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Spatio-Temporal Variation In Urban Vegetation In Maghrebian Cities Since The XXst Century Using Remote Sensing

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Abstract

In Maghreb, vegetation cover, a crucial factor for the sustainability of urban ecosystems, is undergoing significant change in cities. After the French colonial period giving key consideration to public vegetation in the new towns built such as in Sousse, Algiers or Marrakesh, the importance attached to greenery in cities is not clearly defined in independent Tunisia, Algeria and Morocco, and today consideration of urban vegetation in Maghrebian spatial planning policy is still nascent.

By taking a spatialized approach involving satellite remote sensing we show an overall decline in vegetation cover in the cities of Algiers, Sousse and Marrakech between the 1970s and the 2020s with two distinct periods; a swift and fairly steady decline in greenery until 2000, slowing significantly and even reverses slightly after this date. The spatial distribution of vegetation

across the cities has also changed, much more uniform in 1973 than during the later periods where greenery became increasingly concentrated within clearly defined areas.

A neighborhood-based analysis of the vegetation cover makes it possible to connect the contrasting spatial distribution and variation observed with the public spatial and urban planning policies since the 1970s, as well as since the colonial period and their implications in terms of socio-environmental justice and socio-spatial segregation generated by the spatial organization of vegetation in Algiers, Sousse and Marrakesh.

Today, the proportion of green space per capita shows that these cities have an overall average (of 3.1 sq.m. per capita for Marrakesh), falling short of the minimum 10 sq.m. per capita recommended by UN-Habitat.

Keywords:

Urban Vegetation, Spatio-Temporal Variation, Urban Planning Policies, Remote Sensing, Algiers, Sousse, Marrakesh, Maghreb

1. Introduction

More than half of the world's population lives in urban areas today (United Nations, 2018) often beset by environmental problems with water and air pollution and deteriorating ecosystems (Grimm et al., 2008), which are undermining the quality of life for inhabitants.

Compounding the stress of urban dwellers, the COVID pandemic has confirmed the need for “nature” in cities and the importance of a change in urban model for the sake of inhabitants' well-being (Clergeau, 2020; Ajmi et al., 2023). Greenery in cities is of the utmost importance as it provides goods and services and complete ecosystem functions that benefit city dwellers and the environment alike. In addition, it provides a whole host of advantages in terms of human well-being (Declét-Barreto et al., 2013; Ajmi et al., 2024), not least by mitigating the urban heat island (UHI) effect (Gourfi et al., 2022) - a threat to human health (McGrane, 2016) - by reducing stress, improving healing time and cognitive abilities (Lee et al., 2015). Such greenery also provides a range of ecosystem services including protection from some natural disasters - flooding for example (Dana, 2002; Kim, 2016) - strengthening biological processes like pollination (Zitkovic, 2008) and reducing water erosion (Darrel Jenerette et al., 2011; Seitz and Escobedo, 2011).

Vegetation cover is therefore a crucial factor for the sustainability of urban ecosystems (Robinson and Lundholm, 2012). And yet it is undergoing significant change in cities, not only as regards spatial extent but also density, structure and flower composition.

In Maghreb, the forms and functions of urban greenery as well as the importance attached to it have changed over time. The French colonial period marked a turning point in these changes in particular. Indeed, the North African colonies would turn out to be ideal urban testing grounds and the French protectorate in Morocco (1912-1956) and Tunisia (1881-1956) or colonizing state in Algeria (1830-1962) would set special store by vegetation in the new towns built, while still giving key consideration to the pre-existing scenery, the Medinas (old walled quarters) in particular, such as in Marrakesh (Taïbi and El Hannani, 2019), Algiers and Sousse.

That said, the cities of Marrakesh, Algiers, and Sousse prior to the creation of the new European neighbourhoods from the colonization outside the ramparts of the Medinas, were surrounded by countless gardens organized around water resources. In Marrakesh some centuries old orchards (Almohad Agdal and Menara gardens) are neighbouring a palm grove and its farmland irrigated from *khettaras*, underground channels carrying the water from the groundwater sheet of the Haouz plain (Bennani, 2017; El Faiz and Bendaoud, 2000; El Hannani *et al.*, 2017). In Algiers the medina (called Casbah) was surrounded by the ottoman *Fahs*. In Sousse the medina was surrounded by olive groves. Inside the walled ramparts, meanwhile, were *Arsas* ornamental gardens and kitchen gardens for the community, mainly in Marrakesh. Lastly, there were many *Riads*, traditional town houses built around a patio or enclosed inner garden surrounded by a gallery. All of these gardens primarily served a sustenance purpose, but they also provided “green space” in the cities and a setting for the the weekly picnic (*N'Ezha* in Marrakesh), or some religious festivals (El Hannani et al., 2017).

With the French protectorate and colonisation, the ideal city, the model city to which French urban planners, able to give free rein to their creativity, aspired at the turn of the 20th century (Prost, 1932), was a modern, airy, green and open city where open green spaces and public gardens were given pride of place.

Maghreb, free from the regulatory red tape of mainland France, represented choice sites for developing new European cities providing a healthy living environment appealing to the settlers (Gillot, 2014) who found the old walled part of the Medinas frightening on account of its “labyrinthine”, “foul-smelling” and “swarming” quarters (Taïbi and El Hannani, 2019). This French model of the colonial city was thus “projected” as a counterpoint to the local Arabo-Berber model of the Medinas so as to “reveal” Western civilization. The aim was to reflect what a “modern” colonial city should be in the Western sense, with perfect geometry combining functionality, viability and efficiency (El Hannani et al., 2017), by giving precedence to sports amenities, physical education in the open air and green spaces. This was so as to guarantee the physical and mental development of the French (Bennani, 2017).

When independences came in Morocco, Algeria and Tunisia, new neighbourhoods were added to the outskirts of the three cities, amid fairly swift demographic growth. Listed as UNESCO World Heritages of Humanity today, the three medinas supports touristic activities, mainly in Marrakesh and Sousse, thanks to the world-class hotel facilities and sunny climate of the cities, as well as their gardens and golf courses - even though these are enormously water-reliant. In Morocco and Tunisia, the city’s hotel facilities have certainly expanded rapidly in recent years, and the development of tourism represents for example a priority in terms of promotion for the Marrakesh Urban Community (CUM), with 72% of the overall investment amount (monograph paper for Marrakesh, non-dated). However, the three cities has warm, Mediterranean or arid bioclimates with average annual rainfall of just 281 mm for Marrakesh for instance (El Faiz et al., 2016), and a hot and dry summer. This all places them under regular water stress and significant pressure where its vegetation is concerned. Be that as it may, against the current climate backdrop, this vegetation is one way to reduce urban heat islands by helping to keep temperatures under control.

The importance attached to greenery in cities is not clearly defined in Morocco, Algeria and Tunisia today, despite incentives from the governments, for instance the Moroccan ministry for Housing and Urban Planning to encourage local authorities to draw up green plans, the stated intention being to improve residents’ living environments by giving significant precedence to local green space. In Marrakesh, although leaders claim to have “crafted a proactive policy in terms of green space”, with a positive impact on the city’s national and international image (Benabdeljalil and Boujmal, 2008), in 2015 its parks & gardens department said that it did not have a clear idea of the vegetation composition in green public spaces (Taïbi and El Hannani, 2019). In Sousse, as well as in Algiers, the green spaces inventory is very recent and still incomplete. This shows that, in reality, consideration of greenery in Maghrebian spatial planning policies is still nascent. Whatever the official rhetoric might be, in most cases it is not until buildings, roads and car parks have been erected that a landscape architect is then called in to fill in the gaps (Clergeau, 2020). Furthermore, the colonial legacy in terms of greenery, in the same way as urban design or architecture, has considerably shaped the city’s landscapes and functioning.

The areas studied here are, therefore, Marrakesh in Morocco, Algiers in Algeria and Sousse in Tunisia.

The Marrakesh Urban Community (CUM), one of the municipalities in the region of Marrakesh-Safi (Fig. 1), extends over 230 sq.km, with five *arrondissements* (districts) (Marrakech-Medina,

Gueliz, Menara, Ennakhil and Sidi Youssef Ben Ali/SYBA) and 25 neighborhoods. It is home to 928,850 inhabitants with a density of 350 inhabitants per sq.km (HCP, 2014).



Fig. 1. Location of the Marrakesh Urban Community (CUM) and its different neighborhoods (the background image is a color composition of Sentinel-2A images) (Gourfi, 2023)

Sousse, a very old Phoenician city in the centre-east of Tunisia, includes 15 districts 5 of which are specifically studied in its centre: Sousse Medina, Sousse North, Sousse South, Sousse Jawhara and Sousse Riadh with a total area of 78,9 sq.km (Fig. 1).

Algiers old Punic city where the Romans, Arabs, Ottomans and French succeeded one another, is included in a wilaya comprising 13 administrative districts (Dairas) and 57 communes and covering an area of 808 sq.km for a total estimated population of more than 3 154 792 inhabitants.

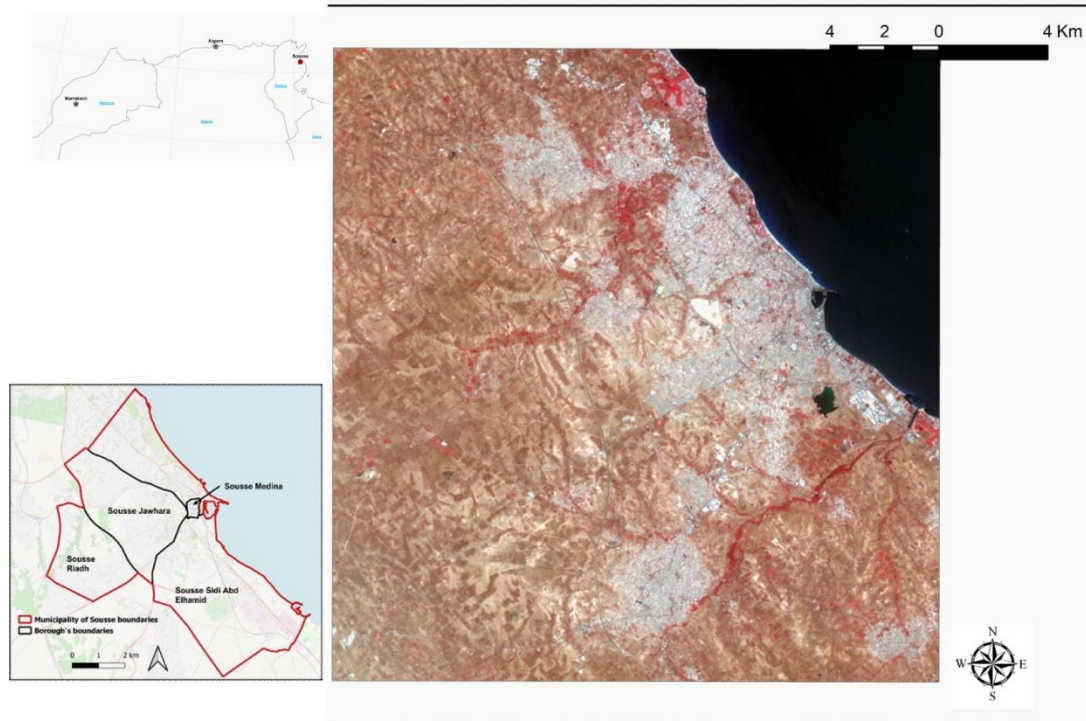


Fig. 2. Location of the Sousse city (From 2020 Landsat images) and the studied five of Sousse's 15 boroughs: Sousse-Khzema, Sousse Medina, Sousse Sidi Abd Elhamid, Sousse Jawhara, and Sousse Erriadh (Gourfi, 2023)

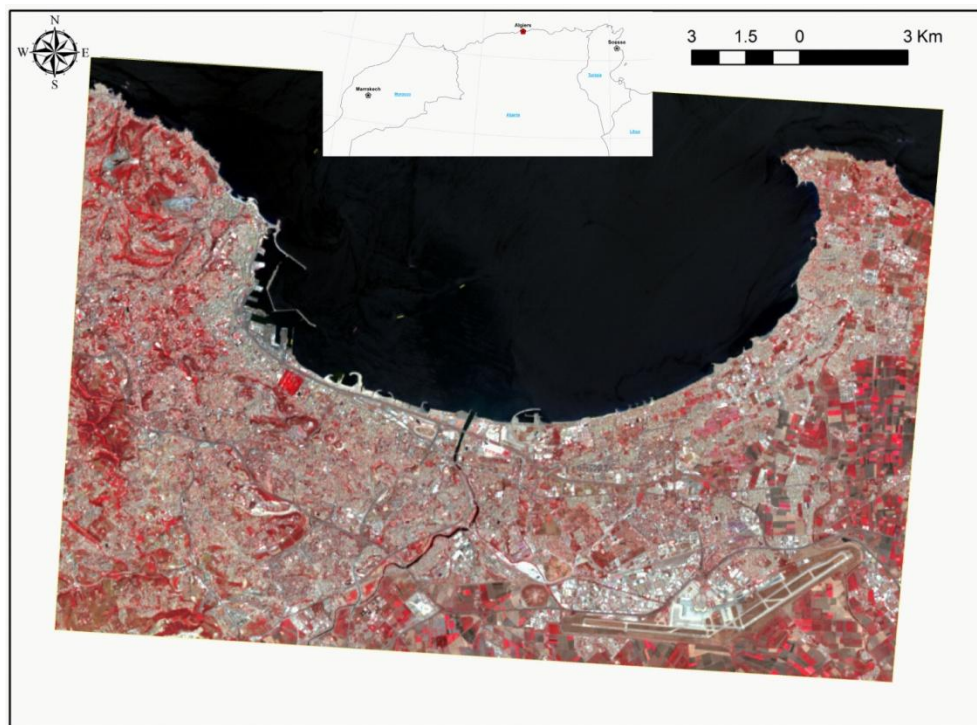


Fig. 3. Location of Algiers (From 2020 Landsat images) (Gourfi, 2023)

In Marrakesh the Medina and Mechwer make up the city's old center, next to which are the neighborhoods of Hivernage and Gueliz as well as the military district during colonial times. The other neighborhoods were built following independence. SYBA, a 1960s working-class informal settlement, was built around ancient foundations and subsequently regularized. To the south, Hay Jadid went through a similar process after the 1990s. Daoudiate is a planned middle-class neighborhood from the 1970s, as are Issil and Amerchich from the 1980s. Mhamid, Massira, Iziki, Azli, Hay Hassani and Riad Salam are high-rise working-class estates planned in the 1990s and 2000s and which spill over into predominantly rural neighborhoods such as Sidi Ghanem, El Inara, Maata Allah, Azkjjour, Bouaakaz and Al Izdihar. The neighborhoods of Ennakhil Nord and Sud, which developed in the palm grove mainly after 2000, are home to villas and hotels and are relatively unurbanized.

We are therefore more interested in the vegetation in these cities and its variations from the 1970s.

Urban vegetation refers to all parks and gardens, whether private or public (in the meaning of open to the public or of ownership of the land), managed, abandoned or spontaneous, located within or near an "urban area". It also concerns isolated plants as well as large green formations (forested areas, hedges, fallow land and lawns for example) (Taïbi and El Hannani, 2019).

By taking a spatialized approach involving satellite remote sensing we are going to document the spatio-temporal variations in urban vegetation in the three cities and determine the factors behind these variations. The aim is particularly to understand the social, economic and political forces driving these trends and its effects on the urban space of the cities. We are also seeking to grasp the implications in terms of socio-environmental justice and socio-spatial segregation generated by this spatial organization of vegetation at the scale of the CUM.

2. Material And Methods

The method adopted in this research has three main steps. The first step is to determine the extent of the green spaces across the three cities and its variation over time from a set of Landsat satellite images dated 1980's and 2020's. During the second step, built-up areas (artificial surfaces) have been determined for a spatial comparison for the year 2020 using Landsat satellite images. For Marrakesh, as an example of maghrebian cities, the method have been developed in order to have details about the evolution of the city and its vegetation. The method has been applied to Landsat satellite images from 1973 to 2020 and a last step involves the use of NDVI data at 8-day intervals from 2000 to 2020, to confirm the results and to compare the variation in vegetation with rainfall rates for Marrakesh.

2.1. Data Source And Preprocessing

The Landsat satellite product (spatial resolution: 30-80 m) were used in this study, dated June or July 1984 or 1985 and 2020 or 2021 for the three cities (Tab. 1a).

We added for Marrakech a collection of Landsat satellite images from 1973 to 2020 (1973, 1985, 1990, 1995, 2000, 2005, 2010 and 2015), mainly used to map vegetation areas changes, and Sentinel-2A satellite product (spatial resolution: 10-20 m) used mainly to map built-up areas in

2020 (Tab. 1b). All the images were acquired from USGS Global Visualization Viewer (GloVis) (Global Visualization Viewer, 2021).

All the images were taken during the months of June, July and August (dry period), in order to characterize only the permanent vegetation cover, which is irrigated during this arid spell. Only images with no or less cloud cover were selected to improve accuracy of vegetation (Landsat) and built-up (Sentinel-2A) classification detection.

Table 1.a Landsat satellite images used for the diachronic study

City	Present (Landsat 8)	Past (Landsat 1)
Algiers	07-29-2021	07-30-1984
Sousse	07-01-2021	06-09-1984
Marrakech	08-12-2020	07-27-1985

Table 1.b Added satellite images used for Marrakech

Satellite	Sensor	No. of MS bands (nominal resolution)	Period
Landsat 1	MSS / RBV	4 (80 m)	27-03-1973 07-27-1985 07-09-1990
Landsat 5	MSS / TM	4 (30 m)	08-08-1995 08-19-2005 07-16-2010
Landsat 7	ETM+	6 (30 m)	08-13-2000
Landsat 8	OLI / TIRS	8 (30 m)	07-14-2015 08-12-2020
Sentinel-2A		13 (10-20 m)	08-14-2020

An atmospheric correction was performed for each image using Line-of-sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) in ENVI software. In addition, a radiometric calibration was used to calibrate image data to radiance, reflectance, and brightness temperatures using ENVI Calibrate Raster routine.

2.2. Determination Of Vegetation And Built-up Areas From Satellite Images

We applied a Principal Component Analysis (PCA) on each Landsat corrected and preprocessed data set, followed by an unsupervised classification on all the principal components produced, and then supervised classifications with a maximum likelihood algorithm on the results, in order to spatialize the vegetation and built-up areas of the cities in the 1980's and 2020's.

For Marrakesh specifically, we also applied the supervised classification on all the principal components produced for the 10 dates from 1973 to 2020 to show the evolution of the vegetation areas of the CUM during that period.

A Principal component analysis (PCA) is a method based on the covariance and variance of the data set (Mutlu et al., 2008), transforming the data into a new coordinate system to reduce multidimensional data sets to lower dimensions (Dópido et al., 2012). The PCA method produces

uncorrelated variables called principal components, and only the first principal components can represent significant variance compared with the original data (Huang et al., 2012).

The supervised classification method with the maximum likelihood algorithm (MLC) was applied in ArcGIS 10.7.1 to extract vegetation and built-up cover information. The MLC algorithm is one of the most commonly used supervised classification methods in remote sensing image processing. This technique is based on the possibility that a pixel belongs to a particular class. In this model, we assume that these possibilities are equal for all classes and that the input bands have normal distributions. The spectral distance method calculates the mean vector of each signature and the spectral distance between the measurement vector of the candidate pixel (samples). For vegetation detection, the samples were selected by viewing on screen (Guo et al., 2021), and also based on the multi-spectral false-color composite image consisting in making the vegetation appear in red (Fig. 2). For built-up detection, samples were selected through Google satellite imagery (Vigneshwaran and Vasantha Kumar, 2018).

For Marrakesh, we used a hexagonal grid applied on the different classification results in order to extract spatial information on vegetation areas. In each polygon of 100 ha we quantify the extent of vegetation from 1973 to 2020, but also built-up and bare soil areas used occasionally in the study for 2020. Built-up areas are urbanized landscapes shaped by stone. Bare soils correspond to stony mineral areas that have not been built on.

In addition, we also used the annual time series of rainfall data from the Marrakesh weather station to analyze the variation in rainfall in the city in relation to the vegetation data results for the period between 1973 and 2020.

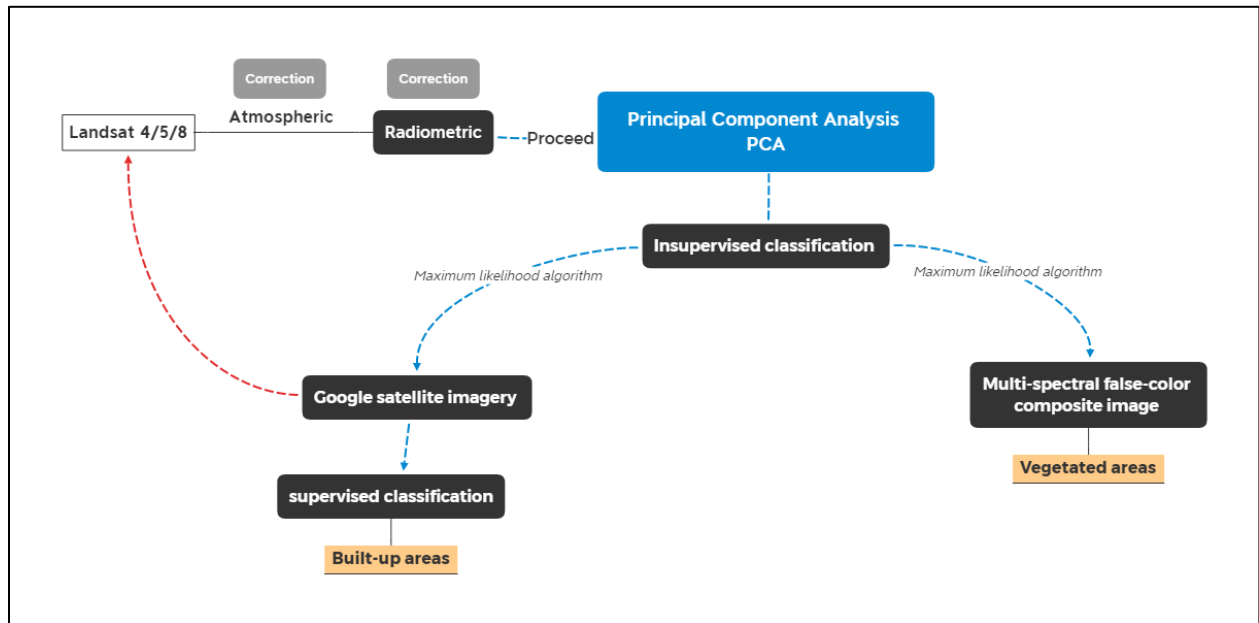


Figure 4: Different steps of images processing (Gourfi, 2023)

3. Results and Discussion

3.1. Evolution Of Built-up And Vegetation Areas: An Overall Urban Sprawl From 1980s To 2020s

Marrakesh

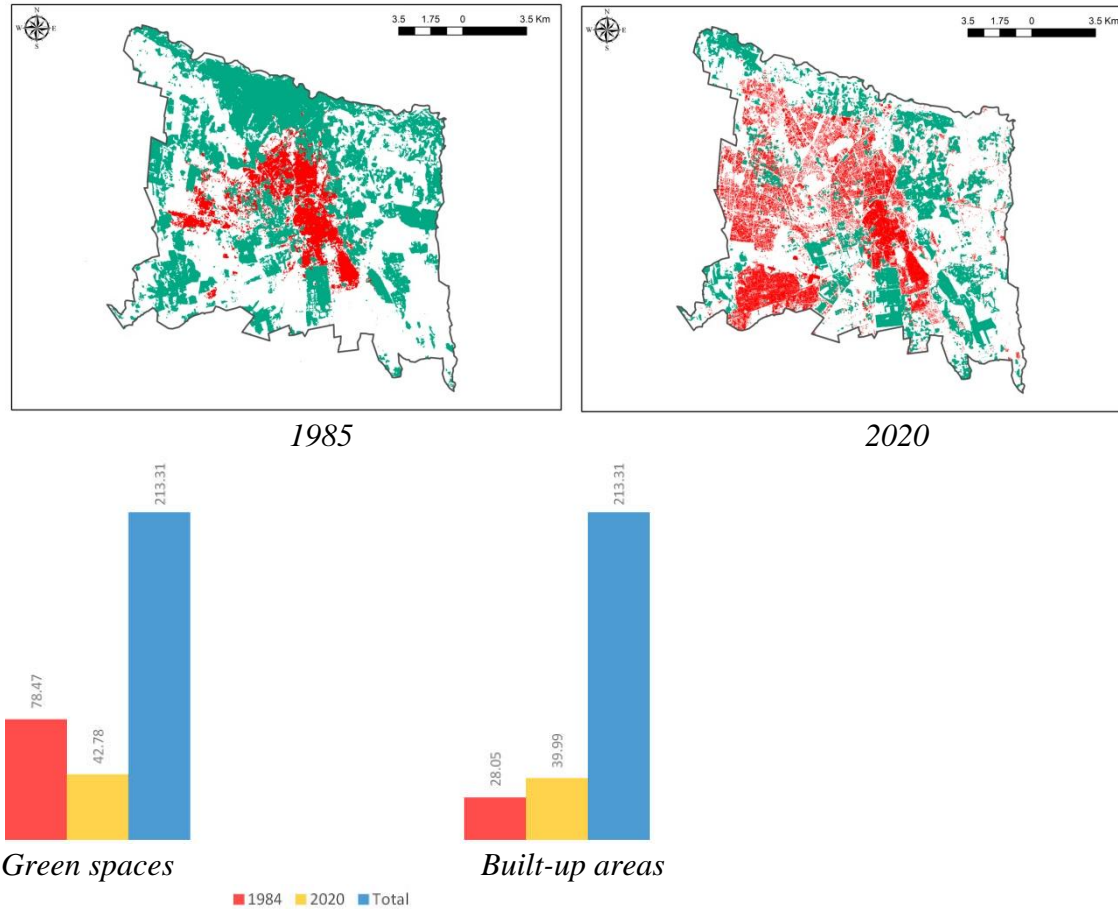
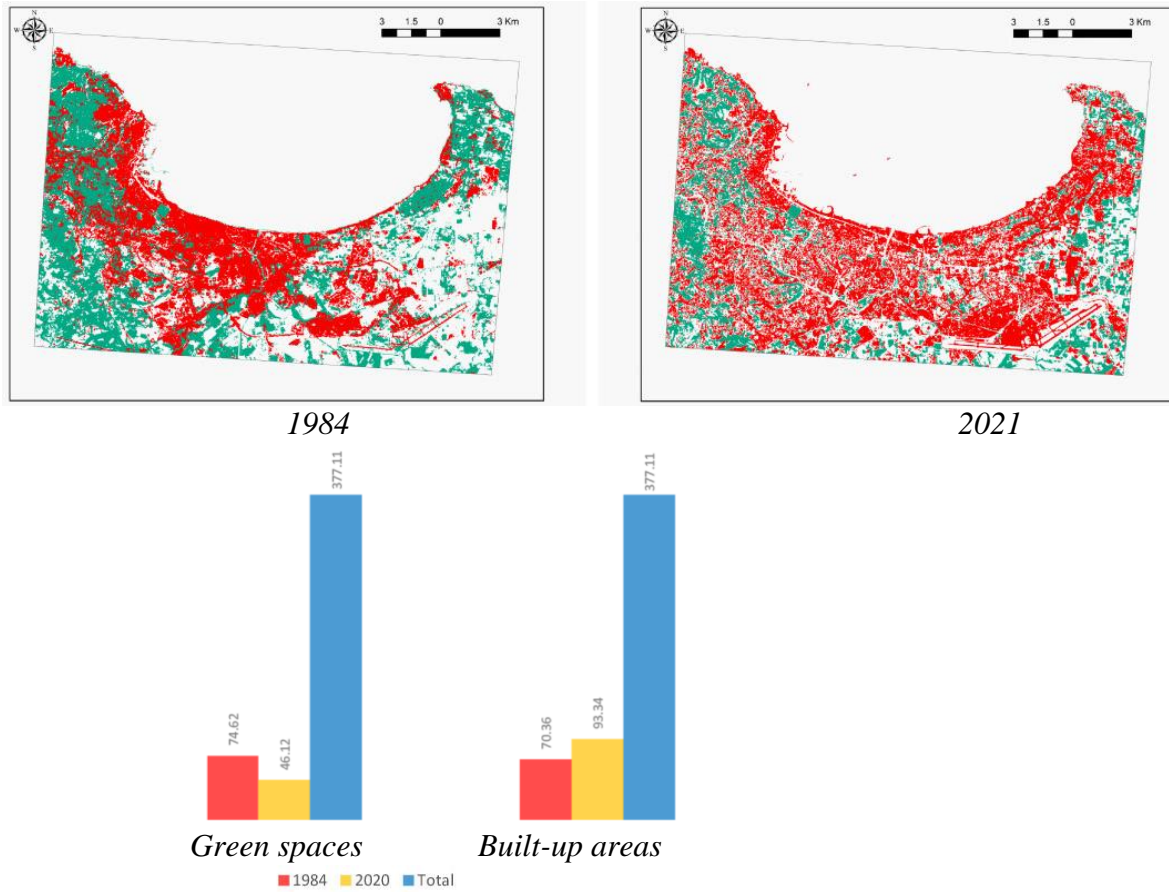


Figure 5: Evolution of built-up and vegetation areas in Marrakesh from 1985 to 2020 (Gourfi, 2023)

In Marrakesh we have an increase of the built-up areas with 11.94 km² more (43% more) to the detriment of green spaces which have suffered a 45% decrease in surface area (35,69 km²) from 1985 to 2020.

Algiers

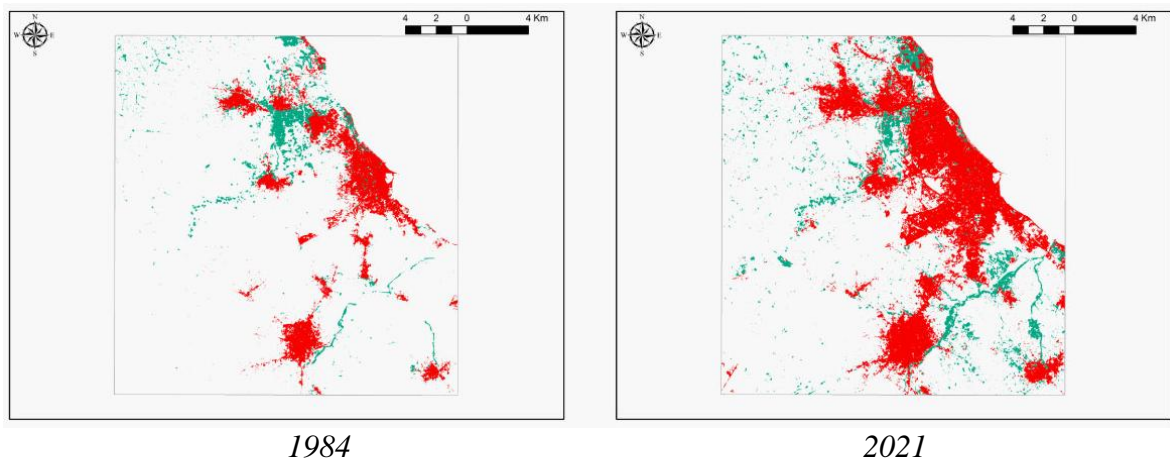


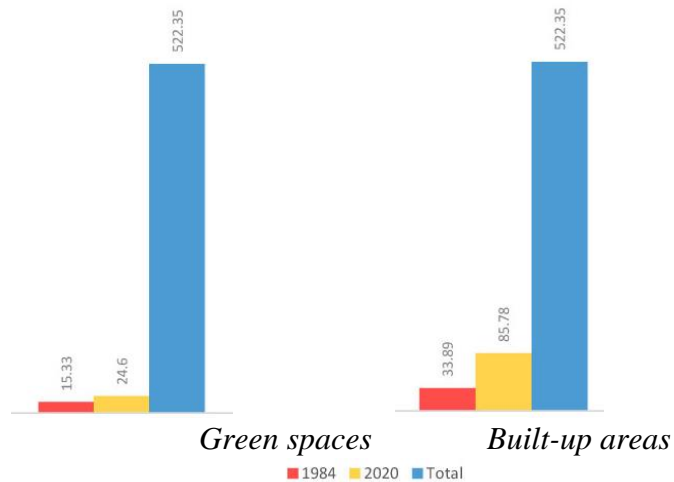
Built-up areas : + 22.98 km² (+33%) **Green spaces** : -28.5 km² (-38%)

Figure 6: Evolution of built-up and vegetation areas in Algiers from 1984 to 2021 (Gourfi, 2023)

We can notice once again an important decrease in green spaces (-38%) in Algiers in conjunction with an increase in built up areas from 1984 to 2021. In 2021, green spaces covered 46.12 km² for a total surface area of 377.11 km² (including built-up areas and bare soils).

Sousse





Built-up areas : + 51.89 ha (+153%) **Green spaces** : +9.27 ha (+60%)

Figure 7: Evolution of built-up and vegetation areas in Sousse from 1984 to 2021 (Gourfi, 2023)

In Sousse, the scenario is quite different as we have an increase of both green spaces and built-up areas from 1984 to 2021.

The apparent increase in vegetated areas in Sousse between 1984 and 2020 is only relative, and probably linked to the development of new irrigated agricultural zones on the outskirts of the city, and because the many former olive orchards absorbed into the city, some of which have been preserved but transformed into private gardens, are now irrigated even in summer, whereas they were not in 1984. As long as the town does not become too densely populated, private individuals are able to preserve the olive trees that play such an important role in Soussian culture, especially when it comes to single-family houses. In addition, the town's expansion is taking place in a more or less anarchic fashion, and is very much a case of urban sprawl.

3.2. An Overall Downward Trend In Vegetation Cover From 1973 To 2020 The Example Of Marrakesh

In Marrakesh, the diachronic study of vegetation cover from the classifications calculated from 1973 to 2020 shows a detailed significant, steady decline over this period (Fig. 8). In 1973, greenery covered 11389.21 ha, a figure which had dropped to just 4528.90 ha in 2020. This corresponds to an average annual reduction between 1973 and 2020 of -145.96 ha (Fig. 9).

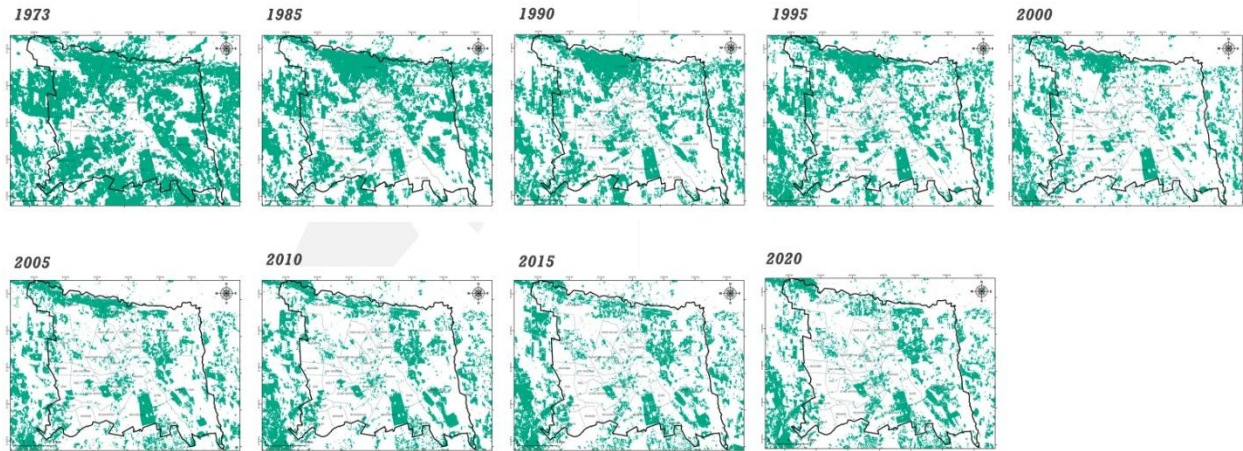


Fig. 8. Vegetation cover from 1973 to 2020 based on the supervised classification of the PCA components (Gourfi, 2023)

However, behind this overall decline in vegetation cover in Marrakesh between 1973 and 2020 are two distinct periods in reality (Fig. 9). Until 2020, the decline in greenery was swift and fairly steady, but after this date it slowed significantly and even reverses slightly.

Over the first period, between 1973 and 1995, the average annual fall in green spaces was -234.52 ha. During this time, the surface area covered by greenery diminished from 11389.21 ha (53.39% of the CUM's total surface area) in 1973 to 6229.85 ha (29.21% of the CUM's total surface area) in 1995. Over the second period, with an overall increase of +6.28 ha per year, green spaces dipped from 4403.55 ha (20.64% of the CUM) in 2000 to 4278.00 ha (20.06% of the CUM) in 2020.

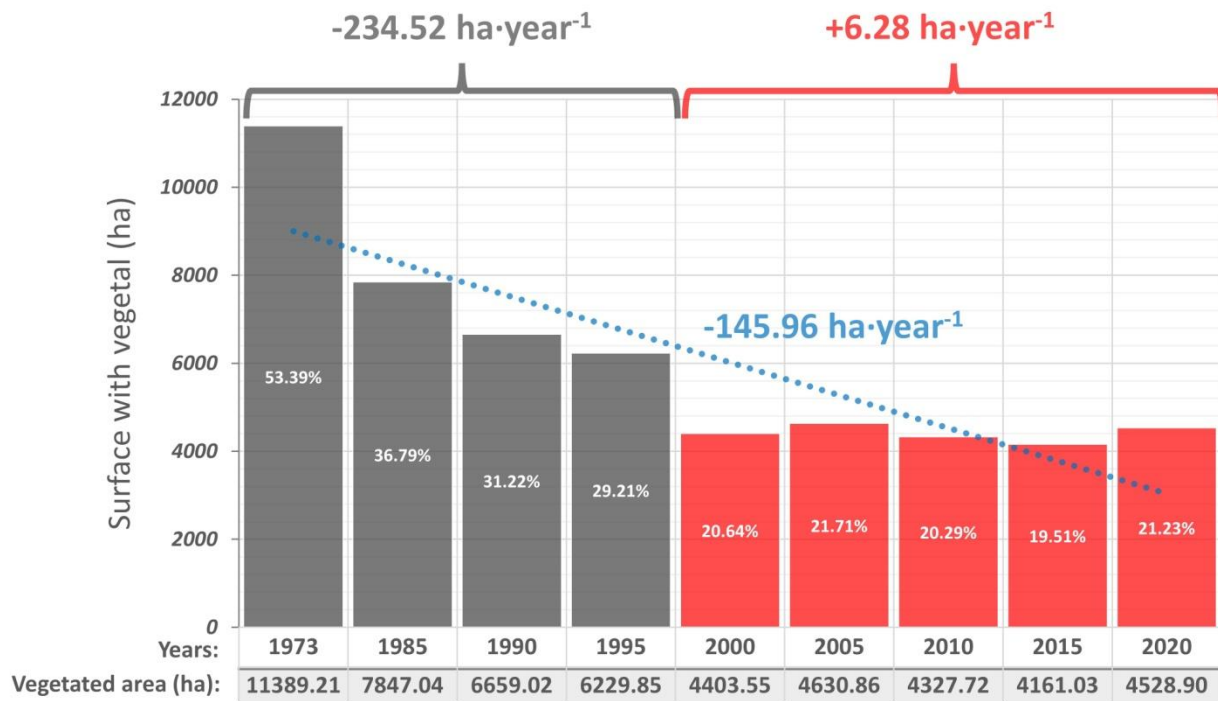


Fig. 9. Variation in vegetation cover in Marrakesh from 1973 to 2020 (Gourfi, 2023)

This overall change in vegetation cover is not uniform in spatial terms. In reality, during each period, it can be broken down into areas characterized by a decline in vegetation compared with the previous date, stable areas that do not change and areas with a change in land use and development of new plant cover. From 1973 to 2020, although the dominant areas are those where greenery disappeared (with 8674.59 ha between these two periods), some vegetation areas did not change (2720.79 ha), and some new green spaces even appeared (1157.48 ha) (Fig.10).

The stable green spaces mainly correspond to the heritage gardens (Agdal and Menara) as well as farmland, which will still be there in 2020, forming a more or less protected, if discontinuous, green belt around the city. The dominant areas characterized by disappearing vegetation, meanwhile, correspond for the most part to areas that were urbanized during this period. The new vegetation areas are mostly golf courses or the expansive grounds of hotels, tourism complexes and/or luxury real estate, which have developed in leaps and bounds since 1973.

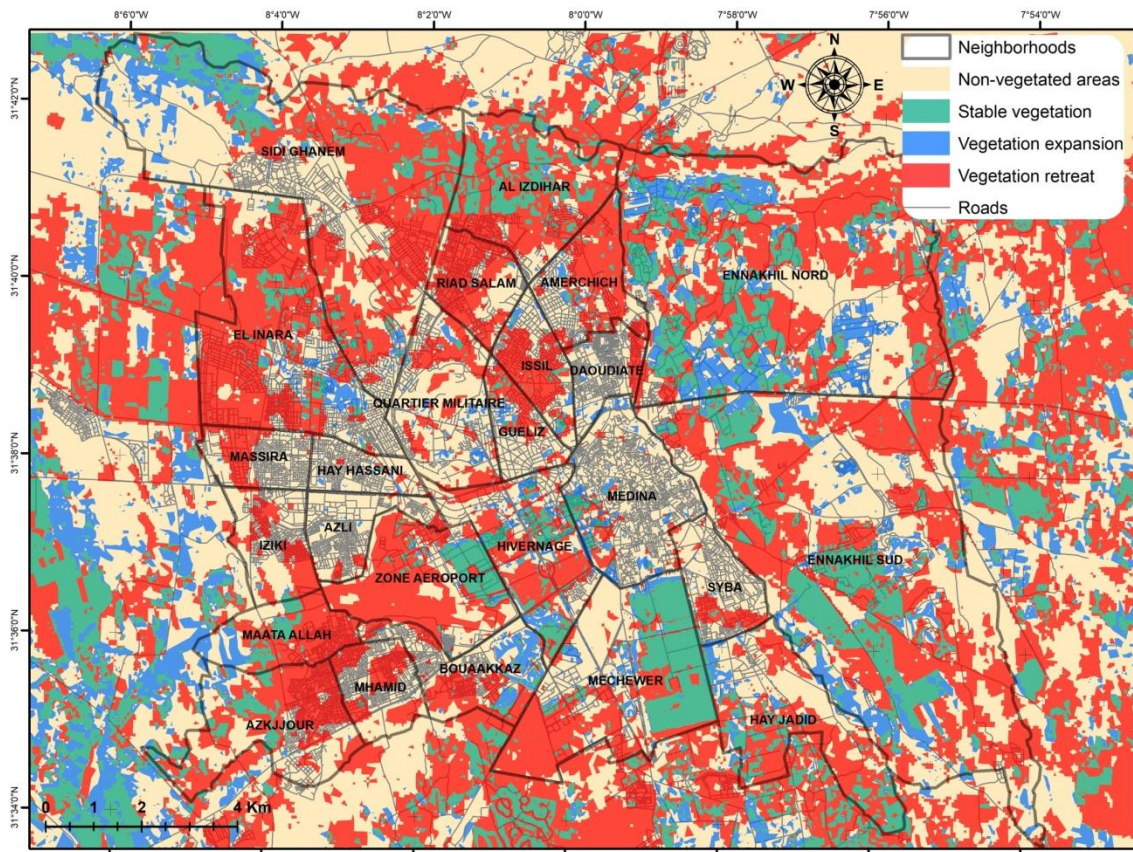


Fig. 10a. Variation in vegetation cover in Marrakesh from 1973 to 2020 (Gourfi, 2023)

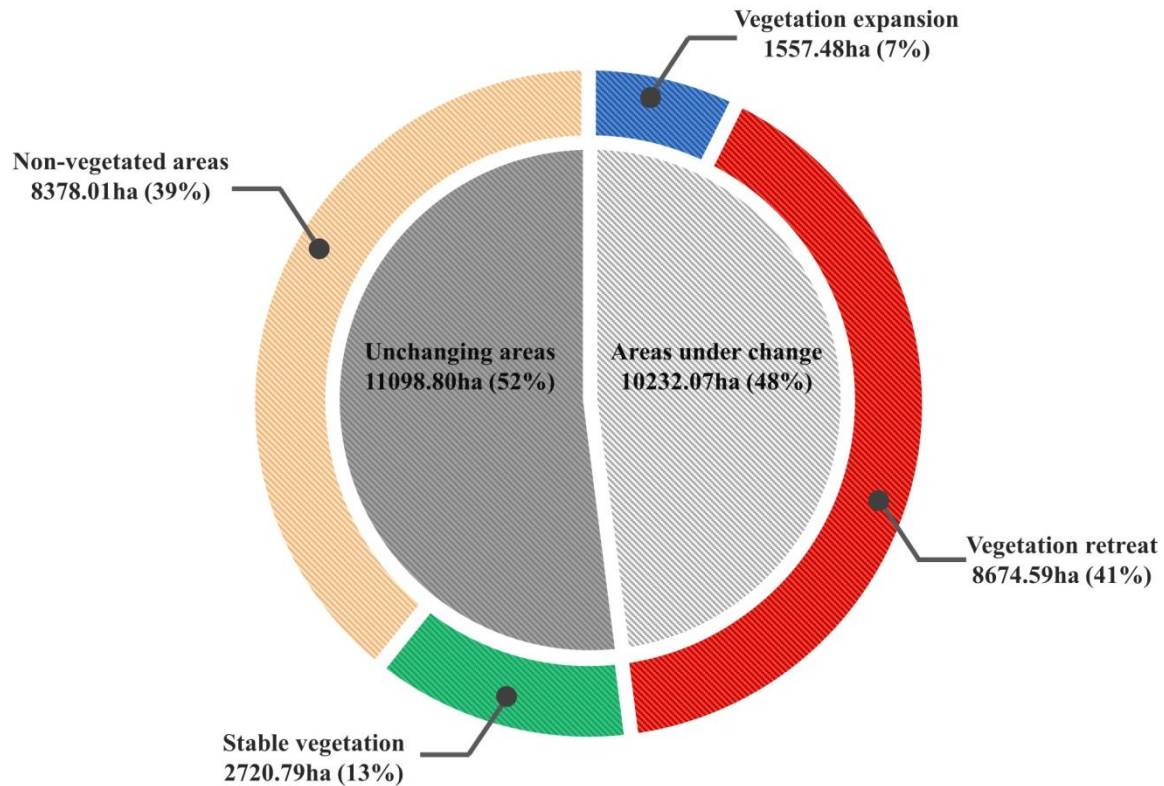


Fig. 10b. Changes in vegetation cover in Marrakesh from 1973 to 2020 (% and surface areas) (Gourfi, 2023)

This overall trend can be analyzed in more detail by spatializing information using a grid of 100 ha hexagonal polygons, thus focusing the analysis on the scale of the CUM's neighborhoods.

The box plot, calculated at each date based on all of the grid's polygons (Fig. 11), shows that, beyond the overall steady decline in vegetation cover, its spatial distribution across the CUM has also changed.

In 1973, the spatial distribution of vegetation areas in the hexagons was much more uniform than during the later periods where a stronger spatial specialization can be observed. In 1973, the standard deviation is very high (Fig. 11), which tells us that, in each polygon, it is possible to have both built-up areas and bare soil areas, and that there was vegetation pretty much everywhere. After 1985, and after 2000 especially, the standard deviations became lower and land use more uniform. Greenery became increasingly concentrated within clearly defined areas.

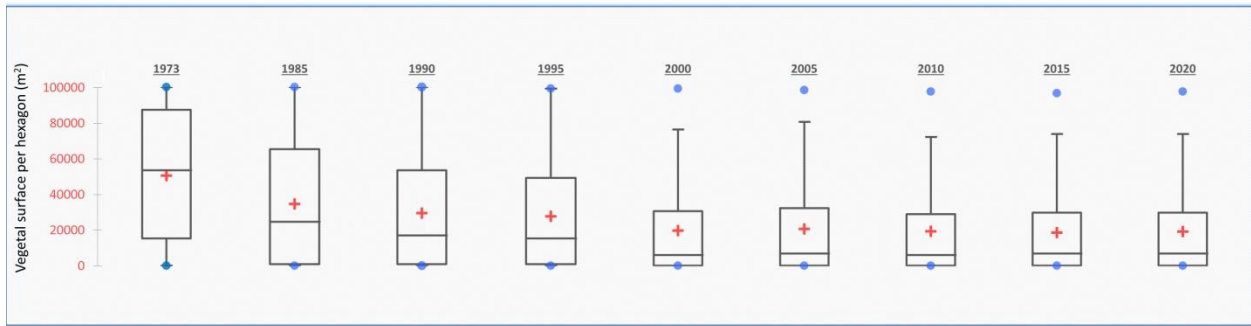


Fig.11. Box plot showing the standard deviation and the average vegetation surface area per hexagon at each date for the whole of the CUM. (Gourfi, 2023)

3.3. Variations Associated With Public Policy-making

The changing trends observed in terms of Marrakesh’s vegetation and the differences observed between its neighborhoods can be attributed to a variety of factors.

Given the city’s arid context, the overall decline in vegetation cover between 1973 and 2000 could be put down to diminishing rainfall - particularly given the droughts of the 1970s and 1980s - and the levelling off of this decline, and subsequent greening in some cases, to an increase in rainfall. And yet the growth in green spaces, calculated on the basis of NDVI data, with average annual rainfall across the CUM over this period (Fig. 12), shows that this is simply not the case. For the most part, green spaces are watered at regular intervals and do not depend on available rainfall.

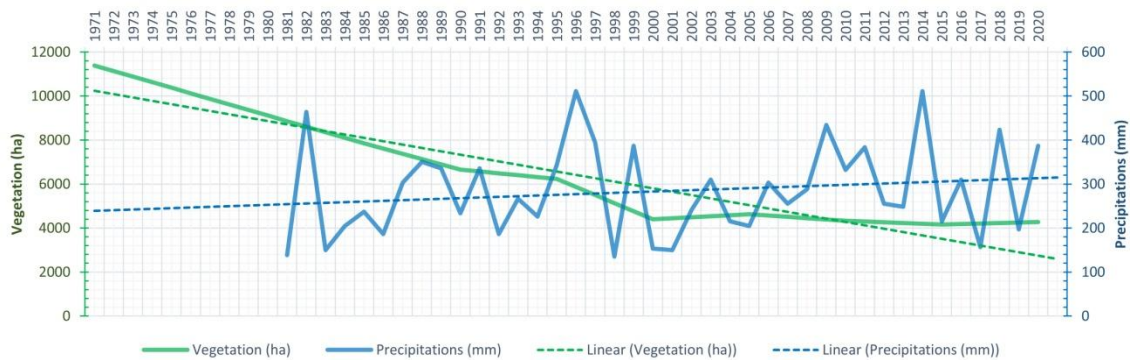


Fig.12. Cross-linking of areas of vegetation (from NDVI) with average annual rainfall data from 1971 to 2020 for the region of Marrakesh. (Gourfi, 2023)

The reasons for such variations therefore lie in the development of the Marrakesh Urban Community (CUM) and the public policies setting this in motion.

The decline in green spaces from 1973 to 2000 stems, of course, from urbanization, in connection with demographic growth and positive natural balance and inward migration. The increase in built-up areas and decline in vegetation have kept pace with this swift growth. The middle classes’ loss of interest in the public green spaces laid out during the colonial period and

their move away from them, leaving them for the working classes without investing in their upkeep, also explain why these spaces have deteriorated so sharply and why vegetation cover has fallen.

Various factors then explain why the decline in green spaces slowed before reversing slightly from the 2000s across the CUM. A range of projects of varying sizes and scales have promoted the protection of existing green spaces, reforestation (olive and palm groves especially) or the layout of new areas of vegetation.

Note, in particular, the creation in 2001 of the Mohammed VI Foundation for Environmental Protection, which is a nationally- and regionally- acclaimed leader in the protection and restoration of green spaces and sites of biological and ecological interest (SIBE) in Morocco. It can be considered the impetus behind the momentum to protect and restore green spaces in Marrakesh. One of the foundation's projects bears specifically on the safeguarding and development of the Marrakesh palm grove. The foundation also leads projects to restore historic parks and gardens across several Moroccan cities, including the Arsat Moulay Abdeslam garden (or Cyber Park) and Ghabat Chabab in Marrakesh.

The 2007-2018 programme to safeguard and develop the palm grove thus aimed at planting 580,770 palm trees, theoretically watered using treated wastewater. Over and above this reforestation programme, the project has paved the way to more effective protection of the palm grove which was steadily being whittled away despite its listing, supposedly to ensure its protection, as historical heritage by a royal *dahir* (decree) dated 1929. Its decline is tied in with the pressure of urbanization from colonial times, since the Gueliz neighbourhood had been built to the detriment of the palm grove (El Hannani et al., 2017), right up until the present day with tourism infrastructure (golf courses, complexes), real estate complexes and luxury villas encroaching on it. This process has been happening amid competition for water where palm trees are no longer the priority. The centuries-old water supply from the *khettaras* (underground galleries that harvest groundwater and deliver it to the surface) has been cut off, and this has all been compounded by the climate crises of the latter half of the 20th century.

More broadly, this royal foundation and the projects it has undertaken have been a driving force in shaping a global context in favour of the protection and development of greenery in the city.

At the local level, the unveiling of a Local Agenda 21 for Marrakesh in 2002, which advocates the "Protection of natural heritage from any urban planning", is a contributing factor to this momentum in favour of greenery in the CUM. Conducted in partnership with the Ministry of Regional Development, Water Resources and the Environment (MATEE), the UNDP and municipality of Marrakesh, this champions a project to safeguard and protect historic gardens and theoretically to restore and protect the last *khettaras* still in operation to prevent them from disappearing. From the city's environmental profile, produced back in 2003 for this Agenda 21, the participatory workshops' method in 2004, and the action plan and initial achievements from 2005, three priority areas stand out: sustainable management of water resources, heritage preservation and tourism promotion, and access to urban services and social integration. These three areas have given rise to a plan of proposed actions including, in particular, the listing of the Northwest palm grove, covering 250 ha, as a Site of Biological and Ecological Interest (SIBE), and other measures aimed at creating green spaces (Barthel, 2013).

The “Vivre ma ville” initiative, set up by the Mayoress of the CUM in 2009, includes a section dedicated to green space and has also contributed to the greening of the city (Barthel, 2013). The goal was to make Marrakesh a green, clean and attractive city by implementing a range of projects across various sites including Ghabat Chabab, Jnane Sidi Bel Abbas, the Northwest palm grove, Ryad Laârouss, Borj Zaitoune, two sites known as Unit 3 and Unit 5, the oasis Hassan 2, and the historic gardens of Menara and Agdal. However, despite the stated ambition, only the projects coinciding with those of the Mohammed VI Foundation could be conducted. The others were either not seen all the way through - or embarked on at all - owing to land issues, no preliminary analysis and political infighting, the elected official’s term in office having come to an end before the project’s completion.

Beyond these examples of restoration and protection of iconic green spaces, it is also possible to note changes in real estate developers’ practices, not least in the context of a “programme-contract” on social housing, with increased tax exemptions in their favour, in connection with a decision by King Mohammed VI to make so-called “social” housing a “national priority” (20 August 2002 speech) to address the housing crisis of the early 2000s. This programme-contract includes planning guidelines for green spaces which specify that the developer must plant a corresponding number of trees in light of the number of homes built, at least 3 metres high, and undertake to look after them for one year or, if the project property base does not enable the corresponding number of trees to be planted, the remainder must be planted in an area designated by the municipality concerned by the project. However as real estate developers often don’t respect these engagements, the green open spaces are frequently created and maintained by the inhabitants themselves.

This post-2000s period, together with the raising of the city’s international profile and reputation since the 1990s (Kurzac-Souali, 2011), also coincides with a thriving tourism scene driven by the showcasing of the city (Kurzac-Souali, 2011) where greenery takes pride of place, in addition to the development of the events and recreation sectors (Kurzac-Souali, 2011). Myriad luxury tourist facilities have been built over this period, setting greater store by vegetation, in gardens and golf courses, because such green space boosts appeal. Today, Marrakesh boasts twelve 18-hole golf courses, versus just two before 2000 (Barthel, 2013).

Against this backdrop, luxury real estate properties also soared in the early 2000s, with developers giving precedence to “attractive natural” elements to enhance the sales value of their projects.

Marrakesh’s residential and tourism real estate market grew exponentially across the board in the 2000s, with a glut of very-high-end properties on offer (Barthel, 2013).

In the wake of the global economic crisis, the downturn in the real estate market from 2008 perhaps explains, on the other hand, the slowing decline in rural farmland, with mid-range real estate projects on the city’s outskirts called off.

4. Conclusion

The example of Marrakesh analysed in detail here is representative of the trends occurring in other cities in north Africa, among which Algiers and Sousse.

The observed variation in green spaces since the 2000s could strike as reassuring given Marrakesh's frenzied pace of urbanization over recent decades. However, on closer inspection of the slowing decline in vegetation cover in the city from 2000 (a sign of renewed interest in greenery in Marrakesh), the percentage of vegetation per capita continues its relative downward trend after this date, since the population has carried on growing (from 823 154 in 2004 to 928 850 in 2014 and will reach 1 175 770 inhabitants in 2030). The proportion of green space per capita shows that Marrakesh is a long way from being able to call itself a green city, since it falls short of the minimum 10 sq.m. per capita recommended by UN-Habitat and by the green plan guide commissioned by Morocco's Ministry of National Planning, Urban Planning, Housing and City Policy (a guide which has not been legislated and is not enforceable as a result).

The neighborhood-based analysis shows an imbalance at city level with stark inequalities. The city's overall level of greenery stems chiefly from the green spaces in some affluent neighborhoods (Hivernage, Ennakhil Nord and Sud) or in the royal grounds (Mechwer), which are, therefore, private green spaces. The level of greenery in working-class neighborhoods is very low that do not exceed 3 sq.m. per capita if we exclude the remaining tracts of farmland on the outskirts of the most recently urbanized neighborhoods.

Accordingly, for the five *arrondissements*, the average area per capita is 10.41 sq.m. for Gueliz; 2.64 sq.m. for Medina; 1.17 sq.m. for Menara; 0.98 sq.m. for Sidi Youssef Ben Ali and 0.30 sq.m. for Annakhil, resulting in an overall average of 3.1 sq.m. per capita.

The image of Marrakesh as a green city - a marketing tool to promote the city - is based upon a few features that are by no means representative, including the handful of tree-lined avenues along the main thoroughfares taken by tourists between the airport, the city center and the touristy areas, as well as some landmark parks and gardens, both public (Arsat Moulay Abdeslam, Menara etc.) and private (Majorelle in particular).

The delisting over recent decades of a neighborhood like Gueliz comes hand-in-hand with a reduction in plant cover and their quality of life.

The socio-spatial segregation initiated during the colonial period by the unfettered urban planning of the time still endures to this day. The physical separation of the "indigenous" city (Medina and Mechwer) from the "new city" (Gueliz, Hivernage and military district) already showcased the former's heritage, with its historical and religious monuments and picturesque old walls, considered to form a considerable touristic capital (Du Vivier De Streel, 1932) and representing the "backdrop" of the European city (Prost, 1932). This urban design had another, health-giving goal (synonymous with modernity, civilization and social progress) by allowing the city to breathe through light, open green spaces with roadside trees (*Citrus aurantium*, *Ficus*, etc.) that fully chimed with the urban planning rationale of the landscape architect JCN. Forestier, and implemented by the urban architect H. Prost (Taïbi and El Hannani, 2019).

Gardens, along with other public spaces, used to symbolize the middle-class practices and designs of Western cities. But once they had been transposed to the Arab world in the new parts of cities, they were abandoned by the same middle classes following independence, shifted to private ownership (Gillot, 2002) and forsaken by the local authorities. Left to the poorer working classes, these green spaces, public gardens and roadside trees deteriorated for want of proper upkeep and overuse as there were not enough of them. The slowing decline in vegetation observed post-2000 seems to signal a reversal in this situation and renewed interest in greenery.

However, any replanting observed remains primarily private, in the gardens of affluent villas or luxury developments of the palm grove or the scores of golf courses for national or foreign visitors. Greenery has thus once again become an elitist marker of space. Changes in the uses initially made of spaces (for agriculture, particularly in the palm grove), now repurposed into ornamental sites for enjoyment, first by well-heeled Europeans during colonisation and then by wealthy Moroccans today, have ended up excluding the working classes, for whom they no longer serve any justifiable purpose, especially in the neighborhoods of Ennakhil Nord and Sud. The repurposing or design of new landscapes, whether urban or rural, forms part of the approaches to controlling territories and their occupants, and “often convey a social or even political message” (Mathis and Pépy, 2017). “To build a garden is to project an image of oneself, of one’s city and one’s country; it is also, as during the second Empire, to proudly proclaim the victory of a middle-class social order one seeks to establish” (Mathis and Pépy, 2017). Nowadays with the growing and hard mineralization of the city, once called a “city garden”, the different stakeholders have to reconsider the urban development model of Marrakesh, necessarily involving more of its inhabitants.

Algiers and Sousse sharing some major elements of their history with Marrakech, such as French colonisation and independence, show the same trends in vegetation evolution.

In the three cities, the parks and gardens inherited from the French colonial period were largely neglected after independence, and almost completely ignored by the urban planning and cities management departments, resulting in a lack of care for intra-urban green spaces. For a long time, urban planning departments considered the development of parks and gardens in urban areas as an element in the well-being and quality of the urban environment, to be secondary to the primary functions of traffic, housing and commerce.

However, we have noticed that the same renewed interest in urban greenery in these cities since the 2000s, in the form of new laws and regulations and rehabilitation projects of French colonial gardens and parks.

5 Recommendations

Remote sensing is a tool that can be used to monitor urban vegetation in great detail and understand its spatial distribution and evolutionary dynamics.

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