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EVALUATION OF THE ENERGY IMPACT OF GREEN AREA SURFACES AND VEGETATION COVER IN FORESTED URBAN ENVIRONMENTS WITH DRY CLIMATES. CASE: MENDOZA METROPOLITAN AREA, ARGENTINA.

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Abstract

The object of this work is to study the energy impact caused by green surface area and vegetation coverage present in the low-density urban environment in the metropolitan area of Mendoza (AMM), Argentina, in order to understand the morphology of forested city in an arid climate, and, in the future, to determine the potential real modification on those urban microclimate environments essentially dependent on energy exchanges.

Methodologically on the urban green space level, the green surface and the different mineralized surfaces have been quantified from surveyed land data, aerial photographs, and by an accompanying representative in-situ survey of 32 city blocks in the AMM. In addition, using the i-tree canopy tool, the urban area covered by tree vegetation mass or vegetation cover has been quantified. Subsequently, using ecophysiological coefficients[1], an environmental index for each environment analyzed has been determined, indicating the percentage of the total area of green space environmentally useful as an environmental modifier.

The results obtained indicate mean values of green surface (herbaceous grass) of 22.83% in the urban environments analyzed (20.22% public and private), plus a 2.62% non-mineralized surface devoid of vegetation cover (permeable irrigation channel). The results using the i-tree tool indicate an urban surface covered by a vegetation tree mass of 26.59%, and a total of 41.08% non-mineralized surface, including trees, grass lawns, bushes and bare ground. In terms of environmental indices, values were established for the 32 environments analyzed, from a mean of 0.46, with the highest indices of 0.59 through the positive effect of vegetation cover from the thermodynamic point of view,

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and, on the other hand, with minimum indices of 0.39 in environments with a low percentage of urban trees and a high quantity of mineralized surface directly exposed to solar radiation.
As a result of such a process, it is possible to determine current conditions and the formulation of an environmental diagnosis based on vegetation cover, adapted to consolidated environments of low density in a model of a forested city in arid climate, and it is hoped that this work presents the possibility of evaluating the energy impact of vegetation cover to implement future norms and rules aimed both at preserving the forested city model, in equilibrium with a model of the sustainable city, and at reversing urban-building growth that does not take such factual indicators into consideration.

Keywords: *sustainable urban development; green area surfaces; vegetation cover; forested urban environments.*

Nomenclature

A	area [m^2]
c	coefficient of adjustment to calculate actual evapotranspiration when cultivated under tree cover
ea	actual vapour pressure [kPa]
es	saturation vapour pressure [kPa]
es-ea	saturation vapour pressure deficit [kPa]
ETo	reference evapotranspiration [mm day^{-1}]
Ea	actual evapotranspiration
SOF	soil occupation factor
TOF	total occupation factor
G	density of heat flux on the ground [MJ m^{-2} day^{-1}]
EI	environmental index
IGSA	índex of green surface area
IVC	índex of vegetation cover
Kc	single crop coefficient of cultivation, índex of adjustment
Nt	number of theoretical sunlight hours
Na	number of actual sunlight hours
QL	latent heat fluxes
Qs	sensitive heat fluxes
Qt	storage net uptake, or release of energy by sensitive heat changes in the urban ground-canopy-air volume
R	stratospheric solar radiation, expressed in equivalent evaporation (mm/day)
RN	solar radiation absorbed by the surfaces
Rn	net radiation at the crop surface [MJ m^{-2} day^{-1}]
Ro	solar radiation incident in location
T	mean daily air temperature at 2 m height [°C]
y	latitude of location
γ	psychrometric constant [kPa °C^{-1}]
Δ	slope vapor pressure curve [kPa °C^{-1}]
$\mu 2$	wind velocity registered at 2 m of height [m s^{-1}]
α	albedo of considered surface
$1-\alpha$	percentage of the proportion of solar radiation solar that is absorbed
Q	all-wave radiation flux/ net radiation
QS	storage net uptake, or release of energy by sensitive heat changes in the urban ground-canopy-air volume
ΔQA	advective heat flux
QF	anthropogenic heat flux from heat released by combustion of fuels (e.g., traffic, building HVAC systems)
QH	sensitive heat fluxes
QE	latent heat fluxes
Q^*	the net all-wave radiation flux/ net radiation
K	short-wave (from the sun) radiation flux, arrows indicate the flow of energy is toward (↓)or(↑) from the surface
L	long-wave (or terrestrial) radiation flux, arrows indicate the flow of energy is toward (↓)or(↑) from the surface

1. Introduction

The constant growth that will exponentially increase world population[2,3]consumption of non-renewable resources, pollution, and rates of urbanization3 in developing countries, becomes particularly critical in urban areas, and requires the study of urban morphology currently and in the foreseeable future in order to establish patterns of evolution that do not hinder the full use of natural resources, such as: solar radiation, natural lighting and natural ventilation. Unplanned growth leads to heavy consumption of non-renewable natural resources and generates enormous amounts of pollutants that are not possible to process, absorb and neutralize. Interrelationships between habitat and energy occupy a central position in the problems of global environment. Acting upon them allows significant benefits that can be obtained in a relatively short time, at least in terms of reducing deterioration in advance. The development potential of energy efficiency in the urban-building environment requires the implementation of policies to control the morphology that responds to the specific objectives of urban and energy planning in their corresponding levels of intervention. In the scientific field, much has been discussed about the interrelationships between energy consumption and urban morphology.[4-7]

The energy balance at the urban level has been defined by Oke[8] but the equation is very difficult to resolve because of the complexity of urban areas and the variation of indicators, and at every point within the city, so it requires some simplification. While the energy available to heat the air and soil, or to evaporate the water, is dependent on the radiation balance.[9-22]

$$Q^* + Q_F = Q_H + Q_E + Q_S + \Delta Q_A \quad \left(\mathrm{Wm}^{-2}\right) \quad (1) \qquad Q^* = K^* + L^* = K{\downarrow} - K{\uparrow} + L{\downarrow} - L{\uparrow} \quad \left(\mathrm{Wm}^{-2}\right) \quad (2)$$

Most cities are sources of heat generation conditioned by meteorological factors (solar irradiance, cloud cover, wind speed, humidity) and the structure of urban-building variables (surface sealing, thermal properties of materIals, surface geometry, wooded and vegetation surfaces). Some causes involved in the increase in temperature are: increase in anthropogenic heat; reduction in evapotranspiration; increase in heat storage; increase in net radiation; and, reduction in convection.

In this sense, tree vegetation cover and green surfaces play an important role in improving the quality of urban environment, and provide significant social and environmental benefits that enhance the quality of life in cities, especially those containing a high percentage of vegetation cover. The contribution of urban trees in improving the microclimate, air quality and life is well-documented,[23-30] with benefits such as reduced heat,[31] decreased CO_2, NO_2, O_3 among other benefits from the absorption of pollutants and the reduction of air pollution.[32-34]

Research related to the regional benefits of trees and the reduction of the urban heat island is very wide-spread, there has been, in recent years, an exponentIal increase in research and completed work.[35-45] The benefits of woodland cooling in the warm season are determined by two main factors: 1. reduced access to solar radiation, as the surfaces below the tree cover allow a reduction of thermal loads on buildings and permit more use of open public spaces[46-51] and, 2. evapotranspiration, using a large percentage of the radiation intercepted to evaporate water from within tree leafs.[52]Regarding methodological aspects, considered important are work on the leaf area index,[53] on quantification of the environmental value of trees and vegetation cover,[54-55] and on determination of ecophysiological coefficients for determining the environmental index.[1]

The aim of this work is to analyze the influence of vegetation cover in the energy balance model of a forested city in an arid climate in order to make an assessment through an environmental index (EI).

The overall goal is the advancement knowledge of thermodynamic principles that explain and measure the conversion of solar irradiance in heat by various types of surface, and the recognition of the phenomenon of evapotranspiration as allowing vegetation surfaces to convert a high proportion of energy to reduce the increase of temperatue.

Regional aspects

In the context of the arid region of west-central Argentina, Mendoza Metropolitan Area (AMM) has obvious signs of environmental degradation due to uncontrolled growth. Among the most significant causes of this decline could be mentioned: the building industry urban morphology and the technology implemented for hygrothermal habitability; the increasing deterioration of infrastructure and urban forest; the progressive casualization of disadvantaged habitat sectors; the major greenhouse gas emissions and particulates from fixed and mobile sources; the pressure of urban microclimate and misuse of scarce regional water resources; and, the expansion of the urban area on the foothills to the west and more fertile oasis farmland to the east, contributing to desertification of peri-urban oasis and aggravating alluvial seismic risks in the areas adjacent to built-up areas.

The city was historically organized on the basis of the street, irrigation ditch and tree systems. In this oasis city model, the strong presence of trees has made it possible to ensure maximum environmental and energy benefits at both extreme seasons. The preservation of the city model with a strong presence of public and private woodland is closely related to hydraulic availability, the sealing of soils in public spaces and the sealing in private open spaces sealings. Another aspect to consider is the modification of the urban climate. It is essentially produced by the different thermal characteristics of city building materials. The replacement of green spaces by large buildings, streets and avenues is greater as the distance to the city center decreases.

In the region, the available climatic resourses are abundant enough to enable the implementation of designs and technologies for available and technically feasible energy efficiency, even without any development and incorporation of new technologies for either building or energy. The potentially most important resources are: solar radiation 4.58Kwh/m^2 day to 5.55 Kwh/m^2 (space heating, water heating and "in situ" photovoltaic generation), the day-night temperature amplitude associated with the summer night breeze (night convective cooling), the low apparent sky temperaturas (night radiative cooling), the low humidity values (evaporative cooling) and the high luminance of the daytime sky (natural space lighting). Each of these strategies, associated with higher levels of energy conservation in the building envelopes, can contribute through its massive deployment, with conventional energy savings and substantial improvements in the quality of life of the population, especially in urban environments. However, even if the technical viability of these strategies is locally demonstrated (de Rosa, 1988), the energy-environmental strategies have not been extensively studied, and constitute a vacant area that would allow for a progressive transition towards energy and environmental sustainability of the constructed regional park.

To avoid increasing deterioration of the forested city, it is necessary to identify and evaluate management strategies for sustainable for an urban environment in itself and in its links with the region. Mendoza, being a zone of high vulnerability to changes such as desertification, global warming, and air pollution, it is essential to project its influence to foresee how the impact of these changes on the zone would be.

Fig. 1: Mendoza's position in Argentina.

Fig. 2: Aerial View of AMM

Fig. 3: Urban-building morphology

Geographic coordinates: latitude –32.85, longitude 63.85 & altitude 750.
Climatic data: i. anual hours: in comfort 21.5%, necessary heating 70.00%, neccesary cooling 8.5%, ii. annual degrees-days: heating (Base 18°C) 1384, cooling (Base 23°C) 163, iii. Global solar radiation, anual average: 18.06 MJ/m^2 día, predomination of clear skies. Relative heliophany 63%. Clearness index 0.59. Average annual precipitation 200mm. Relative Humidity 56%. Wind velocity between 7 and 23 Km/h with south and southeast direction.
Population: city: 93,7145, AMM: 937,154, habitants (national census 2010)
Surface of Mendoza Metropolitan Area (AMM), Argentina: 168km^2.

Selection of a representative sample of urban blocks for detailed analysis.

A preliminary set of 32 units for each of the three (3) primary variables considered is determined: shape of blocks, block orientation, and building morphology; by reading the prepared map. The percentage representation of different types of each variable is established and according to this completes a set of 32 units per variable. The spatial distribution is done using a random method. The relevant procedure is done "in-situ" with the remaining variables: tree characteristics and calculation of the remaining three secondary variables: FF, SOF and TOF.

These scenarios have been previously evaluated from access to solar resource in the winter season, and their energy behavior and the most significant variables for the applicable season have also been evaluated.[56-57]We have also conducted studies on the trees: seasonal transmissivity magnitude of the foliage of deciduous species to direct solar radiation and plentitude to the same environments[58] and the study of the capture of solar radiation from north facades in forested urban environments in dry climates considering urban-building variables in summer and winter.

Fig.4: Location of the studied city blocks over Mendoza’s metropolitan area.

This present work advances the quantification of surfaces and index of vegetation cover for the purpose of helping to close the energy balance, allowing f a debate about the city model proposed for the future, particularly as regards to the use of environmental resource supply for a more sustainable future of the city.

Here are the results of the 32 analyzed Scenarios, allowing evaluation of the building and urban variables of alternative studies.

Table 1: List of the values of the urban and building variables of the sample set analysed.

Scenario	URBAN VARIABLES						BUILDING VARIABLES			
N°	Blocks		Width Road-way (m)	Urban Trees			Morphology	Form Factor	SOF	TOF
	Form	Orientation		Magnitude	Trasmissibility*	Plenitude				
1	05:02	-5	20	2ª	52	57	Irregular	0.49	0.74	0.97
2	05:03	-6	20	2ª	52	55	Irregular	0.64	0.56	0.78
3	05:02	-6	20	2ª	52	65	Irregular	0.60	0.72	0.98
4	05:03	87	20	2ª	43	69	Irregular	0.61	0.69	0.91
5	05:03	86	20	2ª	52	70	Irregular	0.59	0.74	1.00
6	05:04	-6	20	1ª	35	77	Irregular	0.68	0.60	0.66
7	05:05	-5	20	1ª	43	71	Irregular	0.63	0.68	0.75
8	05:05	-1	20	1ª	51	81	Irregular	0.89	0.57	0.61
9	05:04	-1	20	1ª	51	79	Irregular	0.64	0.58	0.61
10	05:04	74	20	1ª	43	76	Irregular	0.65	0.62	0.62
11	05:04	74	20	1ª	43	68	Irregular	0.88	0.52	0.52
12	05:04	74	16	1ª	43	69	Irregular	0.57	0.67	0.67
13	05:02	-23	13	2ª	43	64	Regular	0.62	0.55	0.57
14	05:02	-23	13	2ª	43	74	Regular	0.63	0.55	0.56
15	05:02	-23	13	2ª	43	85	Regular	0.64	0.51	0.52
16	05:02	-23	13	2ª	43	76	Regular	0.59	0.53	0.54
17	05:02	-23	13	2ª	43	83	Regular	0.53	0.53	0.80
18	05:02	-23	13	2ª	43	67	Regular	0.54	0.52	0.79
19	05:01	65	15	3ª	43	54	Regular	0.68	0.52	0.55
20	05:01	65	15	3ª	43	57	Regular	0.56	0.61	0.61
21	05:01	65	15	3ª	43	54	Regular	0.62	0.57	0.59
22	05:02	65	15	3ª	39	47	Regular	0.62	0.58	0.58
23	05:02	65	15	3ª	39	67	Regular	0.64	0.55	0.56
24	05:02	65	15	3ª	39	56	Regular	0.7	0.52	0.53
25	05:02	-24	15	2ª	43	66	Regular	0.63	0.60	0.60
26	05:02	-24	15	2ª	43	71	Regular	0.61	0.57	0.57
27	05:01	-24	15	2ª	43	67	Regular	0.61	0.58	0.58
28	05:02	-24	15	2ª	43	57	Regular	0.64	0.54	0.54
29	05:03	67	18	1ª	43	79	Regular	0.58	0.63	1.05
30	05:03	67	18	1ª	43	68	Regular	0.56	0.65	1.08
31	05:03	67	18	1ª	43	74	Regular	0.56	0.66	1.08
32	05:03	67	18	1ª	43	68	Regular	0.53	0.69	1.16

*autumn-winter trasmissibility

2. Methodology

A quantitative analysis of areas was conducted, differentiating three levels of evaluation: at ground level, from an aerial view, and, finally, an analysis of sensitive heat flux by surface type, to assess for each environment analyzed the percentage of the total surface of environmentally useful green space, as environmental modifiers.

2.1. Determination of the Index of Green Surface Area (IGSA)

Quantification was done of mineralized surfaces (impervious street, sidewalk -pedestrian street-, impervious irrigation ditch, buildings, impervious private), surfaces of green areas (ground level), private and public groundcover (herbaceous grass), and unsealed areas (pervious irrigation ditch and bare ground). An inventory was conducted from land survey data, aerial photographs and accompanied by an in-situ survey and the edition of surfaces of interest, in square meters, for each of the sample units.

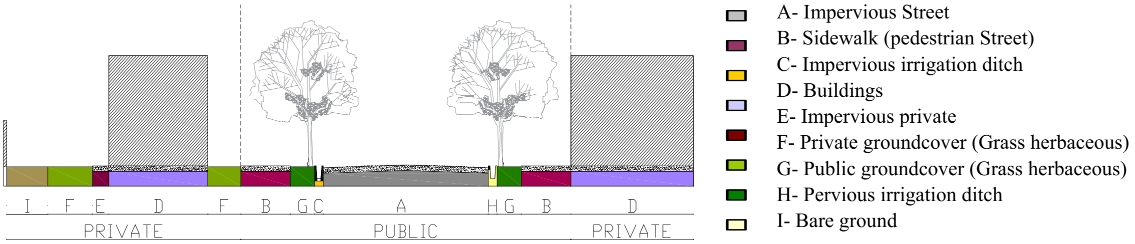

Fig.5: Mineralized surfaces, green area surfaces and unsealed areas

To determine the Index of Green Surface Area (IGSA), it is the ratio between the effective green area (surface that actually contains vegetation) of private and public groundcover (herbaceous grass), excluding bare ground bearing trees and / or shrubs, and the total area of the urban block.

$$\mathrm{IGSA} = \frac{\mathrm{AVS}}{\mathrm{TA}} \cdot 100 \qquad (3)$$

Where:
AVS= private and public groundcover (grass herbaceous)
TA= total area

2.2. Determination of the Index of Vegetation Cover (IVC)

i-treeCanopy is used to estimate tree canopy cover. This tool is designed to allow tree estimation and the other cover classes (e.g., impervious street, sidewalk, impervious irrigation ditch, buildings, etc.). Canopy offers a production of a statistically valid estimate of land cover types using aerial images available on Google Maps. The latest version of Canopy also estimates values for air pollution reduction and capturing atmospheric carbon.

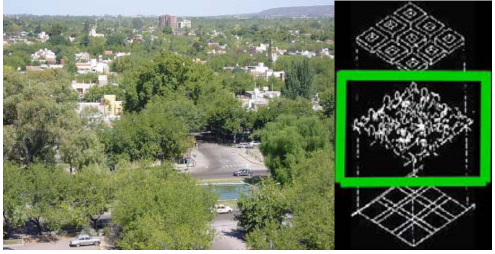

Fig.6: View of AMM

Index of Vegetation Cover (IVC)

$$\mathrm{IVC} = \frac{\mathrm{VC}}{\mathrm{TA}} \cdot 100 \qquad (4)$$

where:
VC= vegetation cover
TA= total area

The combination of these two tools allows for the quantitative determination of the surfaces below and above the treetops. The quantification of vegetation cover and the distinct surfaces allows the advancement of knowledge of the shadows cast by the trees on mineralized surfaces, which reduces the input of solar radiation at ground level, especially in the summer, depending on magnitude of the trees, seasonal transmissibility of the solar irradiance by foliage of deciduous species and planting distance between individual trees; all of which can reduce values close to 90%. [47,50]

The tops of large-dimension trees have "cold" surfaces, compared with the mineralized urban environments. Out of 100% of the incident radiation on the plant, 20% is reflected and 10% transmitted. Green mass absorbs most of the solar radiation intercepted by leaves, and a small part of this energy (1%-2%) is transformed into chemical energy in the process of photosynthesis, which is not considered for this analysis due to small significance, another part of the radiation is transformed into sensitive heat and latent heat, the latter resulting in the process of evapotranspiration.[59]

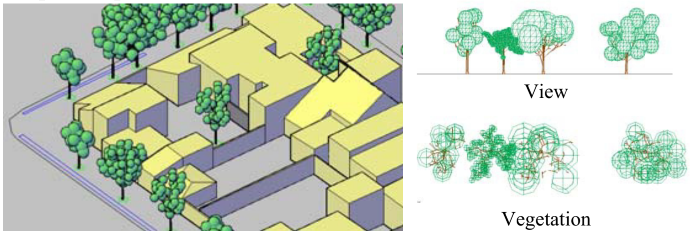

Fig. 7: Reference of scale and location

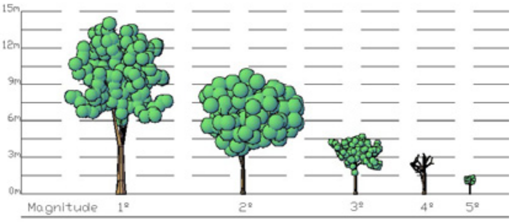

Fig. 8: Magnitude of trees

2.3. Determination of the Environmental Index (EI):

For each type of surface, it is possible to calculate, from eco-physiological coefficients,[1] how much radiant energy can be captured in the form of latent heat and how much returns to the environment in the form of sensitive heat, as a way of characterizing their contribution. Not considered is the study of the anthropogenic heat flux from heat released by combustion of fuels (QF) (e.g., traffic, building HVAC systems).

For dry surfaces, the study of the sensitive heat flux for type of surface was considered to be responsible for the increase in temperature of a body. If a sufficiently long time is taken, the heat transmitted, does not remain in the body but will be emitted as sensitive heat, so the relationship is reduced to: solar radiation absorbed by the surfaces = sensitive heat.

For humid surfaces, there would not be transmitted heat, because it would imply an increase in its temperature (except in situations of severe water stress). In fact, part of the radiation received by the vegetation is immediately disseminated to the atmosphere as windblown sensitive heat, but the result is difficult to quantify what will be included in the calculation from the portion of solar radiation that is not absorbed by the leaves (transmissibility). The radiation passes through and between the treetops, focusing on the next lower surface (masonry, concrete, grass or other vegetation). The calculations would have an abnormally high value because it would include the sensitive heat irradiated by the vegetation.

For the inferior vegetation surfaces, the incident radiation will be affected by the transmissibility of the species, the magnitude of trees and the distance of the vegetation between individuals, of which a portion is reflected ($\alpha 2$ of the new surface) and another part is absorbed ($1 - \alpha 2$), the calculation capable of being repeated as many times as necessary, depending on the vegetable strata traversed.

In the case of wet surfaces, the other part of the radiation received should be considered as latent heat, vegetation capturing the solar radiation before it reaches the ground and vanishes as vapor (transpiration) evapotranspiration, mitigating the increases of the environment temperature.[60-73]

From the sum of surfaces in each analyzed urban environment, the Environmental Index (EI) is obtained, for the period considered and indicating the percentage of the total area of green space environmentally useful. The comparison between the EI of each environment will permit evaluation of which of them is more environmentally friendly, per surface unit, for the zone or region considered.

$$EI = \sum_{ts=1}^{6} \frac{\left(1 - \frac{QH_{ts}}{Ro}\right) \cdot A_{ts}}{100} \qquad (5)$$

where:
ts= type of surface
QH= sensitive heat fluxes
A= actual area for the type of surface

$$Ro = R \cdot (0.29 \cos y + 0.52 n / N) \qquad (6)$$

Ro = solar radiation incident in location
R = stratospheric solar radiation, expressed in equivalent evaporation (mm/day) (Value for the month of December in Mendoza, Argentina at -33° latitud
-R=17.6 (mm/day)
y = latitude of location
n = number of hours of actual sunlight
N = number of hours of theoretical sunlight
n/N is always less than the whole, considering the potential situation of the best possible sunlight

$$QH_1 = Ro \cdot (1 - \alpha_1) \qquad (7)$$

$$QH_2 = [Ro \cdot (1 - \alpha_2) - (\mathrm{ETo} \cdot \mathrm{Kc}_{1\text{-}3})] \cdot (1 - \alpha_1) \qquad (8)$$

$$QH_3 = [Ro \cdot (1 - \alpha_4) - (\mathrm{ETo} \cdot \mathrm{Kc}_4)] \cdot (1 - \alpha_5) \qquad (9)$$

$$QH_4 = [Ro \cdot (1 - \alpha_2) - (\mathrm{ETo} \cdot \mathrm{Kc}_{1\text{-}3})] \cdot (1 - \alpha_4) - (\mathrm{ETo} \cdot \mathrm{Kc}_4 \cdot c) \cdot (1 - \alpha_5) \quad (10)$$

$$QH_5 = Ro \cdot (1 - \alpha_4) \qquad (11)$$

$$QH_6 = [Ro \cdot (1 - \alpha_2) - (\mathrm{ETo} \cdot \mathrm{Kc}_{1\text{-}3})] \cdot (1 - \alpha_5) \qquad (12)$$

where:
QH_1== sensitive heat flux , masonry / cement to direct sunlight
QH_2= sensitive heat flux, masonry and cement in the shade of trees 1st, 2nd or 3rd magnitude
QH_3= sensitive heat flux, lawn, flowering shrubs and low bushes exposed to direct sunlight
QH_4= sensitive heat flux, lawn, flowering shrubs and low bushes , under greater vegetation mayor (trees 1st, 2nd or 3rd magnitude)
QH_5= sensitve heat flux ground / soil to direct sunlight
QH_6= sensitve heat flux ground / soil in the shade of trees 1st, 2nd or 3rd magnitude
α = albedo of the considered surface
1 - α = percentage proportion of solar radiation that is absorbed
α_1= albedo concrete / cement used / masonry ; α2–3= albedo of the trees ; α4= albedo of the lawn (L. perenne, Cynodon dactylon, dry type, Green type), low bush and flowering shrubs; α5= albedo of black / peat soil, agricultural land, dry land, wet peat

$$\mathrm{ET_o} = \frac{0.408\Delta(\mathrm{R_n} - \mathrm{G}) + \gamma \dfrac{900}{\mathrm{T} + 273} \mu_2 (\mathrm{e_s} - \mathrm{e_s})}{\Delta + \gamma(1 + 0.34\mu_2)} \qquad (13)$$

$\mathrm{ET_o}$: evapotranspiratipon of reference [mm day^{-1}],
$\mathrm{R_n}$: net radiation on the crop surface [MJ m^{-2} day^{-1}],
G: density of heat flux on the ground [MJ m^{-2} day^{-1}],
T: mean daily air temperature at 2m height [°C],
μ_2: wind velocity measured at 2 m height [m s^{-1}],
$\mathrm{e_s}$: saturation vapour pressure [kPa],
$\mathrm{e_a}$: vapour pressure [kPa],
$\mathrm{e_s}$-$\mathrm{e_a}$: deficit of saturation vapour pressure [kPa],
Δ: slope vapour pressure curve [kPa °C^{-1}],
γ: psychrometric constant [kPa °C^{-1}].

Data based on the weather station at the Mendoza airport of National Meteorological Service (SMN) 10 historical years, considering the crop evapotranspiration monthly reference (Eto, Penman-Monteith, FAO), for a 50% probability of occurrence (half a year) .
Multiplying refernce evapotranspiration ETo for adjustment index for the place, the species, season and conduction system of the plant analyzed, called crop coefficient Kc, which estimates actual evapotranspiration or of the crop ETr (consumption of water).

$$\mathrm{ETr} = ETo \cdot Kc \qquad (14)$$

Kc crop coefficient [índex of adjustment]. For the purposes of this study, species are grouped into basic strata, for example trees 1st, 2nd and 3rd magnitude, assigning them the Kc and forest fruit similar size, without significantly undermining the objective of comparing types of wooded areas. For the month of December: small deciduous tree Kc = 0.95; deciduous large tree Kc = 1.25; deciduous vine Kc = 0.7; Kc = 0.85 typical lawn
In turf surfaces, low bushes or ground cover growing under tree cover, it was considered to deduct the Kc understory herbaceous ETr by the difference between fruit crops with and without weeds (FAO 24), averaged for the months of highest sunlight. Performing the calculations, it is determined that the Kc lawn, for every month or season, must be affected by a coefficient c = 0.26 to calculate the actual evapotranspiration when grown under tree cover.

$$\mathrm{ETr} = ETo \cdot Kc \cdot c \qquad (15)$$

3. Results

The results obtained indicate, in the urban environments analyzed, average values of the green surface area of 22.83% (private and public groundcover -herbaceous grass-). By including the tree areas, the most representative surfaces are those found to be internal line municipal construction, (private area) without vegetation cover (57.60%), of which 39.66% is constructed area.

The results using the i-tree indicate an urban surface covered by tree vegetation mass of 26.59%, and a total of 41.08% of non-sealed surface, including trees, grass, bushes and bare earth (contributions to the oasis-city model) The remaining 58.92% consists of anthropic mineralized surfaces (impervious street 8.98%, sidewalk -pedestrian street- 5.52%, impervious irrigation ditch 0.31%, buildings 39.66% and impervious private 4.46%), resulting in a ratio of 1: 1.4.

Of 26.59% of vegetation cover, 20.22% covers public areas (street, sidewalk, irrigation ditch, public groundcover).

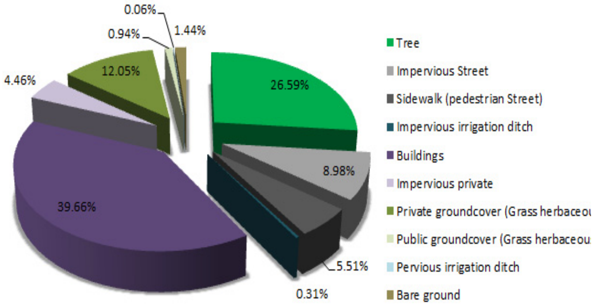

Fig. 9: Representation of total areas.

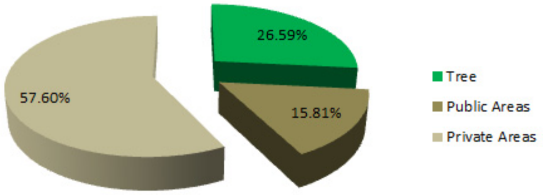

Fig. 10: Representation of vegetation cover, public and private áreas

The existing green space surface (herbaceous grass) existing in the interior of the urban blocks represents an important resource, as with urban street tree planting. Therefore, the public and private management have a shared responsibility in the present urban model city. However, it is the public area which hosts the trees responsible for the green mass present in the city covering 56.61% of the public area (streets, sidewalks, irrigation canals), with a maximum value of trees on public areas of 87.5% (Scenario 15), coinciding with maximum values of the variable tree plentitude of 85% (table 1), that considers the percentage relationship between the number of trees around a city block and the maximum possible amount that could exist in the same block, considering the appropriate distance between individuals, in percentage. In consequent fact, highly vegetated public Scenarios support the determination of the "environmental potential" of urban zones.

In the analysis of public areas covered by urban trees, there coexist diverse situations in the urban fabric related to the historical development of the city: metropolitan areas with examples of great development and plentitude of vegetation and areas with more open and discontinuous tree structure represented by young examples, new vegetation examples, loss or replacement of trees, and species damaged largely by the indiscriminate pruning, longevity or deterioration. The minimum values of vegetation cover in public areas for the 32 environments analyzed is 36.6%.

If you also incorporate green areas (public groundcover), the green percentage over public mineralized surfaces is 59.00%.

In private areas (impervious private, buildings, private public groundcover), the existing vegetation cover within urban blocks (tree planting in private spaces) reaches 6.38% of the surfaces, representing limited resource compared with the public trees, and this should be considered within plans and policies to promote green spaces in the city.

In the 32 low-density environments, two characteristic situations are detected in the function depending on the spatial arrangement pattern of the tres: 1. individual examples; and, 2. in conditions contiguous with an acceptable degree of adaptability (paired samples). The results in the 32 cases analyzed show the truss system of public urban trees in low-density environments is represented by species, such as White Mulberry (*alba Morus*) 41.68%, European Ash (*Fxaxinius excelsior)* 13.05%, and Chinaberry (*Melia azedarach)* 3.58%, there are strong trends of recent planting developments with Boxelder (*Acer negundo*) 9.95% and Texas Umbrella (*Melia azedarach fm. umbraculifera*) 8.37%, the latter two with great morphological variety of examples.[58]

Fig. 11: Images of the Box elder. Methodology of taking of images. Spring period (picture date 27/09).

A total of 1,750 examples were counted in the 32 city blocks. The amount of green mass (foliar volume) is quantitatively measurable (mass indicator - leaf volume), and plays a key role in volumetric plant development energy balance.[58]

Table 2: Species in the 32 city blocks.[58]

Species, Common Name (English / *Spanish*)	Species, Latin Botanical Name	N° of Examples	%	density	form	H Total Height	H Canopy Height	Width
White Mulberry / Morera	*(Morus alba)*	792	41.68	Dense	globular	10-15	11,25	10
European Ash / Fresno europeo	*(Fxaxinius excelsior)*	248	13.05	Dense	globular	+15	26,25	15,6
Boxelder / Acer	*(Acer negundo)*	189	9.95	Medium	globular	5-10	10	7
Texas Umbrella /Paraíso sombrilla	*(Melia azedarach fm. umbraculifera)*	159	8.37	Dense	fan	5-10	6	10
Acacia (viscous 50% & white 50%)	*(Robinia pseudoacacia)*	76	4.00	Medium	globular	+15	9	6
Elm / Olmo	*(Ulmus carpinifolia)*	75	3.95	Dense	globular	+15	24,37	13,75
White Ash / Fresno americano	*(Fraxinus americana L.)*	70	3.68	Médium	globular	+15	11,25	6
Chinaberry / Paraíso	*(Melia azedarach)*	68	3.58	Médium	globular	10-15	11,25	11
Cherry Plum / Ciruelo rojo	*(Prunus cerasifera var. Pissardii)*	41	2.16	Dense	globular	10-15	10	7
Sweetgum / Liquidambar	*(Liquidambar styraciflua)*	32	1.68	Light	globular	+15	17,5	9
Others			7.98					

Another important aspect is the percentage destined to vehicular movement in relation to the pedestrian passages in urban areas, and in this respect the oasis-city model present in low-density AMM has the following values: 51.8% of the areas are for vehicular traffic, and the remaining 48.2% of non-vehicular area (pedestrian street, sidewalks, green surfaces, permeable and impermeable irrigation canals).

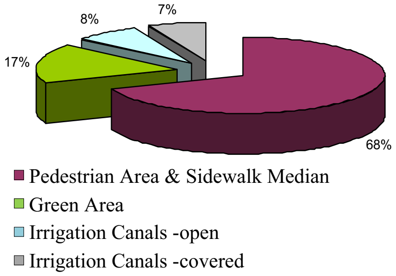

Fig. 12: Representation of sidewalk áreas.

This figure shows the composition of area sidewalks, that represent 18% of the areas of low-density urban environments analyzed. Of a two-dimensional analysis of 100% of these sidewalk surfaces, 68% is represented by medians- sidewalks and pedestrian areas generally sealed or covered in limestone tiles pedestrian areas; and, 15% is represented by irrigation canals, of which 8% are open ditches and 7% covered. Green areas of two-dimensional type 17% (lawn, Chepica etc) are present in the urban landscape especially in low-density environments and are recognized, moreover, for the benefits related to improving the microclimate, with the principal merit of reducing surface temperature as it absorbs about 80% of the incident energy, much of it used for evapotranspiration which keeps the surface temperature low. The reflection coefficient is close to 15-20%, which keeps the reflected radiation towards neighboring surfaces low.

If we analyze the urban morphology, the relationship between urban morphology open space (public and private) and the constructed environment (buildings) is 1: 0.66; of which 55.38% of the open space has tree vegetation cover. The construction surface within the 32 urban blocks studied has increased in the last ten years by approximately 9.22%, with loss and decreased of the surface courtyards and green spaces (herbaceous grass) and increase inthe relation of constructed space to open space. Persisting without solution mainly in private spaces is the percentage of anthropic mineralization, with always-growing trends, without considering vegetation cover or green surfaces (herbaceous grass) in such interventions, only 6.37% of the private area has vegetation cover- in this sense, green legislation concerning constructed and sealed surfaces is imperative for the future.

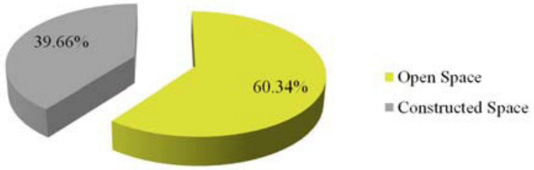

Fig. 13: Relationship between opend and constructed space

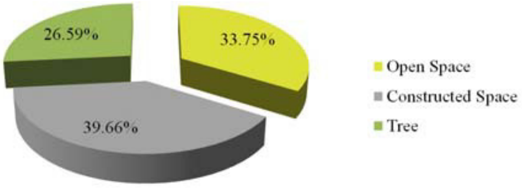

Fig. 14: Tree vegetation cover, opend and constructed space

Following is the calculated: *Index of Green Surface Area (IGSA) and Index of Vegetation Cover (IVC)* for different environments proposed, employing the results of survey data, aerial photographs, on-site surveys and estimation of i-tree canopy using aerial images. In the next figure, the results for each indicator are shown.

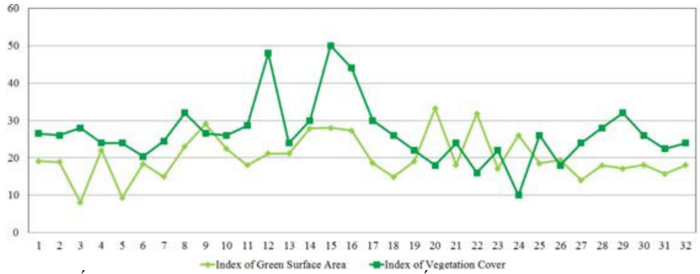

Fig. 15: Índex of Green Surface Area (IGSA) and Índex of Vegetation Cover (IVC)

The figure shows that the extreme values of IGSA are recorded in Scenarios 3 (8.1%) and 20 (33.2%). The result of IVC shows extreme values of 10% (Scenario 24) and 50% (Scenario 15).

In the first case (Scenario 3), with factor values of ground occupation (FOS) of 0.72, the same environment analyzed with i-tree, which considers as total area the private + public space (streets, sidewalks, etc), the constructed area (building) occupies 48%, for the same environment green surface landscaped private groundcover is 2% (lowest value of the 32 environments analyzed); with 8% private impervious surface, the value is high compared to the average of the 32 blocks (4.46%). As for the IVC value, for the same environment itis 28% (close to the average) in this case the tree magnitude (2nd magnitude) (Table 1), the care of the specimens with a density of highly significant cover in summer, allowing greater masking of the solar radiation incident in such an environment and helping to compensate soil sealing and the limited availability of green surface (herbaceous grass).

In the case of Scenario 20, the FOS value is 0.61, equivalent to 39% of courtyard surface and 61% constructed surface, considering only private area. The results of the i-tree tool for this environment presents values of constructed area (building) of 32% and the landscaped green area private groundcover (herbaceous grass) is 24%, the highest of the 32 environments analyzed.

In the case of low-density environments with residential buildings, lot size and its dispersion relative to the central core of high density is a reference indicator when the ratio between constructed space (building) and open space is studied.

However, for the same environment, the availability of vegetation cover is one of the lowest (tree), which produces results of IVC values of 18%, heterogeneity species of the 3rd magnitude, the pattern of spatial arrangement of individual examples and in contiguous condition (paired specimens), the plentitude of growth of 57%, indicating a lack of 43% of examples in the urban block and interventions by pruning, the obtained results indicating that the solar masking in the summer season, and the evapotranspiration values, could be significantly improved with proper intervention.

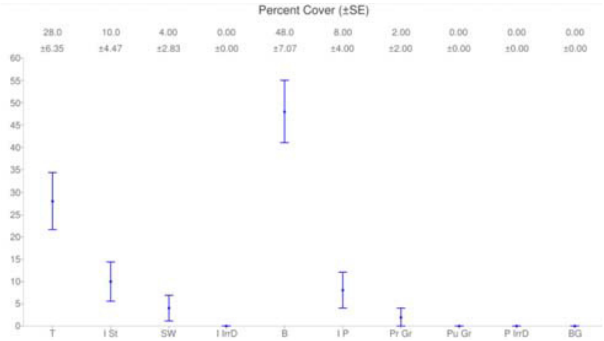

Fig. 16: Scenario 3

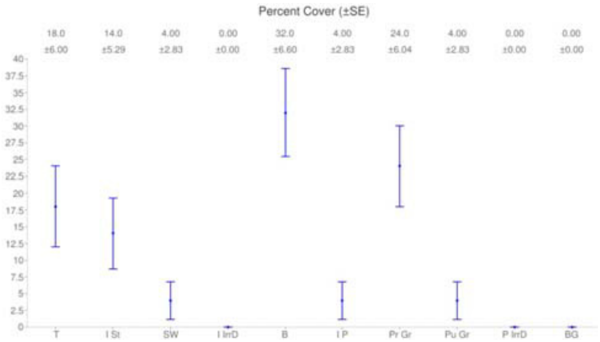

Fig. 17: Scenario 20

In the analysis of extreme cases of Index of Vegetation Cover (IVC) for the summer season, Scenario 24 presents values of 10%; this result may be motivated by the size of young examples of 3rd magnitude present in the block and for being one of the most recently consolidated neighbourhoods inthe total of all cases studied. As for the plentitude of growth (Table 1), the values indicate a lack of 44% of examples in the urban block, in addition to phytosanitary reasons, problems of irrigation and fertilization (this anomaly appears less marked in the other seasons).[58]The results of the simulation with i-tree permits observation of a percentage of private groundcover (herbaceous grass) of 24%, but with values of 50% of the total superface (public and private) occupied by the variable building, and a sealing of private surfaces of 6% (impervious private).

While the values of IGSA for the same environment (26%) are higher than average (20.22%), the impact of the lack of solar masking produced by the trees is critical, with increased solar energy available on the anthropic mineralized surfaces in the summer season, and it is significant when assessing the environmental index (EI).

Scenario 15 with IVC equal to 50% presents treesof the 2nd magnitude and the highest value of tree plentitude of the 32 Scenarios analyzed (85%) (Table 1). In summer, the vegetation cover and solar masking values related to the shadow produced by the density of the cover are highly significant, as is the evapotranspiration. The morphological uniformity, size, shape and magnitude of trees, if combined correctly with the Urban and Building Indicators (width of roadway, sidewalk location, relative position of the tree examples, building morphology, sidewalk overhang, construction profile, withdrawals) could achieve optimal results shaded surfaces on anthropic mineralized surfaces, both public and private. In the summer season, a good Sky Vision Factor (SVF) and Access to Summer Breezes (ABE) contribute to the potential of radiative and convective night cooling combined with direct or indirect evaporative cooling (low humidity content characteristic to arid regions), allowing passive cooling systems.

The IVC values primarily impacting public use surfaces (impervious street, sidewalk, irrigation canal, public groundcover) are coincident with a city tree design where public administration has impacted with the protection of the oasis-city model to public áreas, leaving open spaces inside private area blocks without legislation and protection. Building codes primarily regulate the building footprint (SOF) and density of building blocks (TOF), but have not yet been advanced in relation to private vegetation cover. Accurate knowledge of reductions in access to the sun in different seasons, detailed study of shadows cast on facades, roofs, streets and sidewalks in the summer, and, fundamentally, the knowledge of agronomic and morphological characteristics of the examples are all essential to optimize the maximum use of solar resource in winter and to permit cooling in summer. Quantification and inventory at the regional level of these variables make possible proposals for improvements, legislation and intervention, both to preserve the heritage of the existing environmental model and to develop improvement projects.

Table3: i-tree values, percentage of cover for type of surface for the 32 Scenarios

Escenarios	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Tree (T)	26.5	26.0	28.0	24.0	24.0	20.4	24.5	32.0	26.5	26.0	28.6	48.0	24.0	30.0	50.0	44.0
Impervious Street (I St)	6.1	8.0	10.0	14.0	4.0	2.0	14.3	4.0	8.2	12.0	14.3	4.0	4.0	4.0	0.0	8.0
Sidewalk (pedestrian Street) (SW)	4.1	6.0	4.0	10.0	8.0	4.1	6.1	6.0	6.1	8.0	2.0	6.0	4.0	6.0	4.0	4.0
Impervious irrigation ditch (I IrriD)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	2.0	2.0	0.0	0.0
Buildings (B)	42.9	30.0	48.0	34.0	50.0	51.0	42.9	42.0	38.8	30.0	38.8	34.0	40.0	34.0	34.0	30.0
Impervious private (I P)	8.2	6.0	8.0	4.0	8.0	2.0	4.1	4.0	6.1	0.0	2.0	2.0	4.0	4.0	0.0	0.0
Private groundcover (Pr Gr)	10.2	14.0	2.0	12.0	4.0	18.4	8.2	6.0	14.3	12.0	12.2	4.0	18.0	18.0	10.0	10.0
Public groundcover (Pu Gr)	2.0	2.0	0.0	2.0	2.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0	0.0	0.0	0.0	0.0
Pervious irrigation ditch (P IrriD)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0
Bare ground (BG)	0.0	8.0	0.0	0.0	0.0	2.0	0.0	2.0	0.0	6.0	2.0	2.0	2.0	2.0	2.0	4.0

Escenarios	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
Tree (T)	30.0	26.0	22.0	18.0	24.0	16.0	22.0	10.0	26.0	18.0	24.0	28.0	32.0	26.0	22.4	24.0
Impervious Street (I St)	0.0	2.0	10.0	14.0	6.0	16.0	8.0	6.0	4.0	20.0	8.0	12.0	10.0	18.0	18.4	18.0
Sidewalk (pedestrian Street) (SW)	8.0	8.0	8.0	4.0	6.0	6.0	4.0	2.0	6.0	4.0	4.0	2.0	6.0	10.0	2.0	8.0
Impervious irrigation ditch (I IrriD)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1	0.0
Buildings (B)	44.0	46.0	46.0	32.0	48.0	32.0	46.0	50.0	44.0	38.0	48.0	36.0	34.0	34.0	36.7	34.0
Impervious private (I P)	2.0	4.0	4.0	4.0	4.0	8.0	6.0	6.0	6.0	4.0	0.0	2.0	6.0	8.0	8.2	8.0
Private groundcover (Pr Gr)	12.0	10.0	10.0	24.0	12.0	20.0	14.0	24.0	14.0	14.0	12.0	12.0	12.0	4.0	10.2	8.0
Public groundcover (Pu Gr)	0.0	0.0	0.0	4.0	0.0	2.0	0.0	2.0	0.0	0.0	2.0	6.0	0.0	0.0	0.0	0.0
Pervious irrigation ditch (P IrriD)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bare ground (BG)	4.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0	2.0	0.0	0.0	0.0	0.0

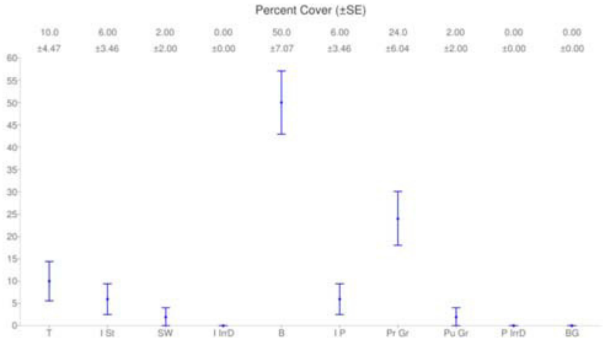

Fig. 18: Scenario 24

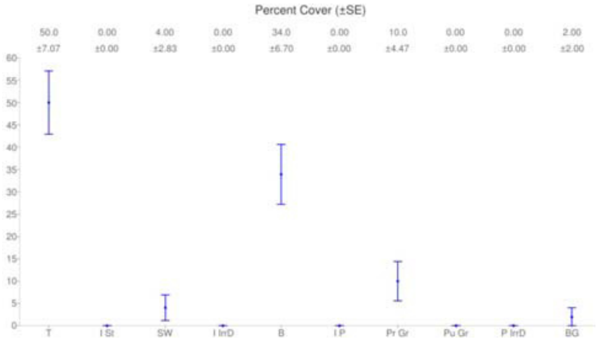

Fig. 19: Scenario 15

In the Figure are shown the results obtained of the *Environmental Index (EI)* for 32 low-density urban environments of the AMM, Argentina, taking the values for December (summer) as being the most critical environmental issue. Calculated is the indicator for each environment and for every type of surface for the percentage intervening.

The same methodology is hoped to be used in the future to calculate the EI of the city through satellite images and in the different seasons of the year to consider the behavior with different climatic and transmissibility of different tree species.[48-50]With this procedure, determintions of environmental indices of different urban-building morphology studies have been made.

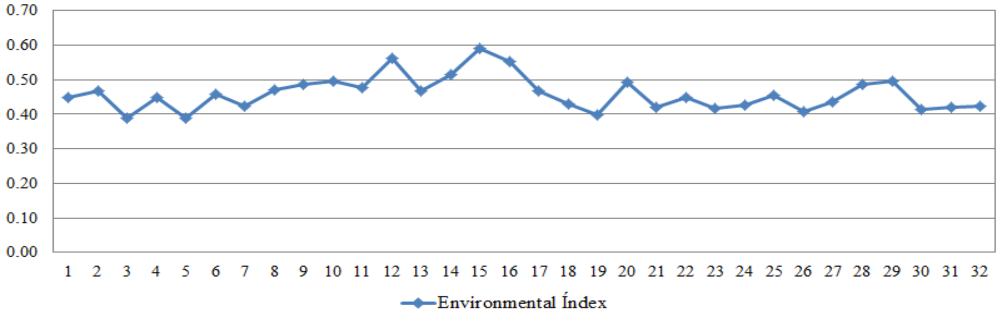

Fig. 20: Environmental Índex (EI)

The results incorporate the evaluation of the environments considering various dry surfaces (anthropogenic mineralized) and wet surfaces (vegetation); considering the albedo of these materials (for their surface) and plant evapotranspiration, plus variables of magnitude, transmissibility and tree plentitude. All these determinant aspects of thermal habitability of urban-building environemnts from the thermodynamic point of view, and the results of these, indicate the percentage of the total area of environmentally-useful green space.

The average value for the 32 analyzed environments is 0.46, with the highest rate of 0.59 represented by Scenario 15 which turns out to be the most environmentally favorabe per surface unit, the lowest values having been obtained in Scenario 5 with an EI of 0.39.

Continuing with the analysis of Scenario 15 (Figure 19) in terms of urban- building variables, the main feature is that it has a factor of ground use (SOF) of 0.51 determined by 49% of private surface without construction (open space), indicating a building footprint on the private surface of 51%. The results obtained with the i-tree tool show a consturcted surface (building) of 34%, considering all (public and private) surfaces. For the same environment, green surface private landscaped groundcover is 10% (slightly below average). The TOF factor determinant of building height is 0.52 (Table 1), equivalent to building a low-density construction level (3m high). Another aspect of this Scenario is that public space has an almost total tree cover. The presence of large trees for their ability to dissipate solar radiation is very important, and this is observed in the environment for the environment analyzed. As previously mentioned, the value of tree plentitude is high, the impact of masking produced by healthy urban trees, with their morphological characteristics and optimum permeability, compensates the percentage of missing examples around the block respecting the maximum amount possible, given the proper distance between individual trees.

There remains, however, 50% of the surface without vegetation cover, of which 38% mineralized: at the urban level 4% is surface treeless (pedestrian street), and 46% in the private space (buildings 34%, private groundcover 10%, and bare ground 2%).

If comparing values of cement with tres of 1st magnitude per unit of volume m^2 (EI = 0.85), 2nd magnitude (EI = 0.80) and 3rd magnitude (EI = 0.74) with herbaceous surfaces, these are better climate regulators compared with typical green lawn (EI = 0.71), but less than a homogeneous surface of dry chepica (C. dactylon) (EI = 0.87).

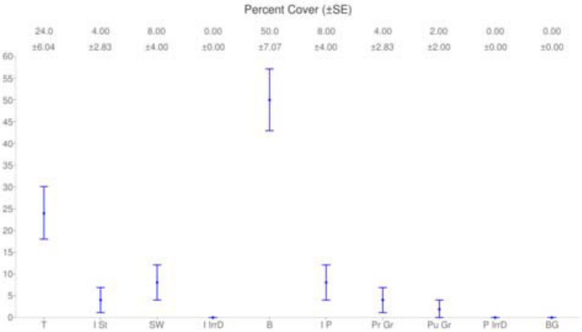

Fig. 21: Scenario 5

EI Scenario 5 results in less favorable environmental conditons for surface unit, the shortage of landscaped courtyards (2% public, private 4%) (herbaceous grass) has the lowest value of all Scenarios studied.

Furthermore, the impact of anthropogenic mineralized surfaces reaching the highest result of the 32 case studies, the 70% being: buildings 50%, impervious Street 4%, sidewalk 8%, impervious private 8%; rising above the average value of dry surfaces, which is 58.92%.

Although urban trees have a vegetation cover, close to the 24% of the average values (26.59), they fail to compensate for the environmental damage caused by constructed and sealed surfaces.

From the point of view of urban environmental influence, the most negative surface, andthe one that decisively influences the EI, is cement (masonry), exposed to direct sun, forthe heat emission. This is clear in the extreme values of the analyzed environments, the environments 3 and 5 showing a large percentage of the surface of concrete or brick (mineralized) respectively, however environment 5 has 24% of green mass while environment 3 has 28%, and this difference in the green mass makes the 5 the worst environment with an EI of 0.38. If we compare the values of Scenario 3 with Scenario 5, it is demonstrated how a 4% improvement of vegetation cover (in urban trees) on mineralized surfaces (1.26%) and on green surfaces (herbaceous grass) (2.74%) can favor Scenarios of similar characteristics.

Future Scenarios

Future scenarios were simulated according to the incorporation of vegetation and the maximum anthropogenic ground mineralization. In the current situation, it shows that the average values for the 32 environments analyzed, where the stretch of street trees partially covers the surface, has an environmental index of EI = 0.46; if for the same urban environments urban trees would be covering the entire surface of streets, the environmental index value would be higher than 0.60, and therefore the most most positive united effect on comfort from the thermodynamic point of view. If these low-density environments usedtrees covering covering less than 10% more than the roof surfaces, the EI values improve to 0.62, and a solution of green mass incorporation on roofs covering 50% of the roofs would improve the EI to 0.73, similar to the values of urban parks. If the same settings for the current trend of loss of urban trees is simulated, and if no urban trees are simulated, and it therefore happens to have the highest percentage of cement in the sun with deficient trees, the value drops to 0.34, for having low percentage of green surface

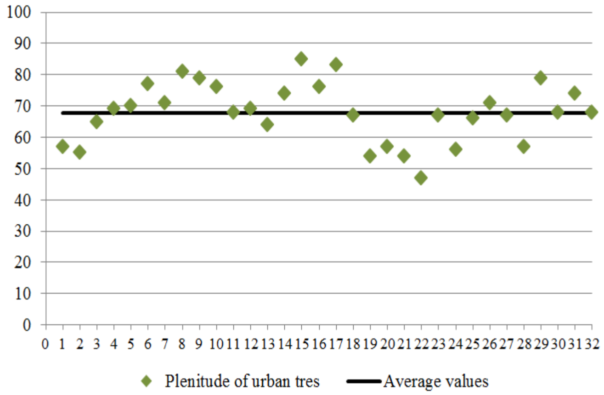

Fig. 22: Present plenitude of urban tres, related to average values

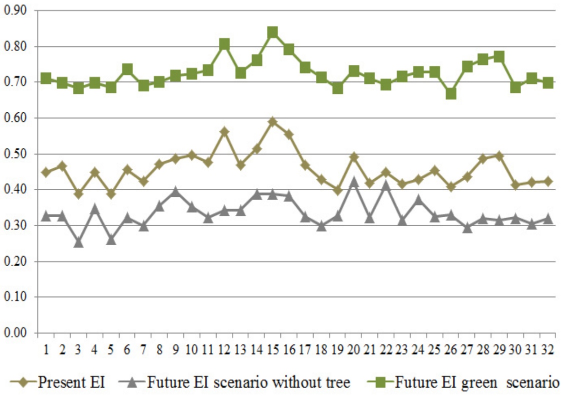

Fig. 23: Present EI, and a future scenari simulation

If, on the contrary, a different model of a city typical of arid climates without the presence of urban trees, sealed floor and bare ground, EI values would be between 0.20 and 0.22.

Table 4: Environmental Index Values per surface unit m^2, calculated for December in the city of Mendoza, Argentina

EI_1= masonry and cement in direct sunlight	0.20
EI_2= masonry and cement in the shade of trees (1st magitude)	0.85
EI_2= masonry and cement in the shade of trees (2nd magnitude)	0.80
EI_2= masonry and cement inthe shade of trees (3rd magitude)	0.74
EI_3= green chepica (C. dactylon)	0.87
EI_3= lawn (typical green)	0.71
EI_4= chepica (C. dactylon) under major vegetation (trees 1st magitude)	0.98
EI_4= chepica (C. dactylon) under major vegetation (trees 2nd magitude)	0.94
EI_4= chepica (C. dactylon) under major vegetation (trees 3rd magitude)	0.90
EI_4= lawn under major vegetation (trees 1st magitude)	0.94
EI_4= lawn under major vegetation (trees 2nd magitude)	0.88
EI_4= lawn under major vegetation (trees 3rd magitude)	0.83
EI_5= earth/soil in direct sunlight	0.22
EI_6 = earth/soil in dir sun. Under tree shade (1nd magitude)	0.86
EI_6= earth/soil in dir sun. Under tree shade (2nd magitude)	0.74
EI_6= earth/soil in dir sun. Under tree shade (3rd magitude)	0.74

Other alternatives of intervention per surface m^2 at urban level have been simulated:

Improvements through green terraces: the implementation of caducifoleis vines on cement EI = 0.64 would be the most negative surface, followed by typical grass surfaces on roofs EI = 0.71; if we consider caducifolies vines on grass surfaces EI = 0.83; and, the optimal solution from the thermodynamic point of view is dry Chepica. Thermodynamically, a homogeneous dry surface of Chepica (bermudagrass) (0.87) is a better climate regulator than a typical green grass surface. In addition to behaving like a crabgrass siftproof, it withstands high temperatures and drought, and prevents soil erosion.

Large lots and vacant lots: the surface of courtyards or vacant lots with bare ground has an environmental index of 0.22, and behaves much like an old cement surface (EI = 0.20), but in the shade of tres of 1st, 2nd and 3rd magnitude, it is more favorable environmentally per unit area than a typical green lawn.

Public and private spaces: the most positive surface is dry Chepica (C. dactylon), typical lawn, low bushes and flowering shrubs under more wooded vegetation: 1st magnitude EI = between 0.98 and 0.94; followed by the same surface with trees 2nd magnitude EI = between 0.94-0.88; and, 3rd magnitude EI = between 0.90 and 0.83. Another alternative is the ground/soil in the shade of trees (1st magnitude) EI = 0.86.

4. Conclusions

This work has permitted the formulation of an environmental energy diagnostic based on the index of green surface area and vegetation cover, adapted to low density consolidated environments in a forested city model with arid climate.

The environmental effects of analysed diverse green environments have been studied from a bi-dimensional scale and a volumetric scale. The environmental index. EI, is explained largely by the areas at ground level (amount of surface and thermal properties of materials) and vegetation cover (foliar volume of tree canopy). The plant cover provides the cooling surface from shading and evapotranspiration, these two factors being closely related to the variables: abundance, thermal transmissivity and magnitude of woodland in the blocks). It has been observed, in the results achieved, a strong correlation between the abundance of trees and EI values, which would allow for strong improvements that could be achieved with the completion of missing examples per block. Public administration and private support in the protection of urban public trees appear to be the main short-term strategies.

Because of the intense solar radiation in summer, shade and evapotraspiration are imperative for reducing the intensity of the ‘urban heat island’ phenomenon. The existence of urban trees, public or private, has an influence on the energy consumption of buildings, with heavy reliance on the species used. Deepening the understanding of the multiple environmental impacts of urban-building morphologies will allow a gradual improvement, in order to minimize emissions and the resulting deterioration of the regional and global environment. The precise advancement of knowledge of reductions in access to the sun in the summer season, the detailed study of shadows cast on facades, roofs, streets and sidewalks, and fundamental knowledge of the agronomic and morphological characteristics of the species are essential to optimize the maximum use of solar resource and to allow night cooling in summer. From the thermodynamic point of view, it has been shown that it would not significantly impact mineralized surfaces if they are protected by tree vegetation cover. Another aspect to be solved within the city is the large number of large blocks, large lots and urban vacant land, as the impact on the thermodynamic behavior is similar on the cemented surfaces.

We arrive now to the most critical point to solve due to its dominant form, and that is private space (open and constructed) and studies on how this private space is so strongly conditioning the oasis city model. The increasingly strong trends are: sealing of soil replacing the green surface by anthropic mineralized materials, building construction in yards, reduction in the open-space / construction space relationship, change in the type of surface vegetation (or herbaceous grass) chépica cover (C. dactylon) widespread in the past, beingreplaced typical green lawn. Understanding the adaptation of species to climate, cuts in winter wáter consumption for crop irrigation (which generates large water savings in the cold season) and beauty that brings a seasonal adaptability, are all critical from the cultural point of view.

In private space, the various regulations for building monitoring are insufficient to improve standards of environmental and energy sustainability of urban building. Incremental and progressive modifications of protection and incorporation of green areas and vegetation cover in the private sector could effectively be implemented to improve standards of environmental and energy sustainability of urban-building park in the region. Urban-building planners need to establish priority projects at the regional level and to define management criteria and specific quantitative targets, which must including private space. Municipalities face major challenges, and incorporating green indicators of private space in urban building codes are essential to ensure continuity and to strengthen the forested city model in dry climates.

Another aspect for the future is progress on the study of the design of parks and gardens, disciplines such as xerogardens (Xeriscape), and assessment on how these will impact heavily on energy consumption. The paradigm shift from a forested green city (street system – irrigation channels - trees) to landscaping in arid zones, often encouraged and based on reducing water consumption, will trigger an increase in temperature at the urban level. How to realize an agreed and sustainable future model from the inclusion of low-water-consumption species but abundant green mass is a challenge to face in the short-term. In parallel, it is needed to resolved and modernize the infrastructure of public Woodland irrigation, designing systems in accord with the oasis city model that are feasible to implement in cities in developing countries that have high levels of urban vandalism.

Unplanned growth currently being registered in the city, following the trend of all Latin American cities, leads to heavy consumption of non-renewable natural resources. In the process of urban planning, it is important to incorporate qualitative terms for the urban landscape. Progress, development, and growth, terms not always synonymous, constitute the ideas upon which new schedules are tended to be based.

While some cities project their "progress" based on their competitiveness in erasing their own identity, changed for decontextualized anodyne images, others do so through the development and enhancement of their own distinctive features, preserving the values that have given meaning- design, environmental and historical cultural heritage, scale, landscape, contact with nature, etc. – with which they add their own spaces and landscapes of modernity. These cities do not deny or destroy their cultural heritage. On the contrary, they are able to assimilate the changes and new challenges, without destroying the pre-existing, but rather adding to and creating new opportunities for the city and its citizens, further enriching those hallmarks of their consolidated urban landscape.

The preservation and improvement of the forested model city in arid lands, the cultural heritage of Mendoza, will require, from research organizations, management bodies and the citizenship in general, joint interdisciplinary and agreed work towards the future.

Further research

The complexity of the urban environment requires that assumptions can be verified to arrive at sound conclusions and proposals that may be safely implemented through mandatory clauses in the province's building codes, and that can assure the cost effectiveness of every proposed measure. In the AMM, professionals have to comply only with the municipal building codes when designing buildings in urban or rural settings. Worse yet, the Provincial Council for Subdivisions regulates the design of subdivisions with an even worse degree of backwardness. Therefore, developing and enforcing a progressive normative related to green and environmental building at provincial and municipal jurisdictions is a high priority.

Optimization of the urban-building morphology will maximize the use of climate resources to obtain high fractions of energy saving in space air-conditioning, with the consequent reduction of greenhouse gas emissions. It is hoped to advance the study and implementation of the methodology to territorial scale from the thermodynamic point of view for different seasons, through satellite images and results indicating the percentage of the total area of green space environmentally-useful green space. The goal is to reach conclusions and implement médium- and long-term regulations to preserve the forested city model in equilibrium with a model of sustainable city, and to enable the reversal of the current trend of growth not in concert with these indicators.

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