prevents the proper implementation of policies, especially at the local level, such as that at issue in the present publication. And it is the urban scale that are focusing in recent years the emerging challenges in the environmental field: hydrogeological, climate change, land use, biodiversity loss, reducing air pollution, transport and mobility, quality of life. All key aspects to be addressed in an integrated manner if you want to actually go the way of sustainable development.
Since 2004, the National System for Environmental Protection (ISPRA/ARPA/APPA) develops and publishes a yearly report on the quality of the urban environment that - among others - is the issues of climate change, biodiversity and the green in major urban areas of the country, through the collection and evaluation of data useful to the population of some key indicators in collaboration with other bodies and institutions (ISTAT, the Italian Academy of Forestry Sciences, Ministry of the Environment, Land and Sea, etc.). ISPRA also conducts research and analysis on the diversity of green spaces present in urban environments, on their ecosystem services and multi-functionality, the instruments of planning and management of the green. It provides technical and scientific support to the Committee for the development of public parks, corporate body established at the Ministry of the Environment of the territory in accordance with the provisions of art. 3 of Law no. 10/2013 "Rules for the development of urban green spaces."
Nature, even that in anthropic environments, is the capital of green infrastructure on which it will be necessary to invest more and more in the future, for smarter and more resilient city, thanks to the variety of ecosystem services provided. But climate change, consequence of increase of greenhouse gas concentrations in the atmosphere, can lead to significant changes in the structure and function of ecosystems, with negative consequences for biodiversity and associated ecosystem services. Forestation measures to be taken should therefore focus on increasing the resilience of ecosystems, ie their ability to absorb and offset the natural and anthropogenic pressures from outside, including the effects of climate change. It is therefore crucial to orient the interventions of urban forestry to sustainability principles that take into account the multifunctional role of forests (ecological role and environmental, but also economic and socio-cultural) according to ecosystemic approach.
These Guidelines provide information targeted to the specific local context of the city of Rome, in response to the bioclimatic, pedological and vegetation in which one operates. In the design and implementation of new green areas are given special attention not only to the use of native soils (eg. agriculture, industry), but also the intended end use (eg. urban park, wooded area, etc. .), and the purpose of the forestation project (combating climate change, protecting biodiversity, or other), so as to direct toward the selection of tree species best suited to different contexts.
Ultimate goal is to have a solid framework in terms of technical and scientific implementation and monitoring of policies of urban forestation and increase the city's green areas, which are sustainable both in terms of ecological and environmental social and economic development, and provide a technical document of support to the decisions of the local government with respect to the design and creation of new forests in urban and suburban areas.

President of ISPRA
Prof. Bernardo De Bernardinis

FOREWORD

The city of Rome in recent years has undergone profound changes. The conformation of the capital, with an old town full of archaeological pre-existences, surrounded by a extensive built on the wide green texture of the *Agro Romano*, gives it a very special situation of climate and environmental well-being, including the wealth of biodiversity that is the result more evident.
Rome, despite the changes that occurred in recent years, is a "green" city. On a total area of about 129,000 hectares, there are about 43,000 hectares of green and about 50,000 hectares under cultivation. Historic villas, parks and gardens (public and private) in central part of the city, going towards the suburbs become nature reserves and agricultural areas.
Thus Rome is the second largest agricultural municipality of Europe with a total of 13.78 sqm/inhabitant of "usable" green. The total of 13.78 square meters/inhabitant is the remarkable achievement of Capitoline administration due to new acquisitions of green areas and new afforestazioni and reclamation: if compared to other Italian and European cities the value is certainly very significant.
Roma Capitale is committed to protect and enhance the environment, to improve builded areas, to preserve landscape and natural features of territory.
Through the Environmental Observatory on Climate Change (Department of Environment Protection), the Administration is partner of Project Turas (Towards Urban Resilience and Sustainability), funded by the European Commission under the Seventh Framework Programme of Research and Development.
The project aims to analyze, develop, demonstrate and disseminate scenarios and support strategies in urban and peri-urban areas to improve policies to mitigate and adapt to the climate change, aimed to increase the urban resilience compared to the environmental emergencies in place.
Within the project Turas, in collaboration with ISPRA (Institute for the Protection and Environmental Research) this manual of the "Guidelines for the Sustainable Urban Forestation has been produced.
ISPRA, besides taking care of the interactions between forests and climate change to participate work of the IPCC (Intergovernmental Panel of Climate Change) and develops the National Inventory of greenhouse gases emissions and of carbon sinks.
Regarding the urban characteristic of the problem here considered, specifically from years ISPRA also conducts monitoring and evaluation of green infrastructure in principal Italian cities, through the Annual Report on the "quality of the urban environment" and research activities to support national policies on the green, including forests.
The guidelines are aimed to provide a solid framework -valid also at the European level - from the technical-scientific point of view to the realization, implementation and monitoring of policies of urban forestation and increase of urban green, sustainable from the ecological point of view and of the environmental, social and economic concerns.
In order to frame properly policies to increase the city's trees in the context of environmental actions for the protection of biodiversity and combating change Climate, the Guidelines document and investigate e technical and managerial aspects linked to proper design, implementation and management of new forest areas, providing all the information necessary to protect and to enhance the heritage trees.

Director of the Department of
Environmental Protection of Roma
Capitale
Dott. Pasquale Libero Pelusi

1. PLANNING

Planning represents a fundamental step for the realization of forestry interventions; thus is desirable that technical offices of interested authority carefully plan every intervention, with the support of public/private experts. These interventions are important also to oppose soil consumption (see the final box "Soil consumption in Italy and EU guidelines to limit, mitigate and compensate soil sealing").

Every urban forestry project has to be integrated in the territorial context: new forested areas, in fact, should be planned considering their integration in existing urban green system, so to assume a role in the ecological connectivity. A careful planning and, primarily, an appropriate species selection, allows to optimize costs and to successfully pursue specific objectives such as carbon sequestration, improvement of air quality, biodiversity protection, environmental education, etc.

Therefore, for a correct planning is important to consider the following aspects:

1. Aim of the forestry project (carbon sequestration, fine dusts capture, biodiversity protection, environmental education, etc.);
2. Site selection (environmental characteristics and restrictions);
3. Planning addresses (wooded areas, tree-lined rows, green belts, etc.);
4. Species selection;
5. Selection of the propagation material.

1.1 Aim of the forestry project

The first step is to identify the main aim of the forestry project, because all the consecutive steps (planning addresses, species selection, etc.) will depend on the function that the new area should have (carbon sequestration, atmospheric pollutants abatement, biodiversity protection, environmental education, etc).

In fact, green areas, especially forested ones, can provide many benefits, both ecological (such as ecological connectivity, biodiversity protection, mitigation of urban heat island, carbon sequestration, soil protection, fine dusts and other atmospheric pollutants capture, etc.) and socio-economical (psychophysical wellbeing, energy saving, tourism, historical-artistic heritage revaluation, contact with nature, etc.).

Thus, first of all, is crucial to identify the main function that the new wooded area should have, also for the selection of the best tree species to plant (for example the poplar is suitable for carbon sequestration, but not for green areas addressed to citizens use, because this species is allergenic and susceptible to collapses).

Specifically, according to the Rome Municipality PRG (Local Strategic Plan) addresses, forestry interventions would have to pursue the following strategic objectives:

- contribute to reduction of greenhouse gases emissions, through carbon sequestration and local microclimate improvement;
- contribute to atmospheric and acoustic pollution mitigation;
- improve environmental functionality and connectivity, contributing to the Ecological network, through the realization of forestry interventions in specific areas, identified as priority for local biodiversity increase;
- improve urban and periurban landscape.

Therefore, among the various ecosystem services provided by urban wooded areas, in this Guidelines will be considered specifically forestry interventions aimed to:

- carbon sequestration (mitigation climate change);
- pollution mitigation (atmospheric and acoustic);
- biodiversity conservation and ecological connectivity.

The analysis of the main documents on urban forest[1], shows that, at various levels (International, European, National), particular emphasis is given both to ecosystem services provided by urban and

[1] See "Technical report on urban forestry" (available only in Italian).

periurban green areas (i.e. their multifunctionality) and to the importance to make aware citizens towards these services (figure 1).

Among ecosystem services particular emphasis is given to benefits provided by wooded areas in terms of climate change and biodiversity conservation, thus consistent with the aim of these Guidelines. In particular, at National scale (Italian), the Law n.10/2013 "Norme per lo sviluppo degli spazi verdi urbani"[2], represents a fundamental normative reference for urban forestry interventions, which realization has to improve the supply of ecosystem services.

An other important aspect is public awareness towards environmental, economic and social benefits provided by forestry interventions. Also this aspects is taken into account in the Law 10/2013, where the importance of encourage "*green culture*" is underlined (Art. 6). Public participation yet in the planning phase of forestry interventions allows a greater guarantee of success, because citizens feel involved and responsible for the result of the intervention[3].

Figure 1 - *Example of a multifunctional urban forestry intervention in a green area of Rome (Pratone delle Valli)*

1.1.1 Carbon sequestration

Vegetation needs CO_2 for photosynthesis, thus plants during growing store in the biomass large quantity of carbon, acting like "carbon sink". CO_2 absorption varies depending on environmental conditions (temperature, light availability, etc.), species and individual features (leaf surface, growing rates, age, health condition, etc.). The capacity of store the atmospheric carbon, in the biomass or in the soil organic matter, is crucial for climate change mitigation. In particular in urban environment, vegetation contributes to climate change mitigation in two ways:

1. absorption of CO_2 through stomata;
2. CO_2 emissions reduction thanks to the energy saving deriving from the presence of trees. In fact trees help in mitigating urban heat island and have an insulated and windbreak effect, resulting in a reduction of energy consumptions due to a less use of air conditioning (in summer) and of heating (in winter).

In urban areas it is important to consider the trees mortality, because in urban environment they are exposed to many stresses (such as pollution). Therefore, it is important to select resistant species and to replace death individuals in short time.

Moreover, energy saving due to the presence of trees in urban and periurban areas is a factor of mayor effect in CO_2 emissions reduction respect to direct carbon storage and sequestration (Rosenfeld et al., 1998[4]), especially in areas characterized by warm and dry summer (such as Mediterranean area, in which Rome is located).

For example some estimates about CO_2 sequestration by urban trees are reported. The estimates are obtained using specific models:

[2] "Rules for urban green areas development" (G.U. n. 27 1st February 2013)

[3] An example is the "Project 1000 trees" at Pratone delle Valli, Rome. For this forestry intervention, citizens were extensively involved through a series of meetings during which the various project hypothesis were illustrated. Furthermore, citizens were actively involved in the bedding out of some trees.

[4] Rosenfeld, A.H., Akbarib, H., Romma, J.J., Pomerantz, M., 1998. *Cool communities: strategies for heat island mitigation and smog reduction.* Energy and Building, 28: 51-62

ESTIMATE	REFERENCE
Carbon sequestration by urban forest estimated in few hundreds Kg of carbon for hectare for year (various USA cities)	Nowak D.J. and D.E. Crane, 2002. *Carbon storage and sequestration by urban trees in the USA*. Environmental Pollution, 116: 381-389.
MillionTreesNYC Project, which expects to plant one million of trees in the city of New York, with a direct carbon storage estimated in more than 1500 t/year	Morani A. et al., 2010. *How to select the best tree planting locations to enhance air pollution removal in the MillionTreesNYC initiative*. Environmental Pollution 159:1040-1047.
Carbon sequestration between 17 t/ha (areas with high tree density) and 1 t/ha (areas with scarce arboreal cover) (various residential areas in Liverpool)	Whitford, V., et al., 2001. *City form and natural process—indicators for the ecological performance on urban areas and their application to Merseyside, UK.* Landscape Urban Planning. 57: 91–103.
Greenhouse gases absorption by the 28,43 Km^2 of green areas, trees and shrubs inside the administrative boundary of the city of Barcellona estimates in about 4 millions t/year of CO_2 eq.	F. Baró, L. Chaparro, E. Gómez-Baggethun, J. Langemeyer, D. J. Nowak , J. Terradas, 2014. *Contribution of Ecosystem Services to Air Quality and Climate Change Mitigation Policies: The Case of Urban Forests in Barcelona, Spain*. In AMBIO A Journal of the Human Environment. 43: 466-479.
Estimates (obtained with different methodologies) of 160 t/year of CO2 sequestered by trees in the Parco Ducale (Bologna); 54 t/year of carbon for trees in Villa Borghese (Roma)	Calfapietra C. et al., 2011. *La foresta urbana per l'abbattimento di CO_2.* CNR and Università di Firenze.
Carbon sequestration by trees inside the Grande Raccordo Anulare (Roma) estimates in more than 2000 t/year	Attorre, F., and Bruno, F.,2010. *Servizi ecologici e valore economico degli spazi verdi urbani*. In "La gestione della natura negli ambienti urbani". Edited by WWF and MATTM: 170-178.

Referring to the project Life+ GAIA (*Green Areas Inner-city Agreement*) in the Municipality of Bologna[5], the Biometeorology Institute (Ibimet) of CNR of Firenze estimated carbon sequestration by 24 species suitable to be planted in urban environment, on the basis of scientific knowledge and of the recommendations provided by the Municipality. For example for the little-leaf linden (*Tilia cordata*) a quantity of CO_2 stored of 3.660 Kg in 30 years in the city and of 5.070 Kg in 50 years in a green area was estimated; for the field mapple (*Acer campestre*) and for the Norway mapple (*A. platanoides*) respectively a quantity of 2.490 Kg and 4.807 Kg in 30 years in the city and of 3.400 Kg and 6.601 Kg in 50 years in a green area; for the Turkey oak (*Quercus cerris*) a quantity of 4.000 Kg in 30 years in the city and of 5.500 Kg in 50 years in a green area[6].

Also small green areas, if conveniently planned and managed, are able to reduce indirectly CO_2 emissions, through the mitigation of temperature range, both in winter and in summer, thanks to a less use of air conditioning and heating. Therefore, with a careful urban redesign, also courtyards could represent an easy and cheap solution for improving citizen wellbeing[7].

In particular, studies carried on by the Biometeorology Institute (Ibimet) of CNR of Firenze, have demonstrated that vegetated areas have a cooling effect which increases, more or less in a linear way, with their dimensions; thus they have a great value for summer temperatures mitigation[8].

1.1.2 Pollutants abatement

Atmospheric pollution represents one of the main environmental threats in urban areas. Specifically, particulate matter (PM10 e PM2.5), nitrogen dioxide (NO_x) and ozone (O_3) are the most important atmospheric pollutants in urban areas. Vegetation contributes to pollutants removal (NO_x,

[5] http://lifegaia.eu/
[6] For estimates of all 24 species see http://lifegaia.eu/Gli-alberi
[7] See, for example "Cortili verdi per combattere afa e gelo". By Press Office of CNR. http://www.stampa.cnr.it/docUfficioStampa/cnrWeb/2006/Nov/06_nov_06_06.pdf
[8] See, for example "Cortili verdi per combattere afa e gelo". By Press Office of CNR http://www.stampa.cnr.it/docUfficioStampa/cnrWeb/2006/Nov/06_nov_06_06.pdf

SO_x, O_3, PM10, PM2.5) both directly (removal by leaves trough stomata uptake for atmospheric pollutants and/or dry deposition on the cuticle) and indirectly changing natural air streams (thus changing local concentration of atmospheric pollutants).

All plants are able to remove pollutants from air, but some species can be more efficient due to their morphological, functional and specie-specific features such as: leaf structure (thickness, shape, stomata density and morphology) and their seasonal persistence on the plant. In general, at the same environmental conditions, the efficiency in absorbing atmospheric pollutants is better in presence of high stomata density and high cuticle thickness. Referring to dusts (PM10, PM2,5, suspended particles, smoke, aerosol), some specie-specific characteristics can contribute to a more efficient removal of pollutants[9], such as leaf surface micromorphology (presence of hair, wax, roughness, etc.), total leaf surface and complexity of leaf morphology. In general, trees are more efficient than shrubs, and among these conifers are better than deciduous trees due to an higher leaf surface and a more complex and well-structured phyllotaxis and crown morphology.

Although the role of vegetation for improve air quality is undeniable[10], it is important to specify that is still controversial the quantification of effective contribute of single species in atmospheric pollutants removal, net to complex plant-atmosphere interactions. Furthermore, it is to remind that some species, particularly those characteristics of Mediterranean area, can emit considerable quantity of Volatile Organic Compounds (so-called VOCs, such as isoprene and terpenes) which in urban areas, especially in presence of high concentrations of NO_x, can induce the increase of tropospheric ozone concentration.

Therefore, in forestry interventions aimed to atmospheric pollutants abatement it is crucial to select the best species association according to their eco-physiolocial and functional features (such as species with a lower ozone formation potential, like turkey oak, cherry-tree, manna ash, field maple, etc.), and considering the surrounding environment.

Vegetation, and in general green areas, is involved also in water cycle, through the so-called "phytopurification". Thus, many species are able to efficaciously absorb pollutants in the soil, storing inside their tissues. For example, *Salix caprea* is efficient in the phytoextraction of zinc, arsenic, cadmium, lead and other heavy metals which are often common in soils around disused industrial areas in suburbs.

In very anthropic areas, significant presence of woodlands, both natural and artificial, contributes to *rhizodegradation*, *phytodegradation*, *phytoextraction*, *phytostabilization* processes, reducing impacts of soil pollutants. However, it is necessary to pay attention to phytovolatilization events, which consist in the absorption, chemical transformation and consecutive release of pollutants in the atmosphere through evapotranspiration (such as mercury, selenium, silver, arsenic, solvents, ethers) [11].

Vegetation, furthermore, can contribute to noise reduction, thanks both to leaves (which redirect acoustic waves and absorb sound energy converting it in heat) and to structural changes of the soil by roots. It is necessary to consider many variables during the planning of a forestry intervention aimed to noise mitigation: in fact, size of noise reduction depends on species (leaf shape and dimension, soil coverage, etc.). In brief, it was observed that abatement of noise levels occurs mainly at high frequencies (Bullen, Fricke, 1982)[12]. Moreover in a place delimited by buildings completely covered by vegetation, it is estimated an average reduction of sound pressure levels of about 4-5 dB, at 125 Hz, and of about 8-9 dB at 4000 Hz (Smyrnova et al. 2011)[13].

1.1.3 Biodiversity conservation

Urban green areas, being a suitable habitat for different animal and plant species, can contribute to biodiversity conservation and safeguard both at local and broad scale. The same Convention on Biological Diversity recognizes the importance of urban biodiversity protection for the achievement of their objectives, with particular reference to urban green areas and urban protected areas.

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[9] For example a study realized in London revealed that rough leaves of linden showed an higher particulate load respect to other broad-leaved species characterized by a smooth leaf surface (AA.VV., 2013. *L'impianto, la gestione e la valorizzazione multifunzionale dei boschi periurbani : interventi forestali non produttivi per la valorizzazione dei boschi* - Supporti tecnici alla Legge regionale forestale della Toscana; 9).

[10] For example see a recent study in the city of Barcellona on PM_{10} e NO_2. F. Baró, L. Chaparro, E. Gómez-Baggethun, J. Langemeyer, D. J. Nowak J., Terradas, 2014. *Contribution of Ecosystem Services to Air Quality and Climate Change Mitigation Policies: The Case of Urban Forests in Barcelona, Spain*. In AMBIO A Journal of the Human Environment. 43: 466-479.

[11] Consiglio Nazionale delle Ricerche, IBAF, Istituto di Biologia Agro-Ambientale e Forestale. "*Le piante per il fitorimedio*". http://www.ibaf.cnr.it/phyto/sito.pdf

[12] Bullen, R., Fricke F. 1982. *Sound propagation through vegetation*. Journal of Sound and Vibration Volume 80, Issue 1, 8 January

[13] Smyrnova Y., Kang J., Cheal C., Hong-Seok Yang 2011. *Numerical simulation of the effects of vegetation on sound fields in urban spaces.* Forum Acusticum.

At national scale, the National Biodiversity Strategy (Strategia Nazionale per la Biodiversità) in the work area "Urban areas" identifies as priority green areas conservation and the requalification of the natural areas system, to allow biodiversity and urban ecosystem protection.

Thus, urban green areas can have an important role in biodiversity conservation, both plants and animals (especially birds, but also invertebrates, included various species of community interest[14]). Referring to vegetation, in cities it is possible to find monumental trees (both single tree and tree-lined rows) and green areas of high naturalistic interest, for example forest fragments in the protected areas of RomaNatura (Figure 2): turkey oak, hornbeam, English oak and evergreen woods in the Natural Reserve of Insugherata; the remarkable cork oak woods in the Urban Regional Park of Pineto small woods of turkey oak and cork oak in the Natural Reserve of Tenuta dei Massimi; oak woods and, along the river, riparian species (elms, white willow, ashes, maples) in the Natural Reserve of Valle dell'Aniene, etc.

Other examples are: Bosco in Città in Milan, a public park of more than 100 ha characterized by a residual forest of Po Valley and seat of the Urban Forestry Centre; Bosco of Carpenedo in Venice, last fragment of the ancient oakhornbeam forest that once covered Venetian inland; Bosco of Cerano and Boschi of Santa Teresa and Lucci in Brindisi (South Italy), residuals of a coastal wood with Mediterranean scrub and holm oak and cork oak woods.

Finally, the most natural urban green areas contribute to create ecological connections between urban and periurban areas, representing an effective local response for safeguarding biodiversity and protect and improve the environment.

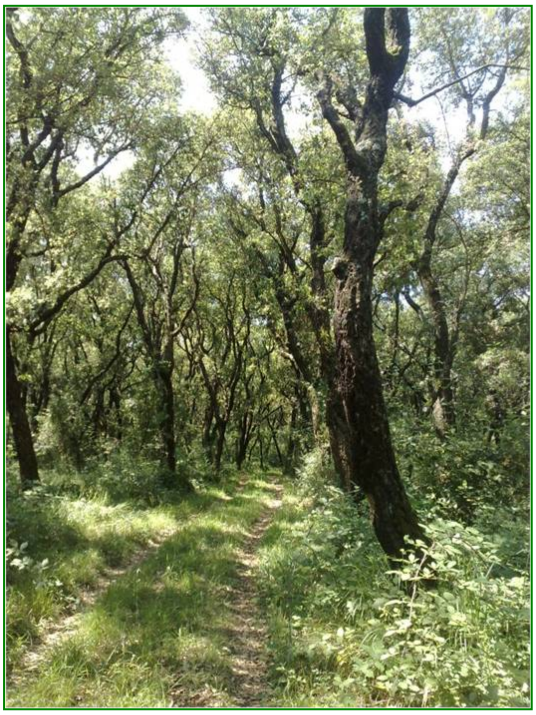

Figure 2 - *Examples of forest fragments in the protected areas of RomaNatura: cork oak woods in the Natural Reserve of Decima Malafede (on the left) and forest fragment along the river in the Natural Reserve of Valle dell'Aniene (on the right)*

1.2 Site selection

As the main function of the new wooded area is chosen, the following step is to identify the most suitable site where to realize the forestation intervention. A selection founded on ecological principles allows a more successful forestry intervention, with, as well, economic benefits. In urban areas, availability of areas where to realize forestry interventions is in general scarce (also with relation to

[14] For example inside the Grande Raccordo Anulare in Rome live 5.200 insects species, included those of priority community interest (such as *Osmoderma eremita*, discovered in Villa Borghese and Villa Pamphili, Rome) (Zapparoli, 2002. *La fauna urbana*. In: "La fauna in Italia" (a cura di A. Minelli, C. Chemini, R. Argano, S. Ruffo), Touring Editore, Milano e Ministero dell'Ambiente e della Tutela del Territorio, Roma).

what is provided for by local planning instruments). For choosing the best area, among those available, it is necessary to consider the following aspects:

- the use of the original soil. In urban and periurban areas, sites potentially available for forestry are mainly:
  - natural and semi-natural areas, such as natural areas along water courses, untamed areas and agricultural areas. Specifically in Rome, both in urban and periurban territory there are extend agricultural areas[15], which offer the advantage to need not great preparatory interventions of the soil. Remarkable forestry examples, moreover, are still present in the Western part of the city and in the coastal territory;
  - if an agricultural land is chosen, it is appropriate to avoid interventions that could negatively interfere with productive units. Furthermore, in these areas tree-lined rows/green belts are to be considered, in addition to possible forestry planting to realize limited to low productivity agricultural units or areas characterized by hydrogeological problems, which recommend a land cover change. Tree-lined rows/ green belts can contribute to ecological connectivity, windbreak, improvement the landscape, etc. Other sites potentially available are natural areas inside protected areas[16]. In this case, forestry interventions, especially if of small dimensions, have to be essentially for conservation and protection purposes;
  - degraded areas to recover[17] (such as industrial disused areas[18], areas exposed to intense environmental pressures). In this case, however, it is indispensable to assess in advance the necessity to restore the soil (possibly using as well phytoremediation). In degraded areas, creation of new wooded areas not only improves the environment, but also can have socio-cultural and landscape benefits. In fact new forested areas can be enriched with usable elements, such as benches, educational panels, outdoor sport routes, etc. In management activities, it has to be considered also degraded areas spontaneously covered by vegetal formation of exotic naturalized species, such as *Ailanthus altissima*, *Acer negundo* and *Robinia pseudoacacia*. In fact, these are pioneer species, able to create, on infrastructural embankments and marginal areas, wood-like formations, which can quickly sequester CO_2. Moreover, *Robinia pseudoacacia*, being a leguminous, is able to enrich degraded soils with nitrogen compounds. Also these formations can be an opportunity of pollution mitigation and environment requalification, if they are well managed and if the exotic species are not invasive;

[15] Rome, with its 63.000 total hectares of cultivated land, distributed in farms and natural reserves, is defined as the biggest agricultural Municipality of Europe.
[16] In Rome some forestry examples aimed to carbon sequestration have been realized yet inside protected areas (figure 3): for example the pilot action of the LIFE project "*Roma per Kyoto*", for which a forestry installation has been realized inside the Natural Reserve Valle dei Casali; other examples are located inside the Natural Reserve Valle dell'Aniene.
[17] In case the forestation intervention aims to mitigate climate change, it is opportune that the surface is not less than 1 hectare (functional criterion for the acquisition of carbon credits on the basis of Marrakech agreements).
[18] For example Parco Dora in Turin, realized in a disused industrial area; Parco di Rubano in Padoa, realized around an old sand pit in an area naturalized trough forestry interventions and creation of a wetland; some woods in the Parco Nord Milano where the existing 90 ha of new plantations has been realized in part on disused industrial land.

 

Figure 3 - *Examples of forestry interventions aimed to carbon sequestration inside a protected area of Rome (Natural Reserve of Valle dell'Aniene)*

o

- restrictions and prescriptions. When realizing forestry interventions, it is compulsory to analyze current local planning instruments and ranking rules (Town Plan, Land Management, Green Areas Plan, Protected Areas Management Plans, Traffic Laws, etc.). Forestry intervention, in fact, has to be integrated in the local planning context and has to respect what is provided for by implementation regulations, for example the respect of the smallest distances from streets. Specifically in Rome, it is necessary to follow what is provided for by "Guidelines for the management of masts of council ownership in the Roma Capitale territory" ("Linee guida per la gestione delle alberature di proprietà comunale nel territorio di Roma Capitale[19]). Finally, it is necessary to check landscape restrictions and all constraints (such as power lines, aqueducts, gas pipelines, etc.);
-
- pedological characteristics. It is necessary to assess soil characteristics, which can represent a limiting factor for plants growing, if it is not suitable for roots penetration. Furthermore, all actions necessary to prepare adequately the soil before planting can change depending on soil characteristics (for example if it is necessary to resort to drainage). Therefore, it is important to analyze soil features, such as structure and texture, rock depth, porosity and permeability, presence of water and/or of an aquifer, drainage characteristics, pH[20], presence of macro elements[21]. Particularly, many urban soils can be modified due to compaction events (footfall, heavy vehicles transit, etc.), alterations deriving from litter and vegetation removal (that means a change in the organic and nutrient supply in the soil), pH modification (for example pH is on average high in soil next to streets and buildings). More details on soils in urban areas and their ecosystem services are provided in the box "Soils in the urban environment";
-
- microclimate. Besides the soil, it is fundamental to characterize implantations site from both a climate (rainfall and temperature) and microclimate point of view (humidity, wind, sunlight exposure, etc.). The knowledge of all these aspects allows the selection of the most suitable vegetal associations to plant. Urban environment, in particular, is characterized by higher temperatures (the so called "urban heat island") caused by an higher solar energy absorption on the part of the numerous sealed surfaces (paved streets, buildings), by a drier air and a less presence of wind (thanks to the many physical obstacles). Furthermore it is necessary to assess exposure to pollutants (such as traffic congested streets), which represent a source of stress for

[19] Deliberation of Town Council (Deliberazione della Giunta Capitolina) n. 307 of 10/17/2014.
[20] Species can prefer basic or acidic soil. For example different oak species (turkey oak, holm oak, etc.) prefer basic soil, while cork oak and chestnut acidic ones.
[21] This aspect is crucial in the urban environment, where in the soil it is easier to find building waste and residues, which can create an unsuitable substrate due to the nutrient lack.

plants (then it has to be considered during species selection). Finally, it is necessary to consider the distance from sea, because plants tolerate sea spray differently;

-
- potential and current vegetation. Another useful element is to analyze the existing vegetation in the selected site, through specific phytosociological surveys. In urban environment, however, it has to be considered that original vegetation can be deeply changed due to anthropic intervention. For this reason, it would be desirable to identify potential vegetation, also using information collected during the analysis of the previous points. A knowledge of the site as complete as possible helps in choosing the best vegetal association for the forestry intervention, valuing the specific potentiality of the site and contributing in a long-term establishment of the new vegetal community.

Box 1 - *Soils in the urban environment*

Urban and sub-urban soils are an essential part of the urban ecosystem that contributes, directly or indirectly, to the good quality of citizens' lives. The urban green infrastructures are dependent on a "Brown infrastructure" (sensu Pouyat et al., 2010) composed of highly diversified soils. The major part of these soils (Anthropogenic Soils), derive from extremely variable human actions. In the urban environment, man represents the main pedogenetic factor.

In the urban environment the typical habitat fragmentation and the wide spectrum of land use determines, in fact, a strong variation of the chemical / physical / biological soil features. A mosaic ranging from natural or seminatural soils (eg. Historic mansions, urban parks, urban and peri-urban protected areas, peripheral agricultural areas), to deeply altered soils, soils covered by impervious/semipervious surfaces until to new soils (eg. former industrial areas, embankments, flower box).

These soils, even if their functions are extremely limited, provide the same ecosystem services of natural soils: reducing the amount of pollutants, providing organic carbon stock and mineral nutrients, improving aesthetic, recreational, cultural functions of green areas and biodiversity preservation.

Despite their peculiarities, such soils continue, with functionality depending of alteration degree, to provide the same ecosystem services of natural soils. Mitigate the effects of pollutants, providing organic carbon stock and mineral nutrients, regulate the hydrological cycle, improving aesthetic, recreational, cultural functions of green areas and biodiversity preservation.

Soil functions are, however, totally lost with its removal, or greatly limited by sealing or high pollution levels. The latter is of particular interest considering the proximity of the population and the progressive growth of the urban and peri-urban horticulture.

Soil functions and ecosystem services

Healthy soil performs ecological, environmental, economic, social and cultural functions such as sequestering CO_2, mitigating stormwater runoff, supporting plant life, and sustaining the microbial populations that form the basis for all living things.

The *seven major soil functions* are as follows:

– *Biomass production:* soil provides food, fodder, renewable energy and raw materials. Food and other agriculture production, essential for human survival, forestry and almost all vegetation are totally dependent on soil.
– *Storing, filtering and transforming nutrients, substances and water:* Soil plays a crucial protective function to mitigate and prevent the passage of pollutants into groundwater and the food chain. The soils protective value depends on the physical- chemical properties, and by biological activity that allows decomposition of the substances placed in the soil. Through its ability to store large amounts of water plays an important role in prevent or reduce flooding.
– *Acting as carbon pool*: Carbon stored in *soils* represents the *largest terrestrial carbon pool*. Soils can play a key role in climate change mitigation through carbon sequestration and greenhouse gases (N_2O and CH_4) emissions regulation
– *Biodiversity pool, such as habitats, species and genes:* soils are a reservoir of biodiversity. They provide habitat for thousands of species regulating for instance pest control or the disposal of wastes,
– *Physical and cultural environment for humans and human activities*: soils provide physical support to plants, animals and human infrastructures,
– *Source of raw materials*: soils can be a source of materials like peat and clay.
– *Archive of geological and archeological heritage*: Soils are the archive of our history and culture. Archeological artifacts are stored in soils. A soil profile can tell a complete story of the events that have been shaping the landscape in that site, in historical as well as in geological times.

Soils provide an array of *ecosystem services* (benefits people obtain from the soil) essential for the environment and human well-being (Table 1).

Nonetheless, owing to unsustainable land uses, soil is degrading by erosion, loss of organic matter, salinization/alkalinization, compaction, sealing, contamination, compromising the maintenance of further productivity until the ultimate soil degradation phase, the desertification (Figure 1)

Table 1 - *Links between human needs, soil ecosystem services and soil functions* (modified from Dominati et al, 2010)

Human needs	Soil ecosystem services	Soil functions
	Supporting	
	Primary production and nutrient cycling	Biomass production, including in agriculture and forestry
	Water cycling	
	Soil biological activity	Biodiversity pool, such as habitats, species and genes;
	Provisioning	
Food and energy security	Provision of food, water, timber and fibre	Biomass production, including in agriculture and forestry
Housing and infrastructure	Provision of raw material	Source of raw materials
	Provision of physical support	Physical and cultural environment for humans and human activities
	Regulating	
Safety and security Health and well-being	Flood mitigation	Storing, filtering and transforming nutrients, substances and water
	Water quality	
	Filtering of nutrients	
	Biological control of pests and disease	
	Recycling of wastes and detoxification	
	Climate regulation	Acting as carbon pool
	Cultural	
Well-being	Spirituality, knowledge, sense of place, aesthetic	Archive of geological and archeological heritage.

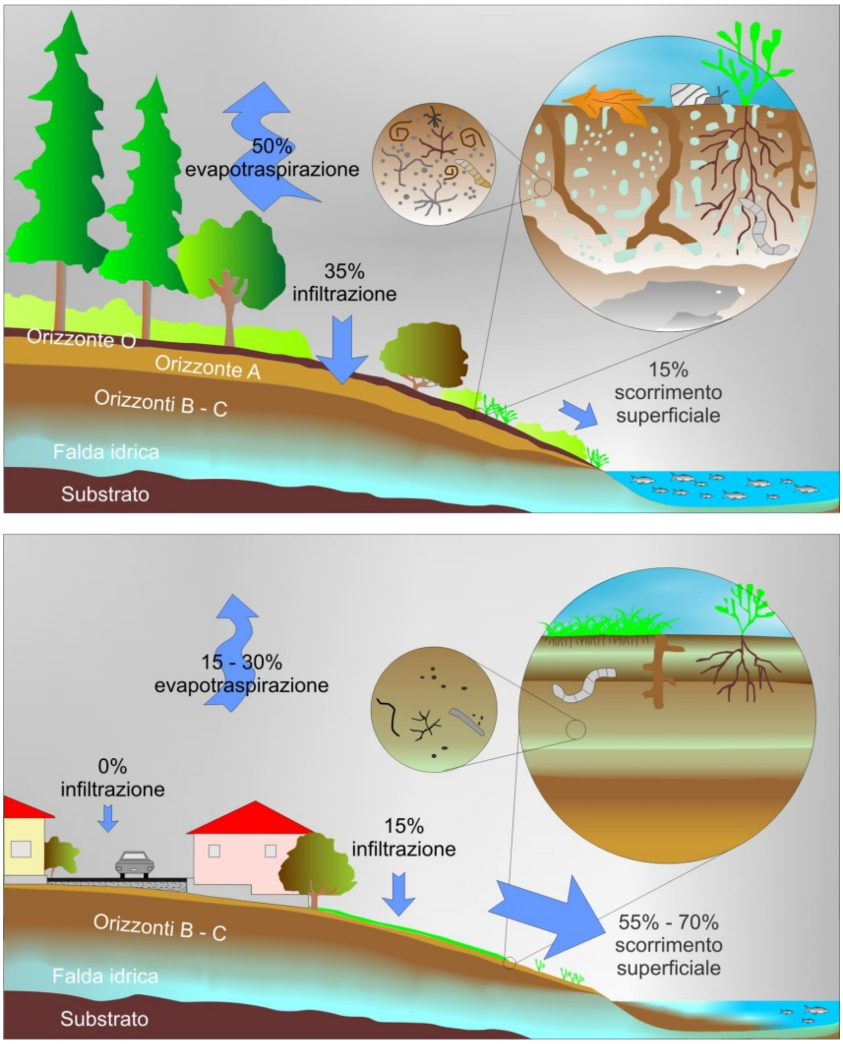

Figure 1 - *Soil in its natural condition is able, thanks to its porosity, permeability and humidity, to retain a large quantity of water from rainfall, contributing to regulate the surface runoff. In an anthropised environment, on the other hand, the presence of impervious surfaces, the reduction of vegetation, the removal of the surface layer, which is rich in organic matter, and the onset of compacting result in a serious deterioration of the soil's function. The decrease in evapotranspiration, and in the soil's capacity to absorb water, result in an increase in surface runoff and in the transport of large quantities of sediment in natural collectors. The values shown in the figure are only indicative and can change significantly, depending on a variety of parameters (the physical and chemical characteristics of the soil, the topography and geology, as well as the duration and intensity of rainfall etc.)*

Features of Urban soils

Whether in a natural or disturbed condition, soils vary widely in their properties. Disturbed soils especially differ from soils in natural areas because their horizons have been mixed, destroyed, removed or compacted mainly the superficial horizons. Natural soils may be buried under fill; chemical and waste materials may have been added. All these activities can result in large changes in the physical, chemical, biological and engineering properties of the urban soils that can range from natural to completely man-made conditions.

WRB-World Reference Base (IUSS, 2014) classifies strongly anthropized soils in two groups:

- *Anthrosols*: soils that have been formed or profoundly modified through long-term human activities, such as peri-urban land, garden or park soil.
- *Technosols*: soils containing many artefacts (material deriving from human activity). These soils are dominated by a profound human influence such us in roads, industrial, mine or military sites.

Within urban "pedodiversity", excluding soils slightly disturbed, anthropogenic soils show typical characteristics:

- **Great vertical and spatial variability**: soil properties gradually change both spatially and vertically. Urban soil profiles show abrupt changes from one layer to another depending upon the human activities and the constructional history of the soil.
- **Structure Modification, compaction and organic matter decline**: compaction phenomena, linked to trampling or vehicular traffic, with consequent reduction of water drainage, are frequent in urban soil. The litter removal, typical in gardens or green areas, reduces organic matter content and soil nutrients. The organic matter reduction increases water erosion, particularly on bare soil.
- **Soil biodiversity loss**: Restricted aeration and scarce water availability caused by soil compaction, the reduction of organic matter and diffuse soil contamination strongly compromise soil biological quality.
- **Modified soil reaction**: soil reaction (pH) values higher than their natural counterparts are observed in soil near the street, industries or civil buildings; the main consequence is a general alteration of soil nutrient balances.
- **Local and diffuse contamination**: urban soil can include a high percentage of pollutants. In addition to contamination associated with industrial activities, waste management or oil spills, source of diffuse pollution such as vehicle traffic able to increase heavy metal concentration, plays an important role.

Soil functions and ecosystem services change spatially and temporally with pedological characteristics, land use and climate change. Soils provide different ecosystem services with various quality. According to a gradient of anthropization, urban soil can be divided in four groups (Morel et al., 2014): Vegetated pseudo-natural soil, Vegetated engineered soil, dumping sites and sealed soil (Table 2).

Table 2 - *Proposed categorization of urban soil based on the ecosystem services they provide.* (from Morel

Ecosystem Services		Soils			
		Vegetated pseudo-natural	**Vegetated engineered**	**Dumping sites**	**Sealed**
Provisioning services	Food production	++	++	(+)	o
	Non-food biomass	++	++(+)	++	o
	Reservoir of minerals	+	+	+++	o
	Fresh water supply	o	+	o	+++
Regulating services	Water storage	++	+++	++	+
	Run-off and flood control	+++	++(+)	+	+(+)
	Pollution attenuation	++	+++	++	+++
	Global Climate	+++	++	++	+
	Local climate	+++	++	+	o
	Biodiversity	+++	+++	++	o
	Invasive species	o	++	o	o
	Air purification	+++	++	+	o
	Noise control	++	+++	++	+
Cultural services	Recreation /Tourism	+++	++	o	o
	Archives of human history	+	+	+++	++
	Landscape	++	+++	+	+
	Education	+++	+++	++	+

Legend

“0” ecosystem service of no value (this symbol refers also to soil groups that provide a significant number of disservices);

+++: ecosystem service of high value;

++: ecosystem service of medium value;

+: ecosystem service of low value.

Brackets are used to introduce intermediate scores

Survey, mapping and quality assessment of urban soils (mainly for *Technosols*) is a very complicated and complex task. Human activities have played an overwhelming role in the distribution of soil or parent materials with different pedogenetic processes.

Strategies for sampling and methods for data spatialization and management, different from those of the conventional pedological methods, must be planned. Great variability of soil types in very narrow spaces makes it impossible to adopt a soils distribution model to guide the survey. For the same reasons the existing soils databases can be useful only to define the soil "potentially" present in urban areas, but not as a source for punctual soil information.

Despite these difficulties the knowledge of soils is of fundamental importance in order to develop management policies of urban green spaces and for food security.

The urban and peri-urban areas are those most affected by the dynamics of land use/land cover changes. Therefore, it makes it essential understand how such soils can be managed, rehabilitated or reconditioned to support green infrastructure or urban agriculture.

Studies in various world cities show that compaction, low content of organic matter and contamination, generally due to atmospheric deposition from various sources and past land uses, are the most common problems of urban soils.

Also some soils of Rome record high values of heavy metals (Pb, Pt, Ba, Cu, Zn), mainly near the main road or in correspondence of past human activity.

The content of heavy metals in soils is highly dependent on geochemical behaviour, pedogenic processes and anthropogenic influences. Nevertheless, their accumulation in the soils is considerable because they are persistent.

Contamination of urban soils by heavy metals may represent, therefore, a serious problem for human health due to the possible presence of high concentrations in places normally frequented by highly sensitive subjects, as in urban gardens, or for their passage in the chain food by means, for example, the consumption of agricultural products.

For this reason is necessary to know the characteristics of the soils not only to quantify the ecosystem services that would be lost due to urbanization but also to evaluate their quality, especially if used for recreational use or for urban agriculture.

Thus, heavy metals in urban and suburban soils can be successfully used as indicators for the evaluation of the environmental contaminations by hazardous metals due to anthropogenic and industrial activities or a high natural content. The study of geochemical contamination, allows differentiation of anthropogenic pollution from the one linked to the geological characteristics (natural background value), and provides useful information on the impact of human activities. It is important for the implementation of suitable measures of long-term prevention and for planning a monitoring of soil and environment quality.

1.3 Planning addresses

Urban forestry includes “*the management of trees and forest resources in and around urban community for the physiological, sociological, economic, and aesthetic benefits*”[22]. Thus urban forestry includes the set of all trees and shrubs existing in urban and periurban areas. So this definition includes not only wood areas, but also green belts and tree-lined rows. Considering the aims of the forestry intervention and the site characteristics, it is possible to consider different typologies of urban forests: for example to mitigate climate change and to increase biodiversity it would be better to create a new wooded area, while for atmospheric pollutants abatement and for anti-noise barriers it would be chosen primarily tree-lined rows, especially in urban areas.

[22] Definition of “*urban forestry*” by the Society of American Foresters (Helms, J. (Ed.), 1998. *The Dictionary of Forestry*. Society of American Foresters, Bethesda.), approved also in Europe (Konijnendijk, C.C., Ricard, R.M., Kenney, A. e Randrup, T.B., 2006. *Defining urban forestry – A comparative perspective of North America and Europe*. Urban Forestry & Urban Greening 4: 93-103).

A wood area requires wider spaces to be created and generally several belts are realized (such as a tree and a shrub belt). Furthermore, the ecological service for which they were created could be not immediately appreciated (for example the shading can require a few years). Finally, if the forestry intervention is placed in a more natural context (such as protected areas and agricultural areas), there are some more advantages such as less stress for new plants (less atmospheric pollution) and the new forested area can perform several environmental (carbon sequestration, mitigation of the urban heat island, habitat for the animals, etc.) and social functions (for example creating shaded areas suitable for sports and other activities[23]). When designing recreational and social sites (from scratch or requalification), especially if used by children (e.g. playgrounds), it will be appropriate to take account of the potential allergenicity of the species to be introduced in order to avoid the occurrence and the burden of symptoms related to allergies and asthma, diseases that already have a high incidence in urban areas (see below the box "Urban green spaces and allergies to pollens: recommendations").

Green belts have a linear shape and generally a limited width. Thus, before their realization it is important to consider distances from streets and privately proprieties. Especially in case of tree-lined rows it is essential to assess the space available for plant growing and the constraints[24], and to choose the most suitable species (for example avoiding species more sensitive to atmospheric pollution or species which can represent a threat for citizens[25]). Moreover new trees should not be an impediment to vehicular traffic and road sign. For a better interception of atmospheric pollutants it is important to choose mainly species with an high breadth growing, so to create a green belt with optimal characteristics to perform this function. As wood areas, also green belts and tree-lined rows can perform different functions, such as anti-noise and windbreak barriers, heat regulation, ecological connectivity, aesthetic values, shading, dust filters, etc.

Finally, for the realization of any forestry interventions it is necessary to consider the species temperament to sunlight (heliophilous vs sciophilous species) to allow a correct growing.

1.4 Species selection

The choice of species is crucial for the success of forestry projects; their effectiveness in performing the functions for which they are realized depends mainly on ecological characteristics of the species.

In fact a wrong choice can involve a series of problems ranging from not achieving the initial objectives, the failure of the intervention and high costs of management and maintenance. It is therefore essential to consider first of all the previous points (purposes of the area, site characteristics, planning addresses), and then analyze the aspects explained below.

In the selection of species to be planted in the forestation interventions, native species must be favorite within the constraints of urban planning and landscape regulations. Only in some cases (such as the tree-lined or where ornamental species are particularly necessary) is conceivable the use of exotic species (not invasive), as should always favored indigenous species.

The main aspects to be considered in the choice of species are listed below, in addition to those discussed in previous paragraphs (aim of the intervention, soil type, microclimate, etc.):

- the speed of growth, which is important in particular for the capture of CO_2;
- root development (especially important for interventions next to roads because roots must not damage the sediment road);
- the bearing and the size of the species to the adult stage (height, shape of the foliage, etc.);
- persistence of the leaves (deciduous versus evergreen), a feature of particular interest in relation to the mitigation of air pollution and noise;
- characteristics of flowering and fruiting and any unwanted elements (such as the plugs, the presence of resins), important especially to increase biodiversity, but also for the safety (for example in the case of tree lined roads);
- the strength of the wood and the propensity to rupture (both branches of the whole plant);

[23] For example Parco Nord in Milan, Parco di Monza and Pratone delle Valli in Rome (here some trees have been planted in the dog area on request of citizens with the aim to make the area more usable and pleasant).
[24] Generally on pavements less than 3 meters it is possible to plant only trees of 3rd size, on pavements between 3 and 4 meters trees of 2nd size and on pavements wider than 4 meters trees of 1st size. Furthermore it is necessary to respect the distances from constrains for the correct development of roots (Vittadini M.R., Bolla D. e Barp A. (a cura di), 2015. *Spazi verdi da vivere. Il verde fa bene alla salute*. Il prato Editore.
http://prevenzione.ulss20.verona.it/docs/Sisp/Ambiente_salute/Spazi_verdi_da_vivere.pdf).
[25] See "*Linee guida per la gestione delle alberature di proprietà comunale nel territorio di Roma Capitale*" (in Italian).

- the resistance to pollutants, especially in the strictly urban environments[26];
- resistance to pathogens and plant parasite[27];
- toxicity (leaves, fruits, sap), aspect to consider in function of the security of citizens (for example, if the new area will be very fruited by children) and in relation to animal biodiversity;
- the frequency of maintenance (for example species with particular needs for water resources), which affects the costs of management;
- longevity, especially in urban areas where the stressors may increase the rate of mortality of individuals.

Regardless of the function that the new forested area will must have, primary aspects to consider are, however, the size and shape of the canopy. In reference to the size in the Green Regulations are generally shown heights of plants at maturity for size classes. For the city of Rome, in urban area, the size classes are so defined in the Regulations of Green and Urban Landscape[28]:

Class size	**Height of plants to maturity**
1st size	> 18 mt
2nd size	12 – 18 mt
3rd size	< 12 mt

For example the Green Regulations of Roma Capitale[29] mentions the following species :

- 1st size: pine (*Pinus pinea*) black poplar (*Populus nigra*), Atlas cedar (*Cedrus atlantica*), etc.;
- 2nd size: holm oak (*Quercus ilex*), Mediterranean cypress *(Cupressus sempervirens*) , elm (*Ulmus minor*), etc.;
- 3rd size: field maple (*Acer campestre*), Judas tree (*Cercis siliquastrum*), privet (*Ligustrum lucidum*), etc.

In general in the planning should be given preference to a mixture of species of various dimensions: this allows a greater stability and resistance of the plant community that is to realize. In addition it will be more aesthetically pleasing and favorable to establishment of more varied habitats for the fauna.

A mixture of species may increase the multifunctionality of forestry intervention, because different species can perform with different effectiveness various functions (mitigation of pollution, CO_2 storage, organication of $NO_{x,}$ encouragement of biodiversity, etc.) .

Even in the case of tree-covered road, it can be useful to design multi-species rows, as in general are often carried monospecific, especially in urban areas (both for aesthetic that maintenance).

For a rational use of the species is also fundamental an adequate knowledge of local soil type and of its hydrological conditions at the end of the installation. In particular, it is important to give priority importance to the acidity, moisture (especially if seasonal or permanent) and porosity.

Nor the component represented by micoflora symbiont and saprophyte had be neglected, because it improves the condition of the soil and the health of the tree species and is supported by plurispecificity of the intervention.

In the Mediterranean context it is appropriate to consider some limiting factors such as the presence of a summer with water stress, and the presence of a dormant period shorter than that of mountain regions (AA.VV., 2010)[30]. Therefore it is necessary to have more tricks in the choice of species and their retrieval, realizing appropriate analysis of flora and vegetation in relation to existing ecological gradients in the areas of plantation (see 1.5).

In the redevelopment of urban areas assumes great importance also planting fruit trees belonging to local rare or endangered cultivars or clones of patriarchs arboreal (a good example was made in Rome

[26] Some species are particularly sensitive to the increased level of air pollution, such as the horse chestnut (*Aesculus hippocastanum*) and some species of oak (Lassini et al., 1998. *Forestazione urbana per la Lombardia*. Regione Lombardia e Azienda Regionale delle Foreste).

[27] Such species, very used in the past, especially in tree-lined rows, are the plane tree (*Platanus* spp.) and elm (*Ulmus* spp.), though both are subject to lethal infections. For example in the square Prato della Valle in Padua the plane trees, infected by canker stain of plane (the last one was shot down in 2011), have been replaced from curly maple trees. The elm, instead, can undergo defoliation by the beetle *Galerucella* elm, whose repeated attacks can weaken the plants predisposing them to other infestations.

[28] The size classes may vary between the various cities according to bioclimatic conditions (e.g. in Turin Class 1 includes trees up to 16 meters).

[29] Regulations of Green and Urban Landscape of Rome is on the definition, but is not yet approved.

[30] AA.VV., 2010. *Analisi e progettazione botanica per gli interventi di mitigazione degli impatti delle infrastrutture lineari*. ISPRA Manuali e linee guida 65.3/2010

in the Villa dei Quintili, in the Regional Park of Appia Antica[31]). In addition to the aesthetic value these interventions also favour the preservation of germplasm and genetic resources .

Following some general principles to consider when choosing species so that the intervention is aimed for: capture of CO_2, mitigation of air and noise pollution, increase of biodiversity. Indications regarding the species that can cause allergy problems, and the use of which must therefore be carefully evaluated, will be also provided.

1.4.1 Criteria for the selection of species appropriate to carbon sequestration

The creation of new forest areas is one of the measures envisaged to contrast climate change[32]. Forests are in fact big sink where carbon accumulates naturally. Private companies that plants a certain number of trees, especially in urban and periurban areas, to offset emissions from some of their activities are increasing[33].

A key aspect for the fixation of carbon in the urban environment is therefore the choice of species that are suited to perform this function as well as the environmental conditions of the site where they will be planted. Specifically to maximize carbon sequestration the following criteria should be adopted:

- to favour fast-growing and long-lived species;
- to favour species that reach large dimensions at maturity;
- to favour species resistant to disease and, in urban areas, to the stress related to pollution. In any case it is important to keep the tree cover, replacing quickly dead individuals;
- to favour species that can reproduce itself and then to renew economically the plantation or to expand spontaneously in areas around;
- to favour fast-growing pioneer species in areas with anthrosols rich in detritus or otherwise thin soils;
- choose different species, but with the same management needs (irrigation, pruning, fertilization, etc.). In particular to give preference to species with low maintenance requirements and which require minimal pruning;
- to preserve the carbon sequestered in the soil reducing conditions affecting the roots: the amount of carbon stored in the soil is in fact 3 times higher[34] than that present in the vegetation; then even small changes can significantly impact the ability to sequester carbon;
- to achieve forestation interventions on surfaces as wide as possible, so as to be planted a greater number of plants.

Species which can be used to maximize the role of CO_2 sequestration are:

- poplars (in Rome *Populus alba*, *P. nigra*, *P. canescens* are indigenous), thanks to their rapid growth. But they may not be suitable in urban environment both as a source of allergies and because potentially subject to collapses. Again they require a large supply of water (therefore it is advisable to plant them in proximity of watercourses[35]);
- white willow (*Salix alba*), a fast-growing species suitable for installations in proximity of watercourses. But it can cause allergies;
- linden (*Tilia cordata, T. platyphyllos, T. x vulgaris*), species typically large and long-lived. Especially the common lime tree (*T. platyphyllos*), not indigenous in Rome, is widely used in the tree-lined road , as well as being aesthetically pleasing, has very fragrant flowers;
- birch (*Betula pendula*), other fast-growing species, but more suited to temperate climates. Moreover, it is not among the native species in Rome[36] and can cause allergies;
- maples (*Acer campestre*, *A. monspessulanus*, *A. platanoides*, *A. pseudoplatanus*), for their growth rate, especially curly maple (*A. platanoides*) which is not native to Rome and is demanding about condition of soils. While *A. campestre* and *A. monspessulanus* are more

[31] See: http://www.viaappiaantica.com/laboratorio-di-mondi-possibili/il-giardino-dei-patriarchi-dellunita-ditalia/
[32] The Kyoto Protocol provides the possibility for signatory countries to use carbon absorption owing to implementation of activities of Land Use, Land Use Change and Forestry for the achievement of objectives established by the Protocol.
[33] Examples include the Life project GAIA ("Green Areas Inner -city agreement") in Bologna, which involves the planting of trees in existing areas and the creation of new green spaces and tree-lines through the contribution of private companies; they will use this contribution to offset emissions resulting from their activities; the aforementioned project Life "*Rome for Kyoto*" which provided for the reforestation of public green area of 12 hectares falling within the Riserva Naturale della Valle dei Casali; the LIFE + Carbomark (*Improvement of policies toward local voluntary carbon markets for climate change mitigation*) in Veneto and Friuli Venezia Giulia, whose overall objective is to promote a local market for carbon credits, on a voluntary basis, to strengthen policies EU concerning the fight against climate change, including the planting of trees in urban areas.
[34] Paci M., 2011. *Ecologia forestale. Elementi di conoscenza dei sistemi forestali applicati alla selvicoltura*. Edagricole.
[35] For example "cupresdsine" poplars were planted in the Aniene Valley Nature Reserve.
[36] A spontaneous formation lives in the SIC Caldara di Manziana, near Rome, but it is linked to particular soil and microclimate conditions.

rustic and adapted to local conditions and also for interventions in pioneer and degraded conditions;

- Turkey oak (*Quercus cerris*), a long-lived and fast-growing indigenous species;
- Lawson cypress (*Chamaecyparis lawsoniana*), introduced species from the United States, very used for experimental forestation, tolerant to pollution and capable of retaining fine dust;
- among shrubs, hawthorn (*Crataegus monogyna*), has a relative fast growth, is a species resistant and needs of low-maintenance. However it is important to retain that it is a shrub with thorns. It can also be a vehicle for the propagation of fire blight (caused by bacterium *Erwinia amylovora*), infection that affects the Rosaceae (including various fruit trees). Its use should therefore be limited in the vicinity of orchards (in some regions of the North is forbidden to implant new individuals).
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1.4.2 Criteria for the selection of species recommended for mitigating air pollution and noise

Urban forestry interventions targeted to reduce air pollution and acoustic fields require a careful choice of the species or of the association of species best adapted, thanks to their autoecological characteristics, as well as environmental ones such as phytoclimate, exposure, water availability and other present vegetal species.

In particular, the creation of green belts is here considered, which can represent not only effective barriers against noise (especially that produced in urban areas by road traffic and, in the periurban areas, including rail and air traffic), but also have other functions such as aesthetic, reduction of light pollution and ecological corridors for the current fauna.

Monospecific green strips ("fifth plant", systems hedges or rows that develop along the line of communication) and bands shrub-tree ("fifth composite") are not considered here, although used, because they are not very functional for the above-mentioned roles and mitigations, and, in addition, they are less resistant to environmental factors and most sensitive to plant health infections.

Some criteria for the creation of mixed systems consisting of multiple species, particularly advisable for shielding the noise and having a positive action in mitigating air pollution, as well as for the supply of other environmental benefits and services, such as those previously defined, are therefore recommended.

In relation to noise pollution, the efficiency of the control of the noise differs between the various species on the basis of phenology, in particular: the foliage characteristics (persistence on the plant[37], thickness of the leaf blade[38], presence of hair and waxes, size of the leaf surface, density and shape of the foliage), the individual habit, the leaves orientation or phyllotaxis and crown density. An example of tree species recommended for the function of shielding the noise is the holm oak (*Quercus ilex*) as evergreen species with thick leaves, dense foliage and compact habit.

Also in reference to air pollution abatement, some peculiarities make some species more effective than others. Among these there are the morpho-anatomical characteristics of the leaves: leaf area, size and shape of the leaves and the foliage, density and morphology of stomata[39], thickness and structure of the cuticle, persistence, etc. Also in relation to the fine particles the greater/lesser ability to capture them is linked to: leaves surface roughness, presence of waxy coatings, hairs, wax and other structures of the epicuticle of the leave.

Different studies show how, on average, trees were more efficient in the capture of the dusts respect to bushes, thanks to their wider leaf area and to the crown structure more articulate and complex. Conifers, in particular the genera *Pinus*, *Picea* and *Cupressus* and in the North also *Abies*, result to be efficient for air pollutants abatement, although they are susceptible to high concentrations of these compounds; for this reason their use in highly polluted contexts is to avoid.

Following, some general criteria to be considered for the choice of species useful to realize green belts able to contribute to the interception of air pollutants and mitigation of noise pollution are shown. The criteria listed are also applicable to the realization of a wider and more complex green system, although with some limitations.

As mentioned in relation to the capture of CO_2, it is essential for the success of the intervention of forestation that species are primarily appropriate to the environment which characterized the site of implantation; among these those with characteristics better suited to the interception and/or absorption

[37] The evergreen species (thus with persistent leaf) perform better shielding function because they ensure continuously to this function. However, deciduous species that during the period of dormancy keep their leaves withered (for example hornbeam, *Carpinus betulus*, and beech, *Fagus sylvatica*) can also be used, to create a green belt aesthetically pleasant even in autumn and winter.

[38] Leaves of greater thickness allow greater energy absorption.

[39] The ability to absorb gaseous pollutants increases with the density of stomata and lesser thickness of the cuticle.

of pollutants and noise mitigation will be identified. Specifically, it should require to follow some recommendations, if possible. In particular, it is recommended:

- to choose always native species, well suitable to the climate and environment of the implant site;
- to privilege tree species with large foliage and tall, preferably characterized by a dense system of branching;
- to prefer long-lived species, so as to ensure for a long time the effectiveness of the green barrier; or varieties resistant to diseases and urban air pollution also because, often individuals are located near roads, thus they could be subjected to the stresses caused by pollution which can make plants potentially more susceptible to infections and parasitosis;
- to choose species with low maintenance requirements, so to reduce the management costs and of the intervention;
- to privilege, as far as possible, evergreen species, while still maintaining a certain variety of species by not incurring problems of green monospecific systems, more vulnerable and critical;
- to favour species with leaves equipped with trichomes, waxes, resins and rough surface, irregularly shaped. Crowns equipped with numerous leaves and of small size are generally more efficient in the interception of atmospheric pollutants;
- another aspect to consider is the characteristic of some species to emit Volatile Organic Compounds (VOC), particularly in urban areas (especially in sites located near sources of pollution, such as roads with heavy traffic). VOC, especially in presence of high concentrations of nitrogen oxides (NOx), may induce to an increase of the concentration of the tropospheric ozone and of the so-called SOA (Secondary Organic Aerosol). It is so necessary to give priority to low-emitting VOC species such as maples, hawthorns and limes;
- near objects (roads, buildings, etc.), it should be preferred species less susceptible to collapse and structural failures and with not superficial root system, so that they can ensure a greater stability and security for citizens and the environment;
- in the creation of green belts, furthermore, it should be reminded the importance of evaluating direction and intensity of the prevailing winds, so to maximise the efficacy of forestry intervention;
- finally, in the implementation of the forestry intervention is important that individuals are arranged properly, in relation to the objective to reach. For example, to limit noise levels it is desirable that plants were arranged continuously and neatly. Concerning to air pollutants abatement, it is appropriate to remind that various studies have shown how important is to maintain air streams inside green belts, so to increase turbulences and to improve interactions between polluted air masses and vegetable surfaces;
- it is therefore necessary to consider, for the choice of implantation system, sizes that the different species (trees and shrubs) will take to maturity. To realize an intervention fully functioning for acoustic and atmospheric pollution mitigation yet in first years after implantation, it should be necessary to adopt preliminary planting patterns to replace later, but this involves significant extra costs, due to different interventions of thinning and new implantations. Therefore during planning phase it is necessary to evaluate if adopt immediately the final planting pattern, taking into account that the full functionality of the intervention will be reached at a later stage, or if, on the other hand, the green belt has to be fully functioning, thanks to the plantation of adult individuals, but at a considerably higher costs.

Some species are more recommended than others for these interventions, because their morpho-functional characteristics make them more efficient in atmospheric pollutants and noise abatement. Among these species, there are:

- maples (*Acer campestre, A. platanoides*), which are particularly resistant to air pollutants, as well as being efficient for the realization of noise barriers and for climate change mitigation actions, such as forestry interventions aimed to the storage of atmospheric CO_2;
- some species of oaks (*Quercus cerris, Q. ilex, Q. robur, Q. frainetto, Q. pubescens*), which represent big, long-lived trees, with large and generally dense foliage. Moreover they are characterized by diversified auto-ecological features which make them suitable for different environments and climates. For the sound-absorbing function can be used turkey oak, downy oak and holm oak, as reminded. However, the use of some oaks must be carefully evaluated

according to the air quality of the chosen site, as they can emit high quantity of VOC; this is the case of holm oak whose use should be limited to areas far from sources of pollutants precursors, because it could tend to facilitate formation of pollutants of secondary origin such as ozone. In peri-urban environment it can be also used the cork oak (*Q. suber*), less suitable in strictly urban environment;

- elms (*Ulmus minor* and *U. montana*), long-lived trees, tall with dense and large foliage, therefore suitable for mitigation of both noise and atmospheric pollution. Both species are used as ornamental trees in urban green; in Rome the first is indigenous;
- lindens (*Tilia cordata, T. platyphyllos, T. x vulgaris*), which in addition to being generally large and long-lived, have dense foliage, all suitable for mitigation of air and acoustic pollution. In Rome grow well even if they are not indigenous and are mainly suitable for the realization of street trees and buffer areas. Furthermore, often their leaves present sticky secretions which can improve the efficiency of holding suspended atmospheric particular matter;
- hackberry (*Celtis australis*), long-lived species, with large and wide canopy, widespread for tree-lined rows and urban green areas thanks to its adaptability and resistance to pollution and large and dense crown which produces shade;
- various conifers, for the reasons above-mentioned (evergreen individuals, greater leaf area, etc.). In the Mediterranean environment species of the genus *Pinus* (e.g. pine *P. pinea*, although it is a species that can cause allergies and not suitable for tree-lined rows because of shallow roots), species of the genus *Cupressus* (such as cypress, *C. sempervirens*), species of the genus *Cedrus* (such as Atlas cedar, *C. atlantica*, ornamental species but of exotic origin). It is important to remind that although conifers are efficient for air and noise pollution mitigation, thanks to their dense and complex crown, however, they are species which suffer of high levels of environmental pollution and, therefore, they should not be placed in environment characterized, for example, by high anthropic emissions;
- among the shrubs, the most common are the heather (*Erica arborea*) and the viburnum (*Viburnum tinus*), both evergreen. They are appropriate for both noise absorbing function and atmospheric pollutants abatement, thanks to their habit which make them suitable for the realization of green belts near the ground, as a support of tree species, such as conifers, which often are characterized by "empty" portions or lacking foliage in the proximity of the ground.

1.4.3 Criteria for the selection of species to increase animal biodiversity

Each animal species has specific ecological requirements, therefore there are not vegetal species more suitable than other for increasing biodiversity. However, it is possible to provide some general criteria, which enable to realize forestry interventions which can contribute to the increase of biodiversity, even if their main function is different (such as capture CO_2, mitigation pollution, etc.).

In detail:

- to favour a mixture of species (avoiding monospecific interventions of forestation) and of various sizes: this helps to create a more diverse habitat for wildlife and permits greater stability and resistance of the plant community (and greater plant biodiversity). The layering of natural forests can be reproduced using appropriate shrub species (e.g. *Cytisus* sp., *Crataegus* sp., *Ligustrum vulgare*). Even in the case of tree-lined street, can be functional for the fauna designing multi-species rows. The variety of species can also facilitate the colonization by soil organisms (bacteria, fungi, invertebrates), essential to maintain over time the new plants;
- to prioritize a variety of planting patterns. In fact, the nature of the arrangement of trees and shrubs is not regular, thus planting new individuals in a way to create a more varied habitat as close to natural conditions;
- to favour native species, so as to contribute to increase even plant biodiversity;
- select also species with flowers and fruits. The presence of flowers helps to increase insect records, which in turn represents a trophic resource for other species (birds, mammals, reptiles). Trees with flowers also have an aesthetic function. Even the fruits (berries, drupes, apples) are a trophic resource for many species, especially birds. The use of trees that produce fruits superseded and/or cones must however be evaluated in situations, as the vicinity of roads, where their fall may represent a security risk The conservation of rare cultivar of fruit tree in the urban park can give an implementation to the conservation of germoplasm. In urban areas interesting interventions of high conservation value and protection of genetic diversity

are the gardens of agricultural biodiversity[40] where variety of fruit trees belonging to rare or endangered local cultivars are reproduced and preserved;

- to favour species with dense foliage and branching, which may represent suitable habitat for nesting. Also the presence of the cavity, especially at the base of the trunk, is a factor which can promote the fauna, which can use them as a shelter;
- to avoid toxic species for wildlife, such as oleander (*Nerium oleander*);
- to increase biodiversity, another intervention than can be designed alongside the forestation is the creation of wetlands, which further diversifying the environment, provides other suitable habitats for the fauna (amphibians, waterfowl, etc.), especially in large areas.

Some species that can be used to increase the animal biodiversity are:

- hackberry (*Celtis australis*), as well as having a large canopy, produces small edible fruits, sweet taste, trophic resource for many birds;
- laurel (*Laurus nobilis*), evergreen species that can be found both as tree and shrub. In addition to being used as a refuge by the fauna, this species can be used to mitigate noise and air pollution;
- various species of the family Rosaceae, including fruit shrubs and trees, are suitable to provide food resources (flowers and fruits) and shelter to wildlife. Among the species are cited, for example, the wild apple (*Malus sylvestris*), cherry (*Prunus avium*) and the canine cherry (*P. mahaleb*, not native in Rome), the common rowan (*Sorbus domestica*) and among the shrubs, hawthorn (*Crataegus monogyna*), blackthorn (*Prunus spinosa*) and cherry laurel (*Prunus laurocerasus*, not native in Rome). Species of other families with similar quality is black elder (*Sambucus nigra*). A problem to evaluate about use of these species is that they are subject to be infected by fire blight (caused by *Erwinia amylovora*). It is therefore appropriate that the Rosaceae are used in association with other species not susceptible to such an infection, in order to avoid the risk of failure of the forestry intervention;
- wild olive (*Olea europeae*), spontaneous form of the olive, long-lived species and rustic withstands, heat-loving and light-loving;
- the poplars (in Rome are indigenous *Popus alba*, *P. nigra* and *P. canescens*) are home to a rich insect fauna (Häne & Kaennel Dobbertin, 2006) [41];
- the Fabaceae shrubs (*Spartium junceum*, *Cytisus* spp., *Emerus major*) and woody labiates (*Teucrium fruticans*) are favourable to the food supply for Apoidea and other Artropoda.

Finally, recently, in addition to the use of fruit species, is spreading also the use of aromatic species (lavender, thyme, red pepper, etc., Figure 4), especially to form ornamental or delimitation hedges (e.g. urban green areas, areas of dogs, etc.). These species, although not arboreal, round up the environment and therefore may contribute to the increase of local biodiversity.

In order to encourage biodiversity is desirable to plan the realization of real urban ecological networks using, for example, the redevelopment of the banks of river waters and the mitigation of the infrastructural network.

[40] For example see Emilia Romagna experiences in: http://www.nuovaterraviva.org/wp-content/uploads/2014/03/fruttetibiodiversita.pdf
[41] Häne, K., Kaennel Dobbertin M., 2006. *Le peuplier noir : un géant aux pieds d'argile*. La Forêt, 7/8.

Figure 4 - *Example of use of aromatic species (lavender) for delimitation hedges*

Following 5 tables are reported, in which species suitable for forestry interventions in the territory of the Rome Municipality are suggested. For each species main ecological characteristics, soil demands, environmental benefits and possible notes are reported. Specifically the following category of species are considered:

- native deciduous trees species (20 species);
- native evergreen trees species (3 species);
- non-native deciduous tree species (10 species);
- non-native evergreen tree species (7 species);
- native shrub species (14 species).

Table 1 - *Characteristics of the main native deciduous trees species with technical and ecological quality for forestry in the Municipality of Rome*

Species or genus	Soil characteristics	Ecological characteristics	Benefits	Notes
Acer campestre	Soil variables as pH and texture; adapted to clay soils.	Heliophilous species, able to withstand the drought season.	Long-lived species of easy rooting. Low potential for ozone formation. Low degree of allergenicity of pollen.	
Acer monspessulanus	Soil variables as pH and texture; adapted to clay soils.	More thermophilic than *Acer campestre*.	Long-lived species of easy rooting. Low potential for ozone formation. Low degree of allergenicity of pollen.	
Alnus glutinosa	Soils with high water table.	Typical species of alluvial areas.	Resistant to pollution. It promotes the quality of the soil and air by means of nitrogen-fixing bacteria (*Frankia alni).*	High degree of allergenicity.
Cercis siliquastrum	It's adapted to poor soils and arid.	Heliophilous and xerophile.	Resistant to pollution.	
Celtis australis	Prefers stony, basic and well drained soils. Optimal pH 7,0-8,0.	Pioneer species resistant to drought.	It can be used in ruderal areas. Important for wildlife. Resistant to pollution.	
Ficus carica	It prefers loose or stony soils and does not tolerate those too compact or with stagnant water	Rustic species without special needs, however, is sensitive to temperatures < 8° that can kill the entire plant.	Resistant to pollution. Suitable for the establishment of noise barriers.	
Fraxinus ornus	Undemanding, It's adapted to basic stone or clay barren lands.	Thermophilic and xerophile species able to colonize rocky places. Good ability to engraftment of post - agricultural soils. Pollen is pleasing to Apoidea.	Low potential for ozone formation. Suitable for the creation of noise barriers.	Degree of allergenicity moderate to high.
Malus sylvestris	Fertile and never very arid soils with pH close to neutral.	Temperate species, in the Mediterranean areas like mesophilic stands with good water availability in summer.	It promotes animal biodiversity.	
Populus alba	Indifferent to the pH It needs of a large supply of water.	Hygrophilous fast growing species.	It colonizes quickly damp surfaces producing new shoots from the roots. Effect of phytoextraction and phytostabilization of pollutants such Zn,	It is potentially subject to collapses. It is employed in environmental recovery and bio-energetic purpose.

Species or genus	Soil characteristics	Ecological characteristics	Benefits	Notes
			Cd, Pb e Na. It can accommodate a rich insect fauna.	Low to moderate degree of allergenicity.
Populus nigra	Prefers moist soil, nutrient-rich, alkaline pH. Require land not too clayey and with high water table.	Hygrophilous fast growing species.	It is able to fix the heavy metals present in the soil. Phytodegradation action for different pollutants . It can accommodate a rich insect fauna.	It is used for the protection of alluvial areas and upgrading of the waterways. Low to moderate degree of allergenicity.
Populus canescens	It usually grows on alluvial soils above the *Populus nigra* and *Salix alba* belt.	Mesohygrophilous species.	It can accommodate a rich insect fauna.	It is used for the protection of alluvial areas and upgrading of the waterways. Low to moderate degree of allergenicity.
Prunus avium	Fertile well drained but never very dry soils, with pH close to neutrality.	Mesophilic areas, it grows well in the undergrowth of oak thermophilic woods if the soils are adequate.	Conducive to animal biodiversity. Fast growing species. Low potential for ozone formation.	
Pyrus spinosa (=Pyrus amygdaliformis)	Indifferent to soil type.	Heliophilous, xerophilous and thermophilic species. It is widespread in the range of holm and thermophilic oaks.	Species with good naturalistic functionality recommended for environmental restoration. It favours the presence of birds useful in the biological control of potentially harmful insects.	
Quercus frainetto	It adapts to all land, however, preferring those fresh, fertile and deep, with acidic pH or sub acid. It shuns those very calcareous.	Supramediterranea species widespread in Italy in the range of *Quercus cerris* woods.	Biodiversity protection.	It is a species which in Italy has many problems of renewal, because very sensitive to competition and to change of soil uses. In Rome was to be much more common in the past.
Quercus cerris	Loose fertile , acid and sub-acid soil (optimum pH < 6.5).	Relatively mesophilic species, more xerophile of English Oak and Durmast Oak and less than Downy Oak.	Long-lived species with low potential for ozone formation. Effective sound-absorbing function. Low degree of allergenicity of pollen.	It characterizes most of the natural forests of the City of Rome.
Quercus pubescens	Indifferent to the ground, it grows best on basic soils	Thermophilic, xerophile and basophilous species.	Very adaptable and long-lived species. Effective sound-	

Species or genus	Soil characteristics	Ecological characteristics	Benefits	Notes
	(optimum pH > 6); it can grew on pioneers and also clayey soils, but well drained.		absorbing function. Good ability to colonize post - agricultural lands. Low degree of allergenicity of pollen.	
Quercus robur	It likes deep, fresh, fertile from sub-acid to subalcaline soils, with good water availability throughout the year, even with the surface water table; It shuns those too compact.	Temperate species, in the Mediterranean climate it's limited to alluvial areas.	Long-lived species with relatively rapid growth than other oaks. Low degree of allergenicity of pollen.	In its natural state in the Campagna Romana is confined to areas with high water table or wet for much of the year.
Salix alba	Indifferent to the pH it needs of soils with good water availability throughout the year.	Typically riparian species.	Fast-growing species suitable for installations in the vicinity of watercourses. Tolerates air pollution. Low degree of allergenicity of pollen.	Not recommended for cultivation in the vicinity of buildings or duct systems, that can be damaged by the roots.
Sorbus domestica	The best conditions for growth are offered by basic, deep and rich texture soils.	It is widespread mainly in the range of thermophilic sub-Mediterranean oaks.	Conducive to animal biodiversity.	
Ulmus minor	Fertile and never very dry soils.	Mesophilic and also ruderal areas (embankments of infrastructure).	Effective in mitigating both acoustic and atmospheric pollution.	Sensitive to Dutch elm disease.

Table 2 - *Characteristics of the main native evergreen trees species with technical and ecological quality for forestry in the Municipality of Rome*				
Species or genus	**Soil characteristics**	**Ecological characteristics**	**Benefits**	**Notes**
Laurus nobilis	Poor but relatively wet even in summer soils.	Mediterranean species of wet places.	Low potential for ozone formation. Effective in mitigating noise and air pollution. It reproduces easily.	In the "Parco del Litorale Romano" rare natural formations survive.
Quercus ilex	It prefers poor alkaline dry in summer soils, but it is also adapted to acidic soil relatively moist.	Mediterranean species adapted to summer drought.	Effective sound-absorbing function. Long-lived species.	It emits VOC. Moderate degree of allergenicity. It is widespread in natural state in the coastal area of the City.
Quercus suber	Acid and sandy soils.	Mediterranean species adapted to summer drought.	Low potential for ozone formation. Long-lived species.	In urban area significant natural cork survive.

Table 3 - *Characteristics of the main* non-native deciduous tree species *with technical and ecological quality for forestry in the Municipality of Rome*				
Species or genus	**Soil characteristics**	**Ecological characteristics**	**Benefits**	**Notes**
Acer platanoides	Loose soil with excellent drainage. Optimum pH: 5.5 - 7.	In the Italian peninsula is mainly mountainous species.	Low potential for ozone formation. Good resistance to air pollution. It requires low maintenance and it has a good wind resistance.	At low altitudes it needs of never dry areas and deep soils.
Acer pseudoplatanus	Well-drained soils, both acidic and alkaline.	In the medium-Tyrrhenian it is typical in moderate climates within the Apennines.	Low potential for ozone formation. Phytostabilization action for Zn, Cd, Pb e Na.	
Acer lobelii	Fertile soils and humid for most of the year.	It is a species typically Apennine.	Low potential for ozone formation.	Endemic species of southern Italy has been planted successfully in some Roman gardens.
Alnus cordata	It can grow on various types of soil, but in the Roman climate never too dry.	Mesoigrophilous species, more adapted to summer drought than *Alnus glutinosa*.	Good naturalistic functions. Good suckers capacity. It enriches soils.	Endemic species of southern Italy.
Betula pendula	It is suitable both to poor that with a deep layer of organic material soils, both in rich water soils to very drained soils. It bears values of soil pH up to 3.3.	Species distinctly heliophilous of cool temperate climate.	Colonizing species with good sprouting ability (even root suckers).	In Italy it is widespread, especially in mountain and becomes rare in the south.
Juglans regia	It needs of very fertile and rich in nitrogen soils; it does not like firm ground.	Species distinctly heliophilous.	Fast growing in juvenile stages.	
Platanus hybrida	It grows well on clay, deep, rich in humus, moist soils, but it's also adapted to rich in nutrients anthrosols.	Heliophilous and well adapted to Submediterrranean and Mediterranean conditions.	Resistant to pollution and pruning. Weatherproof. Rapid growth in juveniles stages.	Hybrid between *Platanus occidentalis*, North america, and *Platanus orientalis*, widespread in southern Europe. Prone to infections (*Macrocystis fimbriata*). It can cause allergies.
Populus tremula	Indifferent to the pH it can grow on very poor soils and it is less tied to moisture than other *Populus* species.	Hygro-mesophilic heliophilous species. In the Tyrrhenian coast is primarily a species of the mountain belt.	Pioneer fast-frowing species in juveniles stages. High capacity of roots suckers.	This poplar species is characterized by the impossibility of propagation by cuttings.

Table 3 - *Characteristics of the main* non-native deciduous tree species *with technical and ecological quality for forestry in the Municipality of Rome*				
Species or genus	**Soil characteristics**	**Ecological characteristics**	**Benefits**	**Notes**
Tilia cordata	It prefers fertile soils with pH neutral not very acidic.	Mesophilic sciaphilous species, less thermophilic than *T. platyphyllos*.	Effective in mitigating both acoustic and atmospheric pollution.	
Tilia platyphyllos	It likes fresh, drained and deep, neutral or sub - alkaline soils. It not tolerate acidic pH in depth; in these soils is replaced by *T. cordata*.	More heliophilous than *Tilia cordata*; it does not tolerate extreme cold and prolonged drought.	Effective in mitigating both acoustic and atmospheric pollution.	
Ulmus montana	Fertile and never very dry soils.	It likes mesophilic areas.	Effective in mitigating both acoustic and atmospheric pollution	

Table 4 - *Characteristics of the main non-native evergreen tree species with technical and ecological quality for forestry in the Municipality of Rome*				
Species or genus	**Soil characteristics**	**Ecological characteristics**	**Benefits**	**Notes**
Cedrus atlantica	Adaptable to soils of different texture, but without standing water.	Quite temperate species. Sun-demanding increases with age.	Long-lived species. Efficient in mitigating noise and air pollution.	Species native to the northwest Africa.
Cedrus deodara	Rich and deep, well drained soils. Indifferent to the pH.	Heliophilous species, it fears frosts and prolonged waterlogging .	Efficient in mitigating noise and air pollution.	Native of the western Himalaya slopes. Sensitive to air pollution.
Cedrus libani	It likes sandy, poor, weak and acid soils, but it grows easily in any terrain, including alkaline and clay.	In nature it grows along the limestone slopes facing north, in the mountain plain.	Efficient in mitigating noise and air pollution.	Native of the Eastern Mediterranean.
Cupressus sempervirens	Indifferent to the substrate, it can grows on degraded, dry and poor soils.	It is a thermophilic species and suffers the prolonged cold.	Efficient in the capture of the dusts.	Subject to Cortical cancer (*Seiridium cardinal*). Plant typical of the Italian landscape although native to Asia Minor and the Eastern Mediterranean. High degree of allergenicity.
Olea europea	It prefers well-drained, even shallow, rocky soils. It suffers in heavy and not well drained soils.	Thermophilic and heliophilous Mediterranean species, with strong xerophilous characters.	Good naturalistic features. It is recommended for environmental restoration measures. Conducive to animal biodiversity. Low potential for ozone formation.	In Rome it is not indigenous although it is cultivated for thousands of years.
Pinus halepensis	It adapts well to all soils, even dry and chalky, but not wet.	Mediterranean pioneer and thermophilic species.	Efficient in the capture of the powders. Low degree of allergenicity.	It is to be considered sub-spontaneous only in Roman coast soils of "Duna recente".
Pinus pinea	It adapts to various soils except those too wet or with stagnant water; it is resistant to high doses of limestone only on sand.	Heliophilous, thermophilic and xerophilous Mediterranean species.	Efficient in the capture of dusts.	Although not native in Rome it grows very well. Not suitable for street trees because of the roots. Producing terpenes that can promote the production of ozone

Table 5 - *Characteristics of the main native shrub species with technical and ecological quality for reforestation in the Municipality of Rome*				
Species or genus	**Soil characteristics**	**Ecological characteristics**	**Benefits**	**Notes**
Arbutus unedo	Loose, even very dry soils.	Heliophilous Mediterranean species resistant to summer drought.	Species with low potential for ozone formation.	In the City of Rome it is widespread in the coastal area.
Cistus salvifolius	Loose acidic soil.	Heliophilous Mediterranean species resistant to summer drought.	Good technical functionality, recommended for naturalistic engineering.	It is widespread on sandy siliceous soils of Roman countryside and coastline.
Crataegus monogyna	It grows on different pH and texture soil, but prefers those with basic chemistry.	Resistant to summer drought.	Species with low potential for ozone formation. Good technical functionality, recommended for naturalistic engineering. Easy reproduction.	Component of spontaneous bushes.
Cytisus scoparius	Acidic loose and sandy soil.	Pioneer calcifuge species.	Good naturalistic functionality.	Component of spontaneous bushes of Campagna Romana.
Cytisus villosus	Siliceous and dry substrates with acid pH.	Mediterranean species resistant to summer drought.	Good naturalistic functionality.	Component of spontaneous bushes and of undergrowth of cork of the Campagna Romana.
Erica multiflora	Basic, loose and poor soils.	Heliphilous Mediterranean species resistant to summer drought.	Good naturalistic functionality Recommended for environmental restoration measures .	Typical of vegetational succession on “Duna recente” in the coastal zone of municipality.
Pistacia lentiscus	It is adapted to pioneer soils.	Heliphilous Mediterranean species resistant to summer drought.	Good naturalistic functionality. Recommended for environmental restoration measures.	Spontaneous species in the coastal area of the City.
Prunus spinosa	Soils rich in salts and humus.	Heliophilous species that participates in processes for natural reforestation.	Good naturalistic functionality. Recommended for environmental restoration measures. It reproduces easily.	Component of spontaneous bushes.
Rosa canina	Variables texture soils but fertile and never very dry, with pH from basic to slightly acidic.	Heliophilous species resistant to summer drought.	Good naturalistic functionality. Recommended for environmental restoration	Ornamental value. Optimal rootstock for cultivars of aesthetic value.

Table 5 - *Characteristics of the main native shrub species with technical and ecological quality for reforestation in the Municipality of Rome*				
Species or genus	**Soil characteristics**	**Ecological characteristics**	**Benefits**	**Notes**
			measures.	
Rosa sempervirens	Poor and pioneer soils.	Mediterranean species that penetrates the deciduous oaks woods.	Good naturalistic functionality. Recommended for environmental restoration measures. It reproduces easily.	Component of spontaneous bushes.
Rosmarinus offinalis	Sandy soils calcareous.	Pioneer Mediterranean species resistant to summer drought.	Good naturalistic functionality. Recommended for environmental restoration measures.	Spontaneous species in the coastal area of the City.
Spartium junceum	It likes clay substrates, but grows well on poor, stony and sloping soils.	Settler species of abandoned pastures and fields.	Good technical functionality, recommended interventions for bioengineering. It reproduces easily.	Component of spontaneous bushes.
Teucrium fruticans	Dry and well drained soils.	Mediterranean species resistant to summer drought.	Good naturalistic functionality. Recommended for environmental restoration measures.	In Rome is locally subspontaneous although not properly belonging to the indigenous flora.
Viburnum tinus	Dry and well drained soils; suitable for use on poor and sandy soils.	Species typical of the Mediterranean evergreen forests and shrubs.	Soundproofing quality and efficient mitigation of air pollution.	

Box 2 - *Urban green spaces and allergies to pollens: recommendations*

Pollens represent the male part (male microgametophyte) in the reproductive process of seed plants. Pollen grains are characterized by a protective double wall: an external one (called *exine*) and an inner one (called *intine*).
When the pollen is mature, it is released for pollination and can reach the female part of the flower by wind (anemophilous plants) or by insects (entomophilous plants), water, birds and other animals[42].
Generally, pollens that cause allergies:

- come from anemophilous plants[43],
- contain certain substances called allergens that, in genetically susceptible people, stimulate the immune system to produce antibodies,
- are produced in large amounts by plants very common in the area[44].

The external wall of the pollen grain contain specific proteins that help pollen grains to be recognized by the female part of the flower. These proteins are responsible for allergic reactions in sensitive people, and act as antigens, stimulating the immune system to produce antibodies (IgE).
When antibodies meet antigens, chemical mediators are produced, such as histamine, to trigger the inflammatory process at the base of allergic symptoms (rhinitis , conjunctivitis, asthma etc.).

Pollen concentration in the air depends mostly on the presence and distribution of plants in the area, and on weather-climatic variables such as wind, humidity, temperature and rainfall.
Climate change can affect pollens production: rising temperatures are associated with increase in length and earlier beginning of pollen season, spread of invasive species and, in combination with high CO_2 concentrations, to an increased production of pollen.

The pollen allergenicity level, the ability and the extent of the pollen grain to induce allergic reactions, has been estimated for many trees, shrubbery or herbaceous species in several studies.
This knowledge has been used by ARPA Emilia Romagna to organize botanical data sheet, where four level of allergenicity are identified: low, moderate, high and very high .

The level of allergenicity of most common species are summarized in following Table. Must be taken into account that the level of allergenicity may also change with different local climatic pattern.
Furthermore, in urban areas the high concentration of air pollutants which will lay down on pollens and carried by them, can amplify the allergenicity of pollens and make people more susceptible to them.
In Italy, as well as in Europe, the increase of pollen-sensitive population requires certain safety measures in the selection of species for green spaces that are suitable for recreational use (parks, gardens, green school areas, etc.), among these measures is suggested:

- to use native species with low-allergenic pollen;
- to use female or sterile plants in the case of species with moderate-very high allergenic pollen;
- to use plants with entomophilous pollination;
- to organize maintenance services of grassy meadows (e.g. mowing) before blooming period to prevent pollen spread;
- to avoid the use of stinging or poisonous plant species (e.g. *Gleditsia triacanthos L.* - honey locust - thorny locust; *Robinia pseudoacacia* L.- False acacia or black locust) or toxic (e.g. *Nerium oleander* L. – Oleander; *Taxus baccata* L.- English yew, or European yew; *Laburnum anagyroides* Meddik - Common Laburnum, Golden Chain or Golden Rain).

In Italy some of these measures were also introduced in regional regulations, such as in the Tuscany Region[45].

[42] "Pollini". Edited by Arpa Umbria , University of Perugia - Faculty of Agriculture, Asl 1 Umbria .
http://www.arpa.umbria.it/resources/documenti/print%20pollini_web.pdf
[43] Some entomophilous species, which produce lower amounts of pollen and rely on insects for pollination dispersion, may still be allergenic.
[44] The anemophilous plants produce large amounts of pollen grains, invisible to the eye, and carried by the wind at long distances.
[45] Tuscany Region - Regulations for the Construction Bio - Eco Sustainable (RES) 2nd edition , 2012.

Table - *Trees, shrubbery and herbaceous species and their pollen allergenicity*
(Source: ARPA EMR– Dept. IdroMeteoClima[46] - Modified by ISPRA)

Category	Family	Gender/Species	Level of pollen allergenicity
	Aceracee	*Acer campester* L. (Maple) *Acer platanoides* L. (Norway maple) *Acer pseudoplatanus* L. (Sycamore) *Acer monspessulanum* L. (Montpellier maple) *Acer opalus* Muller (Italian maple) *Acer negundo* L. (Manitoba maple)	low
	Amarantacee	*Amaranthus retroflexus* L. (Red-root amaranth)	low - moderate
	Betulacee	*Alnus glutinosa* L. (Black alder) *Alnus incana* L. (Grey Alder) *Alnus cordata* L. (Italian Alder) *Betula pendula* R. (Silver birch)	very high
	Chenopodiacee	*Chenopodium album* L. (White goosefoot)	low - moderate
	Composite (Asteraceae)	*Ambrosia artemisiifolia* L. (Common ragweed)	very high
		Artemisia vulgaris L. (Mugwort , common wormwood)	high - very high
		Taraxacum officinale Weber (Common dandelion) *Matricaria chamomilla* L. (Chamomile) *Helianthus annuus* L. (Sunflowers)	low
	Corilacee	*Corylus avellana* L. (Common hazel)	very high
		Ostrya carpinifolia Scop. (Hop hornbeam) *Carpinus betulus* L. (European or common hornbeam)	moderate
	Cupressacee	*Cupressus sempervirens* L. (Mediterranean cypress) *Juniperus communis* L. (Common juniper) *Thuja orientalis* L. (Chinese arborvitae) *Thuja occidentalis* L. (Arborvitae)	high - very high
	Fagacee	*Quercus robur* L. (English oak) *Quercus pubescens* Willd. (Downy oak) *Quercus petraea* (Matt.) Liebl (Sessile oak)	low
		Quercus ilex L. (Evergreen oak) *Fagus sylvatica* L. (European beech) *Castanea sativa* Miller (Sweet chestnut)	-moderate
	Graminacee	*Avena fatua* L.(Common wild oat) *Phragmites communis* Trin. (Common reed)	low
		Hordeum marinum L. (Sea barley) *Holcus lanatus* L. (Yorkshire fog)	- moderate
		Setaria glauca L .(Pearl millet) *Anthoxanthum odoratum* L. (Sweet vernal grass)	-moderate - high
		Bromus scoparius L. (Brome grasses,)	moderate - very high
		Alopecurus pratensis L. (Meadow foxtail)	high - very high

[46] http://www.arpa.emr.it/dettaglio_generale.asp?id=403&idlivello=553)

		Cynodon dactylon (L.) Pers. (Bermuda grass, dog's tooth grass) *Dactylis glomerata* L. (Cock's-foot ,orchard grass) *Festuca calva* (Hack.) K. Richt. (Fescue, hay) *Lolium* sp. (Ryegrass) *Phleum pratense* L. (Timothy-grass) *Poa pratensis* L. (Kentucky bluegrass, smooth meadow-grass) *Zea mais* L. (Maize, corn)	very high
	Oleacee	*Fraxinus excelsior* L. (European ash) *Fraxinus ornus* L. (Manna ash ,South European flowering ash)	moderate - very high
		Olea europea L. (Olive)	very high
	Pinacee	Pinoideae: *Pinus* spp. (Pines) Laricoideae: *Larix* spp. e *Cedrus* spp. (Larches e Cedar) Abietoideae: *Picea abies* L.(Norway spruce) e *Abies alba* Mill.(Silver fir)	low
	Plantaginacee	*Plantago lanceolata* L. (English plantain, narrowleaf plantain) *Plantago major* L.(broadleaf plantain , greater plantain)	low
	Platanacee	*Platanus hybrida* Brot. = *acerifolia* = *hyspanica* (London plane)	low
	Poligonacee	*Rumex* spp.(Dockweed) *Polygonum* spp. (Knotweed)	low
	Salicacee	*Populus nigra* L. (Black poplar) *Populus alba* L. (Abele, silver poplar)	low - moderate
		Salix alba L. (White willow)	low
	Taxacee	*Taxus baccata* L. (English yew, European yew.)	low o
	Ulmacee	*Ulmus minor* M. (Field Elm) *Celtis australis* L. (European nettle tree) *Zelkova carpinifolia* (Pall.) K. Koch (Caucasian elm)	low
	Urticacee	*Urtica* spp. (Nettles, stinging nettles)	low
		Parietaria spp. (Lichwort)	very high

Box 3 - *Soil consumption in Italy and EU guidelines to limit, mitigate and compensate soil sealing*

The negative impacts of the loss of this important and limited environmental resource are well recognized at scientific level. Also at political level, the need to limit urban sprawl and soil sealing, which are the main causes of soil consumption, is well recognized.

The objective of land take limitation was set up at European level already with the thematic strategy for soil protection in 2006, which stressed the need to implement best practices for reducing adverse effects of artificial land use and, in particular, of soil sealing. This overall objective was confirmed in 2011, with the roadmap towards a resource-efficient, with the target of no (zero) net land take in Europe in 2050. Objective strengthened by Parliament with the approval of the 7th environmental action programme in 2014. Year 2015 was also proclaimed by the General Assembly of the United Nations “International Year of Soils”, a proclamation that underlines how the soil represents the essence of life, an essential resource for maintaining the entire ecosystem and the natural heritage.

However, in Italy and in our cities we continue to increase artificial land cover, often without concern for agricultural activities, areas of high environmental value or hydrogeological characteristics. A unpleasant fate for the Italian fragile land and soil, that are lost at a speed of 7 square meters per second, with an irreversible damage to our well-being and the environment. A process often poorly regulated, which led to dramatic results: our country has a level soil consumption among the highest in Europe. The phenomenon reached intolerable levels in some of the most important areas of our territory: the plains and the most productive agricultural areas (soil consumption in Pianura Padana risen to 12%), the most famous coastal areas, the shores of rivers and lakes and even the 9% of flood hazard zones, increasing population risk. Nearly 20% of Italian coastline is lost irreversibly. It is built at 19.4% (over 500 Km2) of land between 0-300 meters away from the shoreline and almost 16% between 300 and 1,000 meters. Coastal areas with the highest values of soil consumption are in Liguria, in northern Tuscany, in the provinces of Roma and Latina, in good part of Campania, Puglia and Sicily, and along the Adriatic coast from Ravenna and Pescara. In Liguria and Marche artificial land cover within 300 meters from the coast is about 40%. (Figure 1, Figure 2).

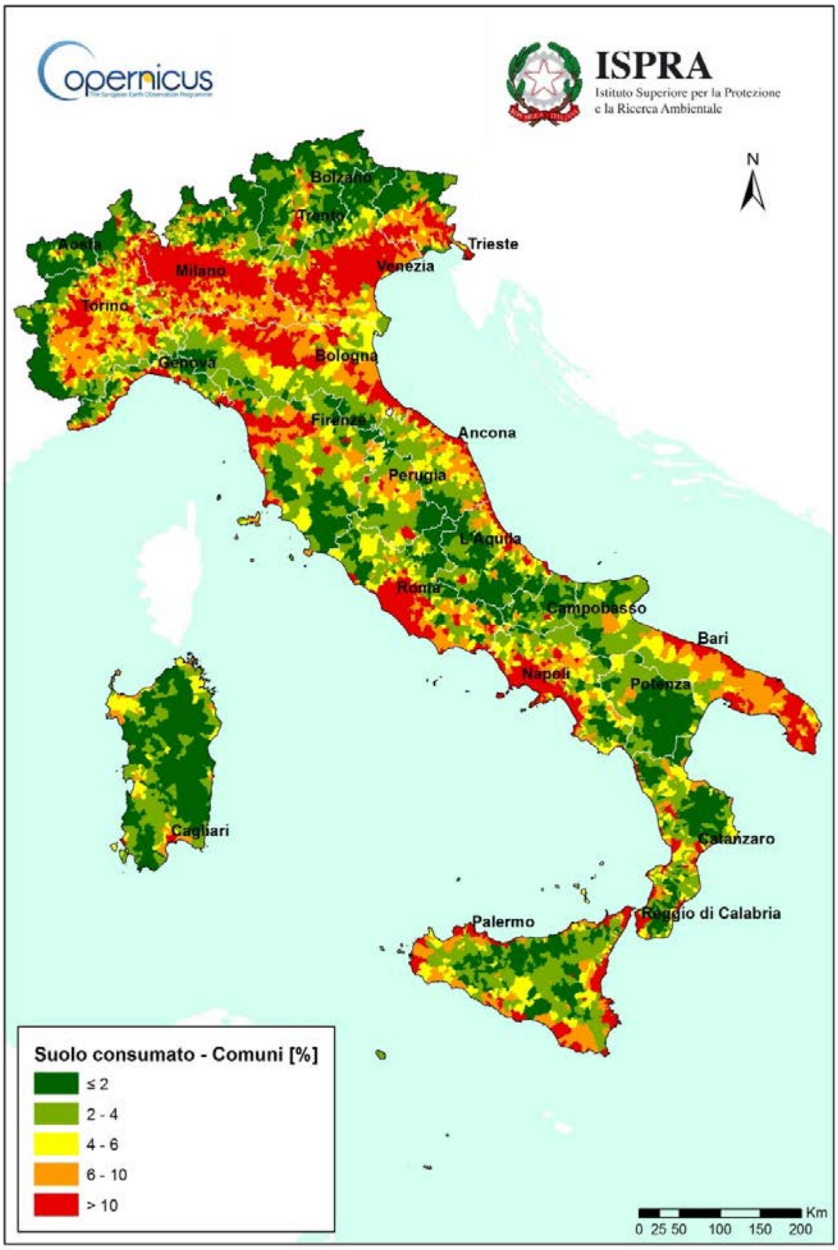

Figure 1 – *Percentage of soil consumption for Municipality (2012). Source: ISPRA*

Moreover, the dispersion of low density urban sprawl increases the overall artificial land use and, most importantly, boosts its negative effects on the territory, for example, in terms of habitat fragmentation and loss of productivity. In Italy, over the past two decades, nearly 40% of large urban transformations took place through the creation of low-density areas, while over a third took place with the construction of new commercial, industrial and tertiary areas. A typical process of urban sprawl in which we lose the distinction between urban and countryside area, amplifying the negative impacts on natural ecosystems.

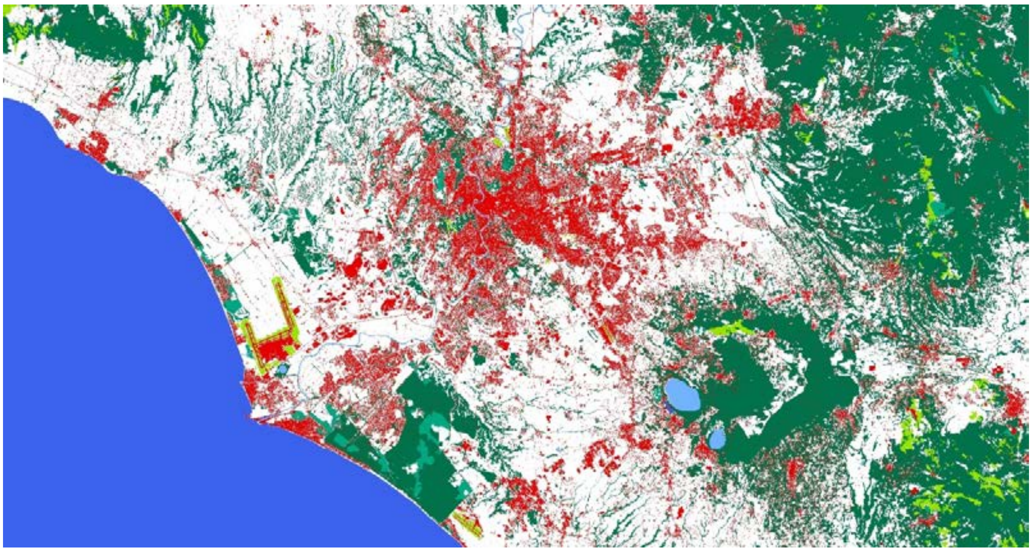

Figure 2 - *Soil consumption in Rome (red)*

Cities continue to expand quickly, with a continuous process of diffusion in the last decades, by subtracting quality through the creation of small-medium size outside the main centers, the growth of metropolitan areas scattered around the margin, joining centres inhabited areas at low and very low density in a continuum that cancelled the city limits landscape. A high natural fragmentation and a lack of identity of urban spaces scattered and without cohesion characterize these areas. Diffuse and dispersed urbanization produces not only loss of landscapes, soils and its ecosystem services, but is also an energy-intensive and settlement pattern predisposing to the spread of private mobility system.

It is therefore clear that, even in our country, it is extremely urgent to define an effective policy of restricting artificial land use, through the setting of clear and progressive objectives. This means preventing the conversion of green areas and the resulting artificial land cover. We should promote the reuse of already built areas, including brownfield regeneration. We should invest in the existing building patrimony, to stimulate the reuse of already compromised soils and urban regeneration, protect all undeveloped areas and not sealed, even in urban areas, and not only agricultural areas. In many European countries were already set target to be used as tools for monitoring purposes and to stimulate progress in the future. Creating incentives to rent unoccupied houses has also helped to limit soil sealing.

Where the soil is already lost or is expected a new urban expansion or new infrastructures, we should adopt mitigation measures in order to maintain at least some of the ecological functions of the soil and to reduce the direct or indirect negative effects to environment and human well-being. Such measures include, for example, evaluation and comparison of soil quality in urban planning processes, with the localization of the new development in lower quality soils, the use of appropriate permeable materials instead of concrete or asphalt, support for green infrastructure and an increasing use of natural systems to collect water.

In urban areas, for example, green roofs and vertical green (Figure 3) are becoming an element characterising different architectural projects, both for new buildings and for regeneration and requalification. The "green architecture" recuperates the building envelope and create a new opportunity for the greening of our cities, replacing the gray concrete. These choices give value to the buildings and offer to the city the ability to change with the seasons, resulting in ever new shapes and colours, and especially to do it in full sustainability.

In addition, for its peculiarity, the green wall, as well as the roof garden, increases the aesthetic value of a building and the public interest. This "green card", as well as improve eco-friendly, it also guarantees the economic rise of the property and the surrounding area and can be one of the founding elements of an urban redevelopment project. In fact, these architectural choices give a considerable contribution to improving the urban image, with a feeling of greater well-being and providing an ideal solution for recreating the green in compact urban or degraded areas.

Finally, these solutions constitute a space for environmental compensation, creating habitats for plants and animals, ensuring the improvement of microclimate, sound isolation, filtration of dust and pollutants and increasing biodiversity in urban areas.

Figure 3 - *Example of vertical green*

1.5 Selection of the propagation stock

Selection of the propagation stock is another important aspect to take in account for a successful forestry intervention: in fact it is necessary to choose carefully arboreal individuals for guaranteeing quality, health (no injuries and/or plant diseases) and, when possible, genetic state. It is important that vegetal material to use was in compliance with declared species and varieties, exempt from structural flaws, injuries and infections, provided with a normal and healthy root apparatus. It has to be examined also breeding manner, choosing between root ball or container[47], as naked root involves problems of taking root, resulting in a fail of planting.

Better results from an ecological and functional point of view are obtained through the breeding of spontaneous species, present in the residual vegetal associations inside urban pattern or in their surroundings.

Unfortunately, plants supply often represents a problem, because, currently a real planning of forestry interventions at National scale is missing. Therefore, very often it is requested to nursery gardens propagation stock that is not immediately available, with resulting delays and/or changes in species selection. Instead, a propagation material of quality reduces the risk of a scarce implants survival and allows a successful forestry intervention. In particular, when choosing trees, it is opportune to assess the following aspects:

- trunk structure, that should be upright and without injuries/alterations, especially on root collar (which is the portion of the tree between the trunk and the root, at ground-level);
- the shape of the crow, that should be symmetrical and display a regular branching, without drastic cuts;
- the correct proportion between height and diameter[48];
- a healthy root apparatus, well structured and with an adequate number of roots. In particular it is necessary to verify the possibly presence of circling and/or spiral roots, which during growing could cause problems to plants. Moreover for plants in clod, it is necessary to control that the root ball is of dimensions appropriate to those of the plant;
- age and dimensions, to select also in relation to planting pattern. As general rule, it should be expedient prefer young individuals, which start to grow again quicker and stronger respect to plants of greater dimensions (and age).

It is advisable that these characteristics are assessed by experts, both in the nursery garden and in the installation site (to control that plants did not be subjected to damages during handling).

While the majority of tree species is available on the market, some difficulties can be found for shrubs, for which the offer of the market is reduced (with considerable lack for some species of genus *Salix*, *Cytisus* etc.) (Cornelini et al., 2002)[49]. In particular in Mediterranean area, due to limiting factors above-mentioned (cf 1.4), it could be more difficult to find suitable species, because common autochthonous species available in nursery garden not always are consistent with the Mediterranean vegetation succession (AA.VV., 2010)[50].

[47] In Italy, the use of root balls (clods) is widespread, as it allows plants to grow on substratum similar to those of destination. In this case, however, it is fundamental to realize transplantations in the nursery garden to allow a correct roots development. Moreover plants in clods are much expensive. Plants in container are generally lighter and do not depend on soil seasonality, as the substratum can be prepared on the basis of specific needs. However it is necessary to pay more attention during both the repotting and the bedding out, to avoid spiral or damaged roots. Generally, naked root are not used, except in shifts among nursery gardens.

[48] For example at a diameter of 20-25 cm should correspond an height of 5,5-6 meters; for a plant with a trunk circumference of 40-45 cm, height has to be about 8 - 10 meters.

[49] Cornelini P., Palmeri F., Sauli G., 2002. *Le specie autoctone da impiegare negli interventi di ingegneria naturalistica*. Acer n.6.

[50] AA.VV., 2010. *Analisi e progettazione botanica per gli interventi di mitigazione degli impatti delle infrastrutture lineari*. ISPRA Manuali e linee guida 65.3/2010.

2. REALIZATION

After planning, the following step is the realization of the forestry intervention, which will be successful as much the planning has been accurate. In addition to more “operational” steps, such as bedding out of plants, it is important to examine also the first maintenance activities, fundamental in order that every plant roots well and survives for long time. Generally, the minimum period to be sure of the achievement of forestry intervention is about 3 years[51], also if some maintenance interventions could last more.

Following are analyzed the main steps for the realization of a model forestry intervention (independent from the function that the new area will must have):

1. Preparatory activities: all the activities necessary to analyze and to prepare the soil will be examined (such as rock removal, weed removal, etc.);
2. Implantation: all aspects connected to bedding out of trees/shrubs will be examined (such as the time and way of planting, planting pattern, digging, etc.);
3. First maintenance: interventions necessary after the bedding out of plants will be analyzed (irrigation, soil surface processing, etc.).

2.1 Preparatory activities

All the activities necessary to correctly prepare the soil are essential for the achievement of the forestry interventions, because they create suitable conditions for the further steps. Preliminary activities vary in relation to the site characteristics: a disused area will request major interventions (such as reclamation) respect to, for example, an untamed area. In this phase, then, it is extremely important to consider all the previous analysis realized during planning, with particular reference to soil and botanical characteristics (cf. 1.2).

Following, all the main procedures to realize before the bedding out of plants are analyzed. Not all of them are always required: for example in sites located inside a protected area it is probable that rock and weed removal will be not necessary.

2.1.1 Rock removal

This procedure is indispensable in degraded areas (such as disused areas, abandoned sites in urban areas, etc.), while in natural/seminatural areas it is better to avoid it if the rockiness is of natural origin. It is an intervention to be considered yet during planning, because equipment, time and ways can request quite high economic resources.

In every case, all waste and building residues must be removed in the site.

2.1.2 Weed removal

Vegetal pest species frequently settle in abandoned areas, and they should be removed before planting new trees and shrubs. Among pest species, for example, tree of heaven (*Ailanthus altissima*) and black cherry (*Prunus serotina*) have to be removed, because very invasive. However, this kind of procedure should be realized only if pest species can represent a threat for the existing natural vegetation. Otherwise, for example along streets, these exotic species, being pioneer species, can contribute to the creation of ecological corridors.

Furthermore, sometimes, like in natural areas, it is not necessary to remove all vegetation, but, on contrary, it is opportune to leave existing vegetation, for aesthetic/landscape reasons, for biodiversity maintenance and/or for creating suitable conditions for the planting (for example if the site is sloping it is better not to remove the vegetation, which contribute to the stability of the area).

For this procedure it is possible to use different equipment (brush cutter, tractors, etc.), depending on site characteristics (extension, existing vegetation, accessibility, etc.).

2.1.3 Soil processing

The best soils for trees are those with an adequate nutrient supply, well aerated and, in addition, suitable for root “exploration”. For these reasons it is necessary to process soil before the planting of

[51] Lassini et al., 1998. *Forestazione urbana per la Lombardia*. Regione Lombardia e Azienda Regionale delle Foreste.

new trees/shrubs. However, in protected areas, soil processing for forestry interventions is subjected to restrictions provided for by Managing Authorities (such as in Rome the RomaNatura Authority)[52].

The main procedure consists in the ploughing or in the sub-soiling, with a variable depth in relation to the existing soil conditions. In case of ploughing, soil horizons are overturned to improve airing of the soil and to create the conditions for a better penetration of roots. However, especially in urban environment, ploughing could be not suitable because it can bring less fertile layers on surface, or worst, building waste and residues. Then, in these cases it is better to choose other procedures, such as sub-soiling[53], which, differently from ploughing, does not modify soil stratification, but cut the soil vertically, allowing to improve soil structure and airing and keeping superficial layers more operative.

For this procedure it is possible to use different equipment (tractors, scrapers, ploughs, etc.).

Finally, sometimes, it is necessary to realize other procedures aimed to further reshuffle soil superficial layers and to improve their characteristics.

2.1.4 Manuring

Subsoil manuring in the implantation site allows to obtain a favorable environment for new plants, facilitating their rapid achievement. Creating a suitable environment for roots development is even more important in urban areas, which, as shown in previous paragraphs, can be characterized by stresses and alterations and present a soil of scarce quality. Then, in these conditions, it could be necessary a manuring, which, not only improves soil fecundity, but also physic and structural characteristics (porosity, drainage, etc.). On the basis of site characteristics and fund availability, the best kind of manuring intervention will be assessed each time. Manuring, however, is not always necessary (for example in protected areas is not realized). There are different interventions that can be used for improving soil characteristics before planting. Following the most common procedures are described.

“Topsoil” consists in a supply of soil collected elsewhere, with the aim to improve chemical-physical characteristics of the soil in the implantation site**[54]**. However, this practice is expensive and not always justifiable when starting soil conditions are not so bad (in this case it could be better to choose other interventions such as those described to follow). Furthermore, in this practice it is fundamental to assess the area of origin of the collected soil (to assess if it is necessary to realize other interventions before using the new soil, for example to add ameliorants). However, in particular adverse conditions (original substratum very damaged), the addition of soil can be the best solution to maximize rooting of plants and, consequently, the achievement of forestry intervention.

Ameliorants are organic matters added in planting holes with the aim to improve soil structure, airing and water retention, so to reduce plantation stress and facilitate plants growing. It is a practice quite widespread in urban environment where, as above-mentioned, soils can be very modified both from a chemical (pH, nutrient supply) and a physical point of view (structure, porosity, water retention, etc.). Ameliorants, in fact, are first choice matter for every environmental reclamation interventions (ANPA, 2002[55]).

The quantity of ameliorants to add depends on original substratum but, anyway, it has to be no less than the 35% per soil volume, in relation to the addition of compost (5-10% in weight), 50-60% (or more) if sand is added.

According to composition and effects on soil, different ameliorants can be distinguished, in details:

- Compost (the decomposed remnants of organic materials). Compost seems to return the best results in degraded areas, especially in the season following implantation. Moreover, it reproduces forest humus characteristics, being rich of microbial flora. Thus, the use of compost of quality can represent the best choice if there is the need to supply an ameliorant which not only help the reclamation of soil structure, but also its microbiological

[52] Regional Law n. 29 of the 6th October 1997 “Norme in materia di aree naturali protette regionali” (“Rules on the subject of regional protected areas”), establishes some important measures to consider in forestry interventions localized inside protected areas, such as the prohibition to collect and to damage spontaneous flora and the prohibition to introduce exotic species.

[53] Sub-soiling is a soil processing, generally in depth, which does not cause the soil horizons overturn, but facilitates roots penetration, drainage and airing.

[54] Ideal topsoil should be collected in the site of provenience and immediately used; if this is not possible, it should be stored in accumulations high less than 2 meters, and, in case of a long period of storage, it should be sown with an appropriate mix of species to reduce erosion, to maintain structure and to stimulate biotic activity (Bradshaw A., Hunt B., Walmsley T., 1995. *Trees in the urban landscape*. E & FN SPON, London, pp. 272.). This practice can be useful also for reducing weed potentially present in the topsoil.

[55] ANPA, 2002. *Il recupero di sostanza organica dai rifiuti per la produzione di ammendanti di qualità*. Manuali e linee guida 7/2002

characteristics (Agnelli et al., 2010[56]). Furthermore, compost can contribute to improve soil water retention;

- Mycorrhizal inocula and biostimulants. These include different products and, generally, they are specie-specific. Some increase root apparatus retake after plantation (also increasing resistance to stresses). Furthermore they increase nutrient supply. When using mycorrhizal inocula, it is important that roots maintain a good humidity to support mycorrhiza development. Among biostimolants, the most used are seaweeds, especially in range biologic management, because they are natural fertilizers and, furthermore, they can contribute to the prevention of several diseases thanks to the supply of vitamins and oligoelemens, etc.;
- Artificial mixes. They are artificial substrata which tolerate footfall and allow roots development, so without threaten plants vitality. Then they are particularly useful near streets or on pavements. In general they are composed of a rocky matrix, of soil, which insinuate between matrix pores, and of an artificial binder.
-

Finally, sometimes, if soil lacks in one or more elements, it could be necessary to resort to chemical manuring, at least for first months after planting. Anyway, it is appropriate to assess in advance the use of manures and fertilizers, which if from a side can help a rapid retake of the new plants, in the other side can cause later imbalances (for example in presence of good nutrient supply, roots can be stimulated to grow too much).

2.2 Planting

A properly planted tree will be more tolerant of adverse conditions and require much less management than one planted incorrectly. In the following paragraphs a description is given of how to correctly execute some major planting interventions, once soil has been properly prepared.

2.2.1 Planting patterns

When planning a forestation project (also after specific surveys), it is necessary to define how many trees will be planted in the selected area and a specific planting density has to be chosen (how many trees per hectare). In case of vast surfaces, a preliminary signing on the soil of each single site where seedlings will be bedded out can be useful (Figure 5)

.

Figura 5 - *Example of preliminary signing with stakes and caution tape in a green area of Rome*

When choosing the planting pattern it is advisable to prefer the one that allows abatement of costs (for example a linear, regular designs if high mechanization has to be used)[57]. However, in order to realize a more natural and woodland-like plantation it is advisable to opt for non-linear and irregular planting models[58] (no straight rows, but, for example, a sinusoidal pattern), with trees species with

[56] Agnelli A., Bellasio C., Boschi C., Colangelo G., Ferrini F., Fini A., Lafortezza R., Mishra S., Nicese F., Pellegrini S., Sanesi G., 2010. *Impiego del compost di qualità nel verde urbano. Una scelta di sostenibilità*. NET n. 51 Confservizi Cispel Toscana.

[57] A planting pattern 2,5x1,5 m allows the way to a compact tractor among rows (Lassini et al., 1998. Forestazione urbana per la Lombardia. Regione Lombardia e Azienda Regionale delle Foreste).

[58] In the past regular planting patterns were mainly used, but in more recent planting geometric scheme has been replaced with planting arranged along curve lines (Marziliano P.A., Lafortezza R., Colangelo G., Villa G., Colombo T., Selleri B., Tucci R., Sanesi G., 2009.

different growth rates and habits. Planting pattern and density should be chosen with respect to the distances of trees from streets and buildings defined by the national Traffic Law and local regulations on urban green (when adopted).

2.2.2 Digging

Digging and preparing the holes where trees will be planted should be done with some basic technical criteria.

Holes should be broad enough to favor root growth: in general, a diameter larger of 50-60 cm than those of the root ball is recommended, so that bigger space and better aerated soil can be explored by the roots. Small holes, on the contrary, can limit root growth due to soil compaction on the sides that should be definitely avoided due to the consequent risk of forming circling roots.

Holes should be wider near the soil surface as this is where most root growth occurs and deep according to the size of the tree to be planted (do not plant too deep). It is far more acceptable to plant in a raised manner to avoid drowning or suffocating the roots (leaving free the collar area). Considering natural lowering of soil during settling period it is appropriate that the collar is at ground level or a little higher. Planting holes should be dug 2 to 3 times wider than the root ball and only as deep as the root ball. Wide, shallow holes encourage horizontal root growth that trees and shrubs naturally produce.

A correct drainage system should also be prepared so that water can flow throughout the soil and roots rot can be avoided; a layer of expanded clay on the bottom of the hole can be a solution, for example. Digging can be mechanized, in lowlands area for instance, or manual. When digging with a machine, such as an auger or backhoe, score the walls of the hole to prevent glazing.

2.2.3 Bedding out

The best time to plant trees is during the dormant season, in early spring before budbreak or in autumn after leaf drop (Figure 6). Trees planted during this period suffer less from planting. During autumnal-winter period, especially in Mediterranean environment, tree can profit of more raining water needed for their growth and their roots have the time to acclimatize before shoot growth (this rule holds also for plants cultivated in pots, which in principle, can be planted all the year round).

Figure 6 - *Bedding out of arboreal species during dormant season (Autumn, as shown by the absence of leaves in the tree on the right)*

New trees plantations will have to be realized according to best agronomic and silvicoltural practices. Good quality nursery stock must be chosen with some criteria: root ball should be compacted and wet, and handled with care during the transportation (see 1.5). Finally the interval between the taking from the nursery and the bedding out should be as short as possible, otherwise it is necessary to keep root balls wet and protect them from heat.

La gestione del paesaggio forestale urbano: l'esperienza del Parco Nord di Milano a 25 anni dai primi impianti. Atti del Terzo Congresso Nazionale di Selvicoltura per il miglioramento e la conservazione dei boschi italiani, 16-19 ottobre 2008, Taormina).

2.2.4 Other procedures

After planting new individuals, some further procedures are necessary, aimed to facilitate the taking root in the planting site and to reduce failure risks due to collapses, root damages, weed spread, etc.

A first intervention is mulching, a procedure necessary to avoid weed growth, by covering the soil surface around the trunk with different kind of materials. In urban forestry interventions, the most common mulching used are:

- plastic film, in strips or portion for single plant. This procedure has benefits also for root growth, because it contribute to keep adequate humidity and temperature of first soil layers (where root development is maximum), and it supports also microbic activity. Moreover, maintaining humidity of superficial layers longer allows to reduce irrigation, especially in areas characterized by hot and dry climate. This kind of mulch, however, is expensive (especially during the laying and the removal) and unsightly (this problem can be resolved by covering the plastic film with natural materials, for example straw). This mulch needs to be removed within first 2-3 years after planting and it should be conveniently dispatched. In addition to plastic sheetings, mulching sheetings in non woven fabric can be used: they have the advantage to be made in a breathable material which allows soil transpiration without creating ponding or asphyctic areas;
- woodchips or other organic material (shredded bark, lapillus, pine bark, dry leaves, straw, hay, etc.), applied for a depth of 10-15 cm and, possibly, far from plant collar. Organic mulches decay over time and are temporary, therefore it is advisable to lay new material every year, in order to keep mulch layer stable. Costs can vary depending on materials chosen;
- grass clipping. In this case costs are the lowest, but the yield can be not the best, then it should be better to choose among other types of mulches.

Finally, it is possible to use disks or squares of various degradable materials (cardboard, plastic, fibers), but they can be used only in very localized areas due to high costs.

Another procedure quite widespread is the resting of new plants, which consists in placing external support poles or underground supports (in the root area) during planting (Figure 7). This procedure allows the normal growth of root apparatus, protecting it from possible damages during rootage. Furthermore, anchoring to supports prevents plants from being eradicated by atmospheric agents or collisions. Type of supports depends on plant[59], and also poles' size (height and diameter) must be appropriate to those of the trunk. Generally just one pole is placed (of different wood such as chestnut, black locust, bamboo, etc.), but it would be better to use two or three supports (also if it is more expensive). Poles have to be placed immediately after the plant, paying attention not to damage it, and they have to be driven up to the original soil. Support poles should be placed sufficiently far from the trunk (at least 40 cm) to avoid rubbing in case the tree swings. Anchoring must leave 2/3 of the crow free to bend in presence of wind. Furthermore, before their use, supports should be treated with substances that avoid going rotten. Fibres of several materials can be used to join the trunk to the pole (often rubber, but also coconut filaments or plastic strings). Whatever is the material, the importance is that it keeps its elasticity for long time in order to allow slight swinging of the plants. Anyway, it is necessary to verify periodically joining rings (c.f. 2.3). Generally supports should be removed after 1-2 years.

Lately, for trees with big root ball, the use of underground supports is spreading. In this case, three poles are driven all through hole depth and boards are attached to them, so to form a triangle which blocks the root ball. This kind of support has the benefit to leave the trunk free, without risks of damage. Furthermore, unlike external poles, underground supports should not be removed.

In addition to mulching and resting, another procedure which can be necessary is a moderate planting pruning, that is mainly the removal of damage or dry branches. Finally, for big trees it could be opportune to realize a pruning which balances crown size with root apparatus dimension.

[59] For example for some conifers, it is not necessary.

Figure 7 - *Examples of support poles*

2.3 First maintenance

After bedding out, it is necessary to realize some maintenance interventions aimed to guarantee the correct and lasting taking root of new planted trees. These practices, not only are fundamental for the long-term achievement of the forestry intervention, but they are important also from public opinion point of view: in fact citizens perceive that the new forested area is attended.

Following, the main after-planting interventions are synthetically described.

Irrigation

One of the first cause of plantation failure is the desiccation of roots and, subsequently, of the plant. Therefore, at least for first years, it is fundamental that the planting trees are irrigated (Figure 8), especially in Mediterranean environment which is characterized by very dry seasons. The use of indigenous species conveniently chosen on the basis of implantation site characteristics restricts the necessity of irrigation to first months and to the first summer.

Figure 8 - *Example of irrigation system*

However, it is opportune to control plants during dry periods, to identify suffering events due to lack of water and intervening when necessary. Generally, in absence of heavy rain, it is advisable to irrigate every 10/15 days with at least 50/100 liters for plants. Usually, localized distribution with drop systems is used, or subirrigation, in order to reduce water consumption. If a fixed irrigation system is not available, another precaution is to arrange a hollow around the hole, through the creation of a soil ring high 5-10 cm, so to generate a water reserve when irrigating. It is crucial to assess also the soil typology (clay versus sandy), which determines the capacity to hold water.

Weeding

In certain circumstances, with the aim to oppose water lack (especially during dry periods and/or in presence of clay and compact soils), it can be useful to effectuate soil weeding, which means to liven up and to crumble the superficial soil layers. This practice avoids the detailed water reclimbing and increases the soil softness, with many benefits such as improving roots development, gas exchange between soil and atmosphere and growth of edaphic microorganisms.

Support system

After laying the support pole (cf 2.2.4), and depending on species growth, it is necessary to verify periodically the joining ring (preferably in vegetal fibre) to avoid constriction events.

Superficial soil processing

For species less competitive and long growing, it is a good practice to reduce competition with other species trough the periodical cleanliness of the surrounding ground. In presence of clay soil, it is also opportune to hoe periodically the superficial layers (above primary roots).

Plants replacement

In the event of an high percentage of desiccation of planted individuals, it is deserve to replace them, if necessary with more suitable species. Before the plants replacement it is necessary to identify the cause of desiccation.

Anyway, it is common that a small percentage of plants does not root. However if all procedures necessary for a successful implantation are correctly realized (cfr. 2.1, 2.2., 2.3), number of lost plants will be negligible (and so easily replace).

Manuring

When the forestry intervention has been realized in a degraded area (cf. 1.2) characterized by very altered soils, it could be necessary to add additional manures, apart of those added before bedding out. However, manuring is not provided in protected areas, where it is never realized.

Weed growing limiting

In particular, apart of above-mentioned mulching, it should be necessary to realize some weeding interventions (manual or mechanic), paying attention not to damage new plants (especially close to root collar).

Formation pruning

During first years, especially for fast growing trees, it is necessary an accurate control of their stability, in order to intervene with appropriate pruning, if necessary. For species susceptible to pruning, this intervention should be always realized so as to avoid fungal infections or other parasitic diseases. To facilitate a fast growing of trunk, for some species it would be necessary also to remove suckers.

ANNEX: PROJECT PLANNING FOR THE DESIGN OF GARDENS , PARKS AND GREEN AREAS UNDER THE REGULATION AND GREEN CITYSCAPE OF ROME CAPITAL [60]

The Regulations of the green and the cityscape of Rome Capital, not yet approved, lists in Art. B17 project materials to be produced for all green building.

Art. B17 - Elaborati progettuali

B17.1 The works comprising the Project and technical culture of accommodation to green , to be presented to the Commission Green Areas , in accordance with the provisions of Leg. 163/2006 and Regulation 207/2010 , must be made at least the following documents

- technical report describing the intervention as a whole, the design choices scenery and specific agronomic techniques that means taken. They must include: framing landscape; the state of affairs and the rilievoplanimetrico appropriate scale; easement overhead and underground; the assessment of any pre-existing trees; the arboreal subjects may be subjected to mechanized transplanting; all details and the design objectives of both works of demolition or new construction;
- the technical specifications, which reference point can be derived from the specifications of Roma Capitale and the technical requirements of the Maintenance of Public Green Ordinary in force at the time the project or from those of New Works in Public Green or specific research market, must contain the specific qualities of the plant material (trees, shrubs, ground cover, seeds, etc.) that is meant to use, with precise specification of the sixth plant for each species of plant chosen; the description of construction techniques and materials, facilities, furniture means that adopt, etc.;
- forecast of noise impact assessment in accordance with Law 447/1995 if necessary. This document must be presented by the designer to the sector responsible;
- bill of quantities of works, freight and supplies provided, making specific reference to the list prices of Roma Capitale in force at the time the project or specific market research;
- project tables, drawn up by the stairs more appropriate, according to the Legislative Decree no. 163/2006 and Regulation 207/2010, it is necessary to better illustrate the works as a whole (the inclusion of the project in the urban green system Legacy), the construction details and the impact of non-permeable surfaces provided by the project. In plan view, all arboreal subjects present or expected to be necessarily depicted with a circle that simulates scale the average diameter of the canopy at maturity. It must be also drawn up the plan of the automatic irrigation and a report on the automatic sprinkler systems including tank and electrical systems;
- photographic documentation certifying both the state of affairs of the areas during any pre-existing trees and adequate rendering to illustrate the project proposal;
- maintenance plan, considered as a technical management and conformed to the management in place at the OU Management Public Green. The specific references can be taken from the specifications and the technical requirements of maintenance. Ordinary Public Green in force at the time the project. The maintenance plan must be prepared by a qualified engineer in the field of green, to the extent permitted by applicable law;relazione conclusiva delle proposte di progettazione partecipata con i cittadini.
- final report of the proposed participatory planning with citizens.

[60] Si specifica che il Regolamento del verde e del paesaggio urbano di Roma Capitale è ancora in via di definizione. Pertanto, non ha ancora, al momento, valore giuridico mancando l'approvazione. Viene qui comunque riportato per completezza d'informazione .

MANUALI E LINEE GUIDA
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