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# Navigating Urban Climate Resilience in Mediterranean Hotspots: A Review and GIS-Enabled Implementation Framework for North Cyprus

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Posted Date: 3 July 2025

doi: 10.20944/preprints202507.0313.v1

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*Review*

# Navigating Urban Climate Resilience in Mediterranean Hotspots: A Review and GIS-Enabled Implementation Framework for North Cyprus

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**Abstract**

The Mediterranean Basin is recognised as a climate change hotspot, exhibiting accelerated warming and intensified hydrological shifts that compound urban heat island (UHI) and flood risks in coastal and inland cities. Geographic Information Systems (GIS) provide valuable tools for downscaling climate projections, mapping vulnerabilities and directing targeted adaptation measures. The impacts of climate change and GIS-based analytical methods in Mediterranean urban contexts have been synthesised in this review, and specific climate trends and vulnerabilities in North Cyprus have been assessed. We find the most important knowledge gaps in assessments of the climate in cities and suggest a plan for adapting to climate change. This plan is in stages and uses Geographic Information System (GIS) technology. The plan includes using cool materials and adding plants to the city quickly. It also includes long-term planning for how the land will be used. This is based on Local Climate Zones, managing floods together, and networks that monitor the environment in real time. Studies of the economy show that integrated strategies are financially possible and can help make cities more resilient in the long term.

**Keywords:** mediterranean climate change; GIS downscaling; urban heat island; North Cyprus; urban adaptation; Local Climate Zones; flood risk mapping

## 1. Introduction

The Mediterranean Basin has experienced an approximate warming of 1.0 °C since the pre-industrial era. Projections indicate that by the year 2100, under scenarios of high emission, there will be an additional increase in temperature ranging from 1.8 to 8.5 degrees Celsius. In such scenarios, the phenomenon of summer warming is observed to be amplified relative to global averages (IPCC, 2021). A reduction in precipitation during summer months (16–49 percent) has been identified as a contributing factor to the increased likelihood of droughts and flash floods (IPCC, 2023). Urban heat islands (UHIs), defined as the temperature difference between urban and rural areas, have been shown to exceed 1.5–4.3 °C in Mediterranean cities. This has been shown to intensify heat stress, increase energy demand, and pose health risks (Stewart & Oke, 2012). Heavy rain events, despite the overall decrease in precipitation, increase the probability of flooding in urban areas characterised by close building spacing and a lack of adequate rainwater absorption capacity ((Kourtis et al., 2024).Geographic Information Systems (GIS) have been demonstrated to facilitate the high-resolution downscaling of coarse global climate models to urban scales via regression–kriging incorporating terrain and coastal proximity covariates (Hengl, Heuvelink, & Stein, 2004). This process has been shown to enable Local Climate Zone (LCZ) mapping (Bechtel et al., 2015) and multi-criteria vulnerability assessments. The World Urban Database and Access Portal Tools (WUDAPT) protocol standardises LCZ classification, thereby facilitating consistent characterisation of urban morphology across cities (Demuzere et al., 2022). North Cyprus is a prime example of compounding vulnerabilities. Since 1975, minimum temperatures in Girne and Lefkoşa have increased by 0.61 °C per decade, and mean temperatures have risen by 0.38 °C per decade (Sarış et al., 2007).These figures are among the highest warming rates recorded in the region. Rapid built-up growth has reduced green space below 4 m² per capita. This growth was between 65.6–83.5 percent between 2013–2021. It has intensified both UHI and flood risks in mountainous and coastal zones (Kourtis et al., 2024).

The present study undertakes a comprehensive review of the extant literature concerning the impact of climatic change on Mediterranean urban contexts, drawing upon both empirical observations and projections made in the relevant academic literature. The paper provides an overview of the GIS methodologies employed for UHI and flood hazard analysis. The present study analyses the urban vulnerabilities of North Cyprus. The proposal entails the formulation of a GIS-driven adaptation roadmap tailored to Nicosia, Kyrenia, and Famagusta.

## 2. Climate Change Trends in Mediterranean Urban Regions

It is evident that the Mediterranean region has exhibited a more pronounced increase in temperature in comparison with the global average, with a recorded rise of up to 20%. According to the Intergovernmental Panel on Climate Change (IPCC), the Mediterranean region is expected to undergo a temperature increase that is projected to range between 5.6 and 9.2°C during summer months and between 3.2 and 6.8°C during winter seasons by the year 2081-2100 (IPCC, 2013). These trends are intensified by UHIs, with land surface temperature anomalies ranging from 1.5 to 4.3 °C being documented in both the dense mid-rise (LCZ 2) and low-rise (LCZ 3) regions. These anomalies reach their zenith 3 to 4 hours after sunset as a consequence of modified radiative cooling (Stewart & Oke, 2012).

Projections indicate that summer precipitation will decline by 16–49 percent, leading to increased drought frequency. At the same time, the likelihood of urban flooding will be exacerbated by the occurrence of extreme rainfall events. The utilisation of Geographic Information System (GIS)-based flood mapping, employing Frequency Ratio and Fuzzy AHP methodologies, has led to the identification of approximately 9 percent of Cyprus as being susceptible to elevated flood risk, a phenomenon that is particularly evident in primary urban districts (Kourtis et al., 2024).

## 3. GIS Methodologies for Urban Climate Analysis

The varied topography and urban forms, as well as the complex interplay of coastal influences present in Mediterranean cities, demand a suite of Geographic Information System (GIS)-based methods in order to capture thermal and hydrological patterns at high resolution. The ensuing section delineates four GIS methodologies that demonstrate optimal collaborative efficacy: namely, climate downscaling, Local Climate Zone classification, thermal hotspot detection via remote sensing and multi-criteria spatial analysis for flood and environmental risk. Each of these is demonstrated through the utilisation of Mediterranean case studies.

The initial data employed in urban climate assessments, irrespective of the scale at which they are conducted (be it at a global or regional context), is typically characterised by a coarse resolution. Seemless surfaces of temperature and precipitation are produced at a resolution of approximately 1 km by means of a combination of deterministic regression, utilising terrain and location predictors, and stochastic interpolation of residuals in regression–kriging (Agnew & Palutikof, 2000). The most commonly included predictor variables are: latitude, longitude, elevation, distance to coast, slope, aspect and land-to-sea ratios. Multiple linear regressions are fitted in a stepwise manner, following which the residuals undergo analysis by variogram and interpolation with ordinary Kriging, with a view to refining the climate surface. In the context of seasonal validations in Mediterranean basins, it has been observed that temperature root-mean-square errors range from 0.8 to 1.4 °C, with precipitation errors measuring between 4 and 27 mm. These findings underscore the efficacy of a regression-plus-kriging approach, which has been demonstrated to surpass the performance of regression alone (Agnew & Palutikof, 2000).

The utilisation of a standardised GIS framework, termed "Local Climate Zones" (LCZs), facilitates comparable UHI analyses across Mediterranean cities (Bechtel et al., 2015). The present

 doi:10.20944/preprints202507.0313.v1



framework is organised in a manner that facilitates the classification of both urban and natural surfaces, with this classification being based on land cover and morphology. Two principal methodologies are employed in the mapping of LCZs. The first of these uses satellite images in different colours, digital data regarding the shape of the land and its topographical relief, and the outlines of edifices. The second approach utilises a bespoke computer protocol and training data from the public. In Seville, a Geographic Information System (GIS)-based Land Cover Zone (LCZ) classification attained over 85 percent accuracy and revealed that compact midrise (LCZ 2) and low-rise (LCZ 3) zones exhibited the highest surface temperatures, surpassing adjacent open low-rise zones by up to 10 degrees Celsius (Sola-Caraballo et al., 2025).The distinction between different Land Cover Zones (LCZs) according to their location facilitates a more efficacious targeting of the mitigation of the Urban Heat Island (UHI) effect by identifying the urban morphologies that are most under pressure.

The utilisation of satellite thermal infrared sensors is of paramount importance in the endeavour to map land surface temperature (LST) within the Mediterranean region. The sensors in question include Landsat 8 TIRS, Sentinel-3 SLSTR, and ECOSTRESS. The conventional approach to this process involves the utilisation of Google Earth Engine or ENVI software to process raw radiance data. Atmospheric and emissivity corrections are then applied via Planck's law inversion, and LST composites are derived. The identification of thermal hotspots is achieved by overlaying LST maps with LCZ, building density and vegetation indices in multi-criteria GIS workflows. In Seville, a spatial interpolation of Landsat 9 LST at 30-metre resolution, combined with GIS-derived NDVI and building density layers, identified hotspots covering 11% of the residential fabric and connected overheating to urban boundaries and impervious surfaces (Sola-Caraballo et al., 2025). A number of ECOSTRESS-based studies in Lecce and Milan have demonstrated clear nocturnal retention in compact LCZs, thus underscoring the significance of thermal mapping at various scales (Pappaccogli et al., 2025).

Cities in the Mediterranean region are subject to two distinct threats: extreme heat and flash flooding. These are caused by the intense characteristics of convective storms. GIS-based Multi-Criteria Decision Analysis (MCDA) can be defined as a methodology that integrates flood-relevant factors, including slope, land use, drainage density, flood return periods and social vulnerability, into composite risk maps. In the Cretan context, an overlaid GIS policy tool was utilised to delineate eight factors along the contaminant pathway. The objective of this tool was to facilitate the classification of stream water quality and ecological risk. This process enabled the distinction between "appropriate" and "non-appropriate" areas for sustainable watershed management (Kourgialas et al., 2024). In the city of Thessaloniki, the application of an Analytical Hierarchy Process within a Geographic Information System (GIS) has enabled the integration of various environmental parameters, including Land Surface Temperature (LST), fractional vegetation cover, noise emissions, air pollution sources, and urban density, to formulate an Environmental Quality Index (EQI). This initiative has successfully identified areas in western areas requiring enhancements to green infrastructure, thus highlighting the potential benefits of integrating environmental data with GIS technology (Yfanti, 2017)

With regard to hydrological response, the SCS-Curve Number method was employed to model small coastal basins on the island. The Geographic Information System (GIS) was also employed to derive CN values from the following cartographic sources: soil map, land cover map, and slope map. The resulting synthetic unit hydrographs were then utilised to predict instances of flash flooding (Papaioannou, Loukas, Katsafados, & Dimitriou, 2021). The identification of flood-prone zones is facilitated by hydrological GIS models, which in turn inform urban drainage upgrades and ecosystem-based adaptation in Mediterranean microcatchments.

The integration of GIS methodologies, including climate downscaling, LCZ mapping, remote sensing of thermal patterns, and MCDA for flood/environmental risk, constitutes a comprehensive toolkit for urban climate analysis in Mediterranean cities. The implementation of these strategies in a collective manner has been shown to facilitate evidence-based planning, thereby helping to mitigate urban overheating, manage stormwater hazards and enhance resilience in coastal and inland Mediterranean contexts.

## 4. North Cyprus Urban Climate Vulnerabilities

North Cyprus is experiencing significant warming trends, as evidenced by numerous scientific analyses. Station data from Kyrenia and Nicosia reveal a marked increase in temperature over recent decades. Accordingly, the long-term analysis of meteorological stations reveals a T_min trend of 0.61°C decade$^{-1}$, and a T_mean trend of 0.38°C decade$^{-1}$ since 1975 (Sarış et al., 2007; (Tymvios et al., 2010). The observed warming rates are supported by the findings of recent comprehensive analyses examining the period 1975-2021, which substantiate that the mean minimum temperature trend (Tmin) exhibited the most pronounced warming rate of 0.61°C decade-1, followed by the mean temperature trend (Tmean) with a rate of 0.38°C decade-1 and the mean maximum temperature trend (Tmax) with a rate of 0.28°C decade-1 (Bey et al., 2024).

The magnitude of the observed warming trend in the overall mean minimum temperature of North Cyprus is reported to be among the fastest documented in the scientific literature (Bey et al., 2024).This accelerated increase in temperature is particularly concerning, as it indicates the region's position as part of the Eastern Mediterranean climate change hotspot, where temperatures are rising at rates significantly higher than global averages.

Concurrent with these observational warming trends, satellite analysis conducted between 2013 and 2023 has revealed substantial urban heat island (UHI) intensification across North Cyprus's major urban centers. The satellite-based thermal analysis demonstrates UHI intensities reaching up to 6.8°C in Kyrenia, 3.1°C in Nicosia, and 2.4°C in Famagusta. The primary drivers of these UHI intensities are identified as the rapid expansion of built-up areas and the subsequent vegetation loss that characterises the urban development process.

The observed warming trends manifest especially clearly in minimum temperatures across all seasons at both Kyrenia and Nicosia stations, with the strongest warming trends evident primarily during nighttime periods (Sarış et al., 2007; Tymvios et al., 2010).This phenomenon aligns with the concept of urban heat island effects, wherein built surfaces accumulate heat during daylight hours and subsequently release it gradually during nocturnal periods, thereby sustaining elevated nighttime temperatures. The impact of urban heat island (UHI) effects on local climate conditions has been demonstrated in the temperature trends of Nicosia in the Mesaoria plain. This suggests a direct influence of urbanization on the region's climate. (Theophilou & Serghides, 2015)

North Cyprus has undergone a substantial increase in urban expansion from 2013 to 2021, with the built-up area growing by a range from 65.6% to 83.5% across major urban centre (Esendağlı & Selim, 2024).This unparalleled rate of development has led to a fundamental shift in the composition and thermal characteristics of urban environments across the region. Specifically, Kyrenia demonstrated a 65.59% increase, Northern Nicosia exhibited a 66.87% increase, and Famagusta exhibited the most significant expansion rate of 83.50% during this eight-year period.

The rapid urban expansion that has occurred in recent decades has been predominantly in a northerly and westerly direction from existing urban cores. This has resulted in the creation of extensive built-up areas that have replaced natural vegetation and permeable surfaces with heat-absorbing materials (Esendağlı & Selim, 2024).This development pattern has exerted significant pressure on the natural structure of the island, concurrently reducing the availability of green spaces that provide vital ecosystem services for urban climate regulation.

The consequences of this urban expansion are particularly severe with regard to the availability of green space per capita. The current green space provision in both Girne and Gazimağusa has fallen to below 4m$^2$ per capita, representing a critical deficit compared to the World Health Organization's recommendation of 9m$^2$ per capita for adequate urban green space(Kara & Akçit, 2015) (World Health Organization, 2016). This deficit in green space is significantly lower than international standards, representing approximately half of the minimum threshold recommended by the WHO for urban environmental health.

A detailed analysis of green space distribution reveals that active green spaces constitute only small fractions of total urban area in North Cyprus cities. In Northern Nicosia, the total area of green space per capita was calculated to be a mere 3.35m², a figure significantly below the 9m² recommended by the WHO. A more detailed analysis of individual neighbourhoods reveals additional concerning patterns, with some areas exhibiting active green space per capita as low as 1.449 m² in certain districts. (Bolkaner & Asilsoy, 2023).

The loss of green infrastructure has resulted in the elimination of critical natural cooling mechanisms that vegetation provides through evapotranspiration, shading, and air purification processes. Research conducted in Girne has demonstrated that urban areas characterised by a mature tree canopy exhibit significantly lower temperatures in comparison to areas devoid of vegetation. (Bolkaner & Asilsoy, 2023). This finding underscores the direct correlation between the loss of green space and the intensification of UHI (Rizwan et al., 2008) . The systematic replacement of vegetation areas, grasslands, and forests with construction materials has been demonstrated to result in fundamental alterations to urban microclimates, thereby reducing natural adaptive capacity to manage climate risks.

The deficiency in green space has been demonstrated to exacerbate both the effects of urban heat island (UHI) and the risks of flood exposure. This is due to the replacement of natural surfaces, which previously facilitated infiltration and evapotranspiration, with impermeable materials, resulting in increased surface runoff and heat retention. This phenomenon, known as compound vulnerability, occurs when the presence of reduced green infrastructure leads to an increase in both heat stress and flood risk, thereby eliminating natural mechanisms that facilitate climate adaptation.

Urban developmental trends demonstrate a conspicuous absence of integration of green infrastructure requirements in the formulation of planning frameworks, with building codes and regulatory stipulations for development conspicuously lacking in their incorporation or incorporation to an insufficient extent of climate-resilient standards and mandatory green space provisions (Bolkaner & Asilsoy, 2023). The development has progressed at a rapid rate and with limited consideration of environmental sustainability requirements. This has created patterns of vulnerability that will require substantial investment in order to be addressed by retrofitting and the implementation of green infrastructure.

Projections based on current development trends suggest that settlement centres will continue to spread significantly through 2050, potentially exacerbating existing green space deficits and UHI intensification, unless comprehensive policy interventions are implemented to redirect development patterns toward more sustainable urban forms centre (Esendağlı & Selim, 2024). It is evident that, in the absence of deliberate action, the urban areas of North Cyprus will be subject to escalating climate vulnerability. This predicament is a direct consequence of the ongoing prioritisation of urban expansion over environmental sustainability standards by developmental actors.

## 5. GIS-Driven Adaptation Roadmap for North Cyprus

### *5.1. Short-Term Actions*

Hotspot Mapping and Thermal Assessment

The utilisation of satellite data in the mapping of Land Surface Temperature (LST) provides a crucial baseline for the identification of urban heat islands. Recent research (Mollière et al., 2024) has demonstrated the potential of satellite-based thermal monitoring to achieve sub-daily temporal resolution for real-time urban heat monitoring. The advent of sophisticated machine learning methodologies has engendered the capacity for the global collection of LST data at 12-hour intervals, with the prediction that sub-hourly data will be obtainable by 2027 (Mollière et al., 2024).The enhanced monitoring capability facilitates the identification of thermal hotspots with unprecedented precision, thus enabling targeted interventions in vulnerable neighbourhoods.

 doi:10.20944/preprints202507.0313.v1



The integration of flood hazard assessment with thermal data provides a comprehensive risk assessment framework, facilitating the identification of potential hazards and the development of effective mitigation strategies. Urban areas that are both susceptible to heat stress and flood vulnerability necessitate the implementation of specialised green-blue-grey infrastructure solutions, which are capable of addressing multiple hazards in a simultaneous manner (Şen & Şat, 2024)

Cool Materials Implementation

A considerable body of scientific research has repeatedly demonstrated the efficacy of high-albedo cool roofs in reducing urban temperatures. As demonstrated in the relevant research, "super cool roofs" with albedo values ≥ 0.60 have the capacity to achieve substantial cooling effects (Elnabawi et al., 2023). For every 0.1 increase in roof albedo, corresponding temperature reductions of 0.41°C maximum and 0.02°C minimum have been documented. The literature suggests that cool roofs reflect incoming solar radiation more efficiently than darker surfaces (Jacobs et al., 2018), thereby reducing heat absorption and transfer to the atmosphere.

The specified objectives concerning the reduction of ambient cooling to 0.6–1.2°C and surface temperature to 8–15°C are consistent with the findings of previously conducted research. A body of research, including studies conducted in multiple cities, has demonstrated that cool roofs have the capacity to reduce the urban heat island effect in a nearly linear fashion as coverage (Jacobs et al., 2018)). In Phoenix, Arizona, it was determined that a 20% increase in urban albedo could potentially result in a reduction of over 150 heat-related emergency calls per year.

The efficacy of reflective permeable pavements in achieving dual benefits in terms of stormwater management and heat reduction has been demonstrated. The surfaces in question demonstrate a reduction in heat absorption when compared to traditional pavement, whilst permitting water infiltration, thus facilitating flood mitigation and temperature reduction (UNEP-DHI, n.d.).

Urban Greening Strategy

Urban tree canopy coverage has been demonstrated to possess a substantial cooling potential, with research indicating that an increase in tree cover provides 0.01°C of cooling per 1% increase in field-measured canopy cover (Ettinger et al., 2024).However, it is the attainment of critical canopy coverage thresholds that engenders the most significant cooling benefits. Research has demonstrated that the presence of a tree canopy covering at least 40% of the urban area can result in a maximum temperature reduction of 4-5°C. (Ziter et al., 2019)

There is a robust scientific basis for the emphasis on native Mediterranean species, as evidenced by the biodiversity of the Mediterranean Woodlands and Forests ecoregion. This ecosystem supports diverse flora, including cork oak, Aleppo pine, evergreen holm oak, and juniper (Olson et al., 2001). It has been demonstrated that native species demonstrate a superior degree of acclimatization to regional climatic conditions, consequently resulting in diminished water requirements and maintenance needs. In addition, these species are instrumental in ensuring the effective functioning of ecosystem services.

A plethora of research has been conducted on the subject, and the findings have demonstrated that the efficiency with which trees cool down is subject to variation depending on the species composition and structure of the trees in question. Complex woodlands, characterised by a diverse species composition and a multi-tiered structure, have been shown to provide superior cooling compared to simple, single-layer plantings (Fung & Jim, 2019). The objective of achieving 1.4°C of localized cooling can be realised in accordance with the documented efficacy of cooling of 0.3°C for every 0.10 canopy cover increase (Krayenhoff et al., 2021).

### *5.2. Medium-Term Actions*

#### Urban Forestry Targets

The objective of achieving 20-25% canopy coverage signifies an empirically validated strategy for advancing urban forestry initiatives. A substantial body of research has repeatedly demonstrated that a considerable amount of tree coverage is necessary to achieve a significant cooling effect, with optimal outcomes manifesting at 40% tree coverage (Ziter et al., 2019).The medium-term objective of achieving a range between 20 and 25 per cent is considered a pragmatic intermediate goal, while also establishing a framework for attaining optimal levels of coverage.

Studies of tree cooling efficiency have indicated that urban forests have the capacity to reduce air temperatures by up to 4.1°C in comparison with concrete surfaces and 3.9°C in comparison with lawn areas. The effectiveness of this phenomenon varies according to season and weather conditions, with the most marked cooling occurring during summer days that are sunny(Fung & Jim, 2019).

#### Integrated Water-Heat Management Systems

The utilisation of bioswales as a strategy for addressing the challenges posed by urbanisation and climate change has been identified as a promising approach, especially with regard to the management of stormwater and urban heat. This approach, founded on ecological principles, has demonstrated significant potential in promoting sustainable urban infrastructure. The vegetated channels in question have been demonstrated to reduce urban flooding by slowing, filtering and infiltrating stormwater naturally, whilst providing cooling benefits through evapotranspiration (Şen & Şat, 2024). The implementation of bioswales within urban districts has been demonstrated to create "green-blue veins" which have been shown to assist in the reduction of heat stress whilst managing water resources. (Boogaard et al., 2006) (Boogaard et al., 2020)

The dual functionality of bioswales renders them especially valuable for climate adaptation. The primary function of these green spaces is the removal of pollutants from stormwater, the promotion of water infiltration that improves groundwater recharge, and the facilitation of evaporation that serves to reduce the urban heat island effect(UNEP-DHI, n.d.). During instances of groundwater flooding, bioswales can function as drainage systems. (Boogaard et al., 2006)

It is evident that green corridors have a significant impact on the enhancement of cooling, which is achieved through a variety of mechanisms. These mechanisms include evapotranspiration, the provision of shade, and the reduction of heat absorption, when compared to conventional urban surfaces. The prevalence of flora in green corridors has been demonstrated to increase evapotranspiration rates, thereby contributing to a reduction in local temperatures and a counterbalancing effect on the heat generated by urban infrastructure. (Yuan, 2024)

#### Regional Coordination Framework

Multi-level governance frameworks are imperative for effective climate adaptation on a large scale. A plethora of studies have demonstrated that effective coordination and cooperation across all levels of government are pivotal in achieving climate objectives(Tänzler, 2018). Local mitigation and adaptation potentials are frequently underutilised due to a paucity of coordination mechanisms.

The capacity of regional adaptation authorities to standardise GIS monitoring systems, facilitate joint procurement of technologies and services, and enable the sharing of technical resources across municipalities, is a key consideration. This approach has been demonstrated to engender a reduction in costs, an enhancement of technical capacity, and an assurance of consistent implementation of adaptation strategies across metropolitan regions(Tänzler, 2018).

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### *5.3. Long-Term Actions*

Climate-Responsive Urban Planning

Local Climate Zone (LCZ) classification has been demonstrated to offer a scientifically robust framework for urban climate planning (Han et al., 2024).The LCZ systems are effective in the classification of urban areas based on climatic variations related to anthropogenic heat, built morphology, and surface characteristics (Sushanth et al., 2022). A plethora of research has demonstrated that different LCZ types exhibit significant variations in thermal performance, with substantial disparities in heat flux being observed between zones.

The integration of LCZ criteria into urban planning facilitates the optimisation of urban geometry for radiative cooling and natural ventilation. Research has demonstrated that characteristics of urban morphology, including building density, surface features, and incident angle, significantly influence microclimate conditions. Dense forest canopies have been shown to enhance buffering capacity against climate extremes (Jones et al., 2022) (De Pauw et al., 2023).

Ecosystem Restoration

It is evident that peri-urban forests and wetlands fulfil a pivotal function in preserving thermal gradients between urban and rural regions. Research indicates that urban forest edges experience unique microclimates shaped by the urban heat island effect, with edge effects reaching deeper into urban forests (at least 50 metres) compared to rural forests. Denser forests, characterised by a higher plant area index, have been shown to offer enhanced buffering against elevated air temperatures. (De Pauw et al., 2023).

Urban wetlands have been demonstrated to make a substantial contribution to climate resilience through multiple pathways. It has been demonstrated that such measures can enhance thermal acceptability and facilitate the establishment of climate-resilient urban systems as integral components of green-blue infrastructure networks(Alikhani et al., 2021). Wetlands have been shown to provide significant benefits to biodiversity, whilst also supporting effective stormwater management and microclimate regulation. The strategic expansion of peri-urban ecosystems has been demonstrated to create natural cooling zones that moderate urban temperatures. These areas function as carbon sinks while providing flood attenuation and biodiversity habitat. (Alikhani et al., 2021) (Thorn et al., 2021).

Smart Monitoring

Real-time monitoring systems facilitate adaptive management of urban climate through continuous data collection and analysis. The Internet of Things (IoT) technology has been found to facilitate comprehensive monitoring of temperature, humidity, and energy usage across urban infrastructure (Jones et al., 2022). The utilisation of centralized management systems enables the expeditious execution of adjustments in accordance with prevailing environmental conditions.

The advent of advanced satellite constellations has engendered a paradigm shift in the realm of urban temperature monitoring, bestowing upon researchers the capability to attain unparalleled temporal resolution. New space constellations will enable frequent observation of urban areas with Land Surface Temperature data collection every 12 hours globally, with this frequency improving to sub-hourly by 2027(Mollière et al., 2024). This enhanced monitoring capability supports proactive heat mitigation and emergency response systems (Hassan & Farea, 2025).Machine learning algorithms have been demonstrated to enhance the accuracy and predictive capability of monitoring systems. These systems facilitate temperature control that is both responsive to current conditions and predictive of future needs (Hassan & Farea, 2025). The integration of ground-based sensors with satellite data provides comprehensive coverage for adaptive management strategies.

 doi:10.20944/preprints202507.0313.v1



Green Finance

The utilisation of green finance mechanisms is imperative for the procurement of funding for large-scale urban adaptation infrastructure. It is estimated that a funding requirement of $4.3 trillion per annum is necessary on a global scale in order to provide urban mitigation (UNEP, 2019). Green bonds provide low-cost capital for cities and municipalities, thereby facilitating the transition from conventional to green infrastructure.

Urban forest carbon credits have been identified as a potentially lucrative source of revenue for the facilitation of tree planting and maintenance programmes. Recent market developments indicate that urban forest credits are commanding premium prices of $34-45 per metric ton of CO2, in comparison to less than $10 for traditional forest credits (Nowak & Crane, 2002). The initial transaction involving the issuance of a $1 million urban forest carbon credit serves to underscore the commercial viability and investor interest in this particular market segment. (Nowak & Crane, 2002)

Tax incentives for green infrastructure have been demonstrated to be a potent instrument for effecting market transformation. These incentives serve to reduce financial barriers to sustainable construction, while concomitantly promoting long-term cost savings through reduced utility bills and maintenance expenses (Asuamah Yeboah, 2024). The utilisation of accelerated depreciation and tax credits for energy-efficient upgrades has been identified as a key factor in promoting the widespread adoption of climate adaptation technologies. (Asuamah Yeboah, 2024)

Carbon credit programmes specifically designed for urban environments have been shown to capture multiple co-benefits beyond carbon sequestration. The quantification of benefits associated with Urban Forest Carbon+ Credits™ includes, but is not limited to, the following: reduction in stormwater, enhancement of air quality, and improvement in public health (Nowak & Crane, 2002). These comprehensive value propositions provide a rationale for premium pricing and attract a diverse range of investor interest.

## 6. Conclusions

The urban areas of the Mediterranean region are confronted with a triple threat of accelerating warming, altered precipitation patterns, and intensifying extreme weather events. The evidence base for targeted adaptation is provided by GIS-based downscaling, LCZ mapping, and multi-criteria hazard analysis. North Cyprus cities, which are particularly vulnerable to extreme heat and flooding, stand to benefit from the proposed phased GIS-driven roadmap, which is designed to enhance urban resilience. The integration of advanced materials, green infrastructure, sophisticated water management systems, and real-time monitoring within a robust governance and financing framework has the potential to position North Cyprus as a Mediterranean exemplar of climate-adaptive urban planning.

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