Increasing Urban Sustainability Designing Vertical Garden: The Experience of Pisticci Municipality (Southern Italy)

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Abstract. Climate change is one of the significant challenges and risks for the environment, economy, and society. It is a phenomenon that involves a persistent alteration of global or regional weather patterns, leading to variations in temperature, precipitation, and extreme weather events. This transformation is primarily caused by human actions such as burning fossil fuels and deforestation, which produce greenhouse gases that trap heat in the atmosphere, causing global warming. This problem can be addressed by reducing urban fragmentation, land take, soil sealing, urban sprawl, urban sprinkling, and loss of ecosystem services. These phenomena can be tackled on various levels. On a larger scale, it involves implementing urban strategies and regulations that can mitigate these trends. At a local scale, realizing green spaces and infrastructure could reduce this trend. Vertical gardens have the potential to increase green space in several situations.

1 Introduction

Today, climate change is one most important challenges of humanity. It poses significant challenges and threats to our environment, economy, and society. Climate change refers to a long-term shift in global or regional weather patterns, often resulting in changes in temperature, precipitation, and weather extremes. This shift is caused by human activities, such as burning fossil fuels and deforestation, which release greenhouse gases into the atmosphere and trap heat, leading to global warming.

Climate change is primarily caused by the release of greenhouse gases into the atmosphere. These emissions are mainly the result of human activities, such as burning fossil fuels, deforestation, heavy industry, traffic, and agriculture.

The effects of this phenomenon can be detected in terms of global temperature increase over the past century leading to heat waves, droughts, and wildfires; fluctuations in precipitation patterns, and more frequent and intense rainfall occurring in some regions in others arise droughts; the rise of global temperatures produces glaciers and ice sheets melt, causing sea levels to rise also leading to flooding and erosion of coastlines; impact

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on ecosystems and biodiversity and significant economic effects, such as loss of crops and fisheries, property damage due to extreme weather events, and increased healthcare costs.

Tackling climate change requires immediate and sustained action to reduce greenhouse gas emissions and adapt to its impacts. This involves taking measures such as transitioning to renewable energy sources, improving energy efficiency, protecting and restoring natural ecosystems, and promoting sustainable land use and transportation practices. Greenhouse gas emissions (GHG) could be significantly reduced by adopting renewable energy sources, such as wind, solar, and geothermal, carbon pricing, and emissions reduction targets.

Climate change mitigation could be implemented by reducing greenhouse gas (GHG) emissions and stabilizing or reducing the concentration of GHGs in the atmosphere, thereby slowing down or preventing the negative impacts of climate change.

The main actions to mitigate climate change could be summarized in the following steps:

- Energy transition: Transitioning to renewable energy sources, such as wind, solar, and geothermal, can significantly reduce greenhouse gas emissions and mitigate climate change. This involves phasing out fossil fuels, the primary carbon emissions source.
- Energy efficiency: Improving energy efficiency in buildings, transportation, and industry can also help to reduce GHG emissions. This involves implementing energy-saving technologies and practices, such as using LED light bulbs, insulating buildings, and optimizing transportation routes.
- Sustainable land use: Sustainable land use practices, such as agroforestry and conservation agriculture, can help to reduce GHG emissions by sequestering carbon in soil and vegetation.
- Carbon capture and storage: Carbon capture and storage (CCS) technologies can capture carbon dioxide (CO2) emissions from industrial processes and store them underground, preventing them from entering the atmosphere.
- Climate-friendly consumer choices: Individuals can make choices in their everyday lives, such as reducing meat consumption, driving less, and choosing energy-efficient appliances.
- International cooperation: International cooperation and commitments, such as the Paris Agreement, are crucial for mitigating climate change on a global scale. This involves countries working together to set emissions reduction targets, share knowledge and technology, and provide financial support to developing countries.

Climate change mitigation requires a comprehensive approach involving government policies, private sector actions, and individual behavior changes. Reducing GHG emissions and stabilizing the climate can prevent the worst impacts of climate change and build a more sustainable future for everybody.

International cooperation and commitments, such as the Paris Agreement, are also crucial for addressing climate change on a global scale. Also, pursuing Sustainable Development Goals (SDGs) [1] could be essential in mitigating GHG emissions.

More particularly, Sustainable Development Goal 13, “take urgent action to combat climate change and its impacts,” suggests to integrate climate change measures into national policies, strategies, and planning, and SDG 7, “ensure access to affordable,

reliable, sustainable and modern energy" to ensure access to modern, affordable, reliable, and sustainable energy for all people, also promoting investments in the use of renewable energy sources, in energy infrastructure and clean energy technologies and improving energy efficiency.

2 Natural Solutions for Climate Change Mitigation

The primary measure to reduce climate change impacts is related to environmental depletion reduction. This impoverishment is generated by urban fragmentation, land take, soil sealing, urban sprawl, urban sprinkling, and loss of ecosystem services.

Urban fragmentation [2–5] refers to breaking up and dividing urban areas into smaller, disconnected, or isolated patches, often resulting in a discontinuous and scattered development pattern. This phenomenon typically occurs due to rapid urbanization and sprawl, where urban areas expand outward in a low-density and haphazard manner.

Urban sprawl [6–14] refers to the unplanned, uncontrolled, and often rapid expansion of urban areas into previously undeveloped or rural land, resulting in low-density, spread-out, and car-dependent development patterns. Urban sprawl typically involves the outward growth of cities, often fragmented and disconnected, resulting in converting agricultural land, natural habitats, or other open spaces into urbanized areas.

Land take [15–19] refers to converting land previously classified as non-built-up or non-urban land into built-up or urban land. It involves the transformation of natural or agricultural land into land used for residential, commercial, industrial, or infrastructural purposes, such as roads, highways, and urban development.

Land take is a phenomenon associated with urbanization and land development, and it can significantly impact the environment, society, and economy. The process of land take can result in the loss of natural habitats, agricultural land, and open spaces, leading to biodiversity loss, soil degradation, and reduced ecosystem services. It can also contribute to climate change by increasing the loss of carbon-sequestering vegetation and promoting urban heat island effects.

Soil sealing [20–23] refers to covering the natural soil surface with impermeable materials, such as pavement, concrete, buildings, or other artificial structures, resulting in the loss of its natural functions and properties. Soil sealing is a form of land degradation that occurs when the natural soil surface is covered with impervious materials, preventing water infiltration, air exchange, and nutrient cycling and altering the natural hydrological and ecological processes.

Soil sealing is often associated with urbanization and land development, as it is commonly used for constructing roads, buildings, parking lots, and other infrastructure in urban and suburban areas. It can also occur in different land use types, such as industrial, commercial, and agricultural areas, where natural soils are covered with impermeable materials for various purposes.

Urban sprinkling [24–30] occurs in very low population density and is characterized by territorial pulverization due to small settlements.

Ecosystem services [31–36] refer to the wide range of benefits that people receive from nature or ecosystems. These services result from natural ecological processes that

support human well-being, provide goods and services essential for human survival and prosperity, and contribute to economic, social, and cultural values.

These phenomena can be addressed at different scales. At a broader scale adopting urban plans and policies able to reduce these trends, and at a local scale, implementing programs for increasing green areas and infrastructures.

Green infrastructure [37–42] refers to a planned network of natural and semi-natural areas, such as forests, wetlands, parks, green roofs, and green walls, designed to provide multiple environmental, social, and economic benefits to communities and ecosystems. Green infrastructure is an approach to urban and regional planning that seeks to integrate nature-based solutions into the design, development, and management of built environments to promote sustainability, resilience, and well-being.

The concept of green infrastructure recognizes that natural systems can provide valuable services essential for human well-being and environmental health, such as stormwater management, air purification, climate regulation, biodiversity conservation, and recreational opportunities. Green infrastructure can also enhance the aesthetic value of urban and rural landscapes, create habitats for wildlife, and provide cultural and educational opportunities for communities.

Green infrastructure can be implemented at different scales, from small-scale interventions, such as green roofs on individual buildings, to large-scale regional planning, such as green corridors or greenbelts that connect different natural areas. Green infrastructure can be designed to be multifunctional, meaning it can provide multiple benefits. It can be integrated into other land uses, such as residential, commercial, and transportation corridors.

It is crucial to strengthen urban green areas to improve the impact of anthropization on the environment. Using vast space to include green places in urban spaces is essential. In several cases, vertical gardens could be a solution to increasing green areas.

3 Vertical Gardens

Vertical gardens are green walls that can be created inside or outside a building, using plants and flowers to create a green area in a limited space. Vertical gardens, also known as green walls, have been proposed as a potential solution for mitigating the effects of climate change. The climate crisis reminds us to design more environmentally sustainable urban areas immediately. Vertical gardens can reduce CO2 emissions and, at the same time, produce oxygen. It is an innovative approach to designing our cities without remaining an experience related to a few projects. Although they are not a complete solution to climate change, they can be an effective tool for mitigating its effects in urban areas.

Here are some ways in which they can help:

- Temperature regulation: Green walls can help regulate temperature by reducing the heat buildings absorb. This can help reduce the urban heat island effect when cities are significantly warmer than surrounding rural areas.
- Carbon sequestration: Plants absorb carbon dioxide from the atmosphere and store it in their tissues. By increasing the amount of vegetation in urban areas, green walls can help sequester carbon and reduce greenhouse gas emissions.

- Air quality improvement: Plants absorb pollutants from the air, including volatile organic compounds (VOCs) and particulate matter. By adding green walls to urban areas, we can improve air quality and reduce the risk of respiratory problems.
- Water management: Green walls can help manage stormwater runoff by absorbing and filtering rainwater. This can help reduce the risk of flooding and improve water quality.
- Biodiversity promotion: Green walls can provide habitat for birds, insects, and other animals, which can help promote biodiversity in urban areas.

Vertical gardens can be categorized into typologies based on design and installation methods. Here are some common typologies of vertical gardens:

1. Green Facade: This type of vertical garden is installed on the exterior facade of a building, covering the walls with plants. Green facades can be installed using different systems, such as trellis, cable, wire, or modular panel systems.
2. Panel System: In this typology, pre-fabricated panels with built-in pockets or trays are attached to the walls to hold the plants. These panels are often made of metal, plastic, or composite materials and can be installed with irrigation and drainage systems.
3. Modular System: Modular systems involve individual modules or modules with pockets attached to the wall, forming a grid or matrix. Plants are then inserted into these pockets, creating a living wall. Modular systems offer flexibility in design and installation and can be easily replaced or modified as needed.
4. Tray System: Tray systems consist of trays or containers attached to the wall, each containing plants and a growing medium. These trays can be removed and replaced, allowing easy maintenance and plant replacement.
5. Pocket System: Pocket systems involve pockets or sleeves attached to the wall where plants are inserted. These pockets can be made of fabric, felt, or other materials and arranged in different patterns or configurations.
6. Hydroponic System: Hydroponic systems use a soilless growing medium and a nutrient-rich water solution to deliver nutrients directly to the plants. These systems are typically used for indoor vertical gardens and offer precise control over plant nutrition and water uptake.
7. Indoor Systems: Vertical gardens can also be installed indoors, using artificial lighting, irrigation, and climate control systems to create optimal growing conditions for the plants. Indoor vertical gardens are often used in commercial or residential buildings and retail or public spaces.

It is fundamental to consider the following good practices for designing, installing, and maintaining vertical gardens:

1. Plant Selection: Choose appropriate plant species suitable for vertical growth and the local climate. Consider sunlight exposure, temperature, wind, and humidity levels when selecting plants for the vertical garden. Opt for plants with low water requirements that thrive in vertical growing conditions.
2. Irrigation and Drainage: Install an efficient irrigation system that provides adequate water to the plants without causing waterlogging or over-irrigation. Use a drip irrigation system that delivers water directly to the root zone of the plants, minimizing water waste. Ensure proper drainage to prevent water accumulation and root rot.

3. Growing Medium: Use a high-quality growing medium that provides adequate nutrients, water retention, and plant aeration. The growing medium should be lightweight to prevent excessive weight on the vertical structure, and it should be able to support plant growth without compacting over time.
4. Structural Considerations: Ensure that the vertical structure or wall is structurally sound and can support the weight of the plants, growing medium, and irrigation system. Consult with a structural engineer or a qualified professional to ensure the vertical garden system's proper installation and load-bearing capacity.
5. Maintenance: Regular maintenance is essential for the health and longevity of the vertical garden. This may include pruning, fertilizing, pest and disease control, and monitoring the irrigation system. Inspect the vertical garden periodically for any signs of plant stress, nutrient deficiencies, or structural issues.
6. Sustainability: Consider sustainable practices in the design and maintenance of the vertical garden. Use organic or slow-release fertilizers, avoid chemical pesticides, and minimize water use through efficient irrigation and rainwater harvesting. Consider using native or drought-tolerant plant species that require less maintenance and resources.
7. Education and Engagement: Use the vertical garden as an educational tool to raise awareness about the benefits of green spaces, biodiversity, and environmental conservation. Engage the local community and stakeholders in the vertical garden's planning, installation, and maintenance to promote a sense of ownership and stewardship.

There are numerous examples of vertical gardens around the world. Here are a few notable ones:

1. One Central Park, Sydney, Australia: Designed by Patrick Blanc, One Central Park features two towers covered in vertical gardens with over 38,000 plants from 383 species. The gardens are irrigated with recycled water and combine native and exotic plants to create a lush and sustainable living wall.
2. The Bosco Verticale (Vertical Forest), Milan, Italy: Designed by Stefano Boeri Architects, the Bosco Verticale is a pair of residential towers covered by 94 different plant species, 59 of which are helpful for birds, 60 are tree species, and 33 are evergreens. The project aims to increase greenery in urban areas and promote biodiversity while improving air quality and reducing energy consumption.
3. Gardens by the Bay, Singapore: The Supertree Grove at Gardens by the Bay in Singapore features towering vertical gardens in the form of iconic tree-like structures. These vertical gardens are covered in various plant species and serve as a visual focal point of the park while providing shade, improving air quality, and capturing rainwater for irrigation.
4. Green Oasis at Bikini Berlin, Germany: Located in Berlin, the Green Oasis is a large vertical garden covering the facade of the Bikini Berlin building. It features a mix of plant species, including ferns, mosses, and other shade-loving plants, creating a lush and vibrant green wall.
5. Sky Garden, London, United Kingdom: Sky Garden is a public garden on the top of the Walkie-Talkie building in London. It features a large vertical garden covering the interior walls of the building, with a variety of plant species and stunning views of the city.

4 The Case Study

The experience of vertical gardens has been developed with a project in Pisticci Municipality in Southern Italy's Basilicata region (Fig. 1).

Basilicata region is characterized by a low population density (536.659 people distributed over 9,992 km^2, or 53.5 people per km^2) that, partly due to poor policy and partially due to a lack of significant private investors, has not been able to capitalize on its highly valuable landscape in the past decades to develop tourism. Pisticci municipality could represent a typical example of this trend.

Pisticci has a population of 16.836 inhabitants and is the fifth-bigger municipality in Basilicata. It is between the Cavone and Basento rivers and connected with S.S. Basentana and S.S. Jonica motorways. Ridges and uplands characterize the northern portion of the city, whereas the region near the Ionian Sea is primarily flat in shape.

The problem of land take affects the coastline region due to the considerable tourism demand. The territory has a different morphology which leads to the location of settlements along the main ridge.

The history of Pisticci is strongly linked to the landslides that changed its urban structure, morphology, toponymy, and history several times. This is due to the clayey nature of the soil on the Pisticci hillside. The recognized main cause of such events in Pisticci is a small torrent, called "La Salsa," of brackish water flowing under the districts of the town center most affected by the landslides and blamed for the destabilization of the terrain.



Fig. 1. Location of Pisticci Municipality.



Fig. 2. Shotcrete intervention in Pisticci Municipality.

In 1976, after three centuries without significant events, a part of the 'Croci' district collapsed following the November rains. The affected area was evacuated in time, so there were no victims or injuries. The landslide affected an area about 250 m wide and 800 m long. The landslide was reclaimed by regularising the escarpment and landslide body, deep and surface drainage, pile bulkheads, and lining the prominent escarpment with shotcrete (Fig. 2). The intervention is located where the landslide occurred in November 1976, which caused much of the Croci district to collapse. The project's strategic goal is to improve urban spaces' quality and usability by intervening in public green areas. The goal is to develop multifunctional networks: green infrastructure, ecological values, identity, cultural and social values. The idea of urban regeneration is part of a reorientation for urban development to contrast processes of physical and social degradation in the city by intervening in an area, which despite its historical and scenic values, now appears as an urban void. The project aims to promote interaction between areas affected by de-qualification and the public areas below it, which are considered marginal, with the center of the town of Pisticci. The two areas are not entirely disconnected; small actions and a few interventions can improve their connectivity.

4.1 Pisticci's Vertical Garden

The project is based on several interventions linked together to improve the area's quality and make this place more livable. The overall project is based on the following interventions: Green Wall, Photovoltaic panels, designed to ensure the energy independence of the whole project, a terraced garden through naturalistic engineering interventions, and regeneration of the parking area (Fig. 3).

The main project goal is to transform urban environments into places suitable for well-being by integrating urban structures with the environment. Plants can be crucial in merging the anthropized with nature, eliminating the typical sharp separation between the built and natural environments. This can allow to observe and live the nature even in an urban environment, conveying the more relaxed atmosphere of the rural environment even in cities. In this case, technology no longer represents an element of disconnection



Fig. 3. Project scheme of Pisticci's vertical garden.

from nature, of environmental depletion, but can be the bridge between worlds that have always been considered antithetical. Vertical gardens can symbolize this union, offering the possibility of including and propagating greenery in the most anthropized and degraded areas. This is the reason that led to the hypothesis of the project of a vertical garden measuring 4,000 m^2, the largest green wall in Europe, to mask "the scar" of Pisticci, due to shotcrete intervention, with an integrated system of hanging green.

The perfect exposure for solar panels is when facing directly towards the sun with no shading, which means the panels should be oriented towards the south in the northern hemisphere or the north in the southern hemisphere. It is essential to avoid shading the panels from trees, buildings, or other obstructions, as it can significantly reduce their efficiency. Pisticci's vertical garden is well-oriented and has no obstacles that can produce shadows. In order to make the whole project independent from the energetic point of view, several modules of photovoltaic panels will be included along the shotcrete wall, alternating them with green elements. Energy efficiency will be pursued, making the project's irrigation and lighting systems independent (Fig. 4).

The terraced garden involves landscaping the slope just below the shotcrete wall. Today it appears as a large area of uncultivated greenery, which will be transformed into a livable space where it will be possible to walk comfortably among the greenery and reach the historic center of Pisticci in a pleasant and reasonably fast way.



Fig. 4. Project of Pisticci's vertical garden.

Applying naturalistic engineering techniques on the slope will ensure the environmental upgrading of the intervention area, leading to a significant reduction in the visual impact. Only native species will be used for revegetation works and in the vertical garden. The aim is to achieve a situation close to the natural one, contributing to improving morphological diversity and increasing biodiversity. The final results should lead to reproducing a phytocoenosis, i.e., an association of plants that establishes a profound interdependence relation, constituting a vegetation formation with precise characters correctly inserted into the environmental context. In this way, technical functionality is combined with perfect ecological-landscape integration of the project.

The regeneration of the parking area involves implementing measures that minimize the environmental impact while meeting visitors' parking needs. The project includes green infrastructure elements such as permeable pavements, rain gardens, and bioswales to manage stormwater runoff. These features help reduce the burden on the local drainage system, improve water quality, and promote groundwater recharge. It also integrates trees, shrubs, and native plantings within and around the parking area. Vegetation enhances the aesthetics, provides shade, reduces the heat island effect, and supports biodiversity by attracting pollinators and other wildlife.

By implementing these sustainable measures, the regeneration of a parking area can contribute to environmental conservation, promote sustainable transportation options, and enhance the overall visitor experience while minimizing the facility's ecological footprint.

5 Conclusions

In conclusion, the project combining a Green Wall, Photovoltaic panels, a terraced garden, and the regeneration of a parking area offers numerous benefits and opportunities.

The Green Wall provides a vertical garden that enhances the aesthetic appeal of the structure, while also improving air quality and biodiversity. The living vegetation helps to purify the air by filtering out pollutants and producing oxygen. Moreover, the presence of greenery promotes a sense of well-being and connection with nature.

Integrating Photovoltaic panels in the design allows for generating clean and renewable energy. The project reduces greenhouse gas emissions and reliance on traditional energy sources by harnessing solar power. This benefits the environment and demonstrates a commitment to sustainability and energy efficiency.

The inclusion of a terraced garden adds a functional and beautiful green space. The terraces can be utilized for recreational purposes, such as outdoor seating areas or community gardens, providing opportunities for social interaction and leisure activities. Additionally, the terraced garden can help manage rainwater runoff, reducing the strain on drainage systems and minimizing the risk of flooding.

Renewing a parking area into a green space is a significant improvement in urban sustainability. Converting an underutilized or environmentally damaging space into a vibrant and eco-friendly area contributes to the overall livability and attractiveness of the urban environment.

In summary, integrating a Green Wall, Photovoltaic panels, a terraced garden, and the regeneration of a parking area in a project showcases a holistic approach to sustainable development. It combines environmental benefits, such as improved air quality and energy generation, with social advantages, such as creating green spaces for community engagement. This type of project demonstrates a commitment to sustainable practices and contributes to urban areas' overall well-being and resilience.

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